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A contextual problem-posing hypercontent model for vocational mathematics learning

Suci Haryanti, Muhammad Japar, Ellis Salsabila
Department of Educational Technology, Faculty of Education, State University of Jakarta, Jakarta, Indonesia

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ABSTRACT

This study develops and validates a contextual problem-posing learning model integrated with hypercontent to enhance vocational mathematics learning. The model was designed using the Dick and Carey instructional design framework within an educational design research (EDR) approach. The research involved preliminary analysis, expert validation, and quasi-experimental implementation with vocational students as well as science, technology, engineering, and mathematics (STEM) teachers. Learning effectiveness was evaluated using normalized gain (N-gain), paired t-tests, and effect size analysis, while teacher acceptance was examined through survey responses. The results indicate strong expert agreement on the model's validity and high teacher acceptance, particularly in promoting student motivation and creativity. The implementation also showed significant improvement in student learning outcomes with a medium N-gain. These findings suggest that the proposed model provides a structured framework for integrating contextual problem posing and hypercontent technology in vocational mathematics education, supporting the development of conceptual understanding and 21st-century competencies.

Corresponding Author:

Suci Haryanti
Department of Educational Technology, Faculty of Education, State University of Jakarta
Rawamangun, Pulo Gadung, East Jakarta, Special Capital Region of Jakarta 13220, Indonesia
Email: suci_9902922008@mhs.unj.ac.id

1. INTRODUCTION

Mathematics education in the 21st-century faces increasing demands to prepare students for complex and technology-driven environments. Mathematics provides essential problem-solving skills that support lifelong learning and participation in science, technology, engineering, and mathematics (STEM)-related fields [1]. In vocational education, however, mathematical knowledge must also be connected with practical industrial applications. Despite its importance, mathematics is often perceived as difficult by students, leading to reduced engagement and limited participation in STEM pathways [2], [3].

Traditional mathematics instruction frequently emphasizes procedural imitation rather than creative reasoning. Previous studies have shown that many mathematical tasks in school curricula can be solved through routine procedures, while only a small proportion requires creative thinking [4]. To address this issue, contemporary educational reform highlights the importance of developing 21st-century competencies, particularly critical thinking, creativity, communication, and collaboration [5]. Problem-posing pedagogy has been identified as an effective approach for fostering mathematical creativity and deeper conceptual understanding [6]. In addition, digital technologies have demonstrated strong potential to enhance mathematics learning through interactive and multimodal learning environments [7], [8].

However, few studies have systematically combined contextual problem-posing pedagogy with digital hypercontent technology in vocational mathematics education [9], [10]. Existing research tends to examine problem posing and digital learning tools separately, leaving a gap in integrated instructional models that connect contextual learning, digital media, and structured instructional design [11]–[13]. To address this gap, this study develops and validates a contextual problem-posing hypercontent (CPPH) learning model using the Dick and Carey instructional design framework. The study aims to construct a structured instructional model for vocational mathematics and evaluate its validity, teacher acceptance, and effectiveness in improving student learning outcomes. This study contributes to vocational mathematics education by integrating contextual problem posing, hypercontent technology, and systematic instructional design within a single instructional framework.

2. METHOD

2.1. Research design

This study employed an educational design research (EDR) methodology to develop and validate an instructional model for vocational mathematics. The development process was guided by the Dick and Carey systematic instructional design model, which structured the stages of analysis, design, development, implementation, and evaluation. Constructivist learning theory provided the pedagogical foundation for the model, particularly in supporting contextual problem posing and student-centered learning. The integration of hypercontent materials was aligned within the instructional development stages rather than treated as a separate framework to ensure coherence and methodological clarity.

2.2. Research setting and participants

The study was conducted at State Vocational High School (SMK N) 68 Jakarta, focusing on grade XI students enrolled in the Metal Fabrication and Welding Technology Programs. Participants were involved in different phases of the research: preliminary analysis phase involved 68 grade XI students who participated in needs analysis and contextual investigation of mathematics learning difficulties. Instrument refinement phase involved 44 of the 68 students, who completed detailed learning needs questionnaires to inform hypercontent development. Formative evaluation phase included one-to-one and small-group trials with 9 students representing high, medium, and low achievement levels [14]. Summative evaluation involved 20 students in a pre-test–post-test implementation to evaluate instructional effectiveness, corresponding to the limited number of students in the intact class. Although the sample size was limited due to classroom constraints, effect size analysis was conducted to complement statistical significance testing.

In addition, 136 mathematics and natural sciences teachers from across Indonesia participated in the teacher acceptance evaluation survey. Expert validation involved nine experts: three instructional design experts, three educational media experts, and three mathematics content experts. This multi-phase participation structure ensured systematic refinement before effectiveness testing.

2.3. Development procedure

The development process followed the ten stages of the Dick and Carey instructional design model in a systematic and sequential manner. First, instructional goals were identified through comprehensive curriculum review and analysis of industry requirements. Second, instructional analysis was conducted through focus group discussions with vocational mathematics teachers to determine essential competencies and content sequencing. Third, learner characteristics and learning contexts were analyzed to ensure alignment with students' prior knowledge and vocational needs. Fourth, specific and measurable performance objectives were formulated. Fifth, assessment instruments were developed to evaluate learning outcomes. Sixth, instructional strategies were designed by incorporating structured contextual problem-posing sequences. Seventh, hypercontent-based instructional materials were developed to support multimodal and flexible learning. Eighth, formative evaluation was conducted through expert validation, one-to-one testing, and small-group trials. Ninth, instructional components were revised based on evaluation feedback. Finally, summative evaluation was carried out through quasi-experimental implementation to determine the effectiveness of the developed model.

2.4. Research instruments

Multiple instruments were employed to collect data across the different phases of the study. A needs analysis questionnaire was used to identify students' learning difficulties, while expert validation sheets covering instructional design, media, and mathematics content were used to assess the theoretical validity of the CPPH model. Student practicality questionnaires and interview protocols were administered during the formative evaluation phase to capture learners' perceptions of the hypercontent materials, and pre-test and post-test instruments consisting of 20 contextual mathematics items were used to measure students' learning outcomes before and after implementation.

2.5. Validity and reliability analysis

Content validity was assessed using Aiken's V coefficient, which measures the degree of agreement among expert validators on item relevance. The Aiken's V formula is (1):

$$V = \frac{\Sigma s}{n\,(c-1)} \quad (1)$$

where *s* represents the adjusted rating score, *n* is the number of experts, and *c* is the number of rating categories. Aiken's V values were interpreted as: $V \geq 0.80$: very high validity; $0.60 \leq V < 0.80$: high validity; and $V < 0.60$: needs revision. Additionally, the content validity index (CVI) was calculated to determine overall instrument agreement across domains. Internal consistency reliability of the pre-test and post-test instruments was examined using Cronbach's alpha coefficient.

2.6. Data analysis techniques

Practicality was evaluated through descriptive percentage analysis of student responses. Materials were categorized as highly practical when response agreement exceeded 80%. Effectiveness was analyzed using the normalized gain (N-gain) formula (2) proposed by Hake [15]:

$$N\text{-}gain = (Post\text{-}test - Pre\text{-}test)/(Maximum\ Score - Pre\text{-}test) \quad (2)$$

N-gain categories: high (>0.7), medium (0.3-0.7) and low (<0.3). Statistical significance was tested using paired t-tests ($\alpha=0.05$). Effect size was calculated using Cohen's d to determine practical significance.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Needs analysis findings

The three-year preliminary analysis revealed unstable mathematics achievement among grade XI vocational students at SMK N 68 Jakarta. Performance trends indicated substantial fluctuations across academic years, suggesting inconsistencies in students' mastery of mathematical concepts. The wide score dispersion also reflects considerable differences in learning outcomes among students.

Student perception data further indicated that mathematics was widely regarded as a challenging subject. Classroom observations and interviews identified several instructional gaps, including limited foundational skills, insufficient contextualization of mathematics within vocational practice, minimal technology integration, and the absence of structured problem-posing activities. These findings highlight the need for an instructional approach that integrates contextual learning, digital resources, and structured mathematical problem creation.

As illustrated in Table 1, student achievement trends fluctuated considerably, with a notable decline during the pandemic period before partial recovery in the following year. This instability suggests that existing instructional approaches were insufficient to maintain consistent learning outcomes. Similar trends have been reported in global studies indicating widespread declines in mathematics achievement following pandemic-related disruptions [16].

Table 1. Academic performance analysis (2020-2022)

Academic year	2020	2021	2022
Total students	66	66	68
Highest score	95	93	95
Lowest score	10	23	10
Class average	59	53	64
Students≥75	20 (30.3%)	5 (7.6%)	37 (54.4%)
Students<75	44 (69.7%)	61 (92.4%)	(45.6%)

Figure 1 further illustrates students' perceptions of mathematics difficulty. The results show that a majority of students perceived mathematics as difficult, while only a small proportion considered it easy. This perception aligns with previous research indicating that low confidence and limited conceptual understanding often hinder students' participation in STEM-related learning pathways.

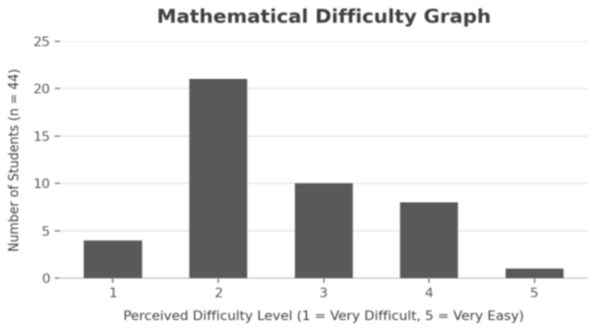

Figure 1. Mathematical difficulty levels of students

3.1.2. Model development output

The CPPH instructional model was developed using the Dick and Carey systematic instructional design framework, which emphasizes alignment among learning objectives, instructional strategies, and assessment procedures. The development process followed a structured sequence consisting of needs analysis, instructional analysis, learner and context analysis, objective formulation, assessment design, instructional strategy development, material development, formative evaluation, revision, and summative testing [17]. This systematic approach ensured coherence between pedagogical objectives and instructional implementation.

The resulting model consists of five instructional phases: learning objective communication, contextual problem presentation, guided problem solving, contextual problem creation, and reflection. This sequence positions problem creation as an integral component of the learning process rather than as an occasional enrichment activity. Previous studies have shown that structured problem-posing activities promote deeper conceptual understanding and enhance students' mathematical creativity [1], [18].

Hypercontent learning materials were integrated across eight chapters on circle concepts. These materials incorporated authentic industrial contexts related to metal fabrication, including simulations, instructional videos, contextual journals, and digital calculation tools. The integration of multimodal learning resources is consistent with multimedia learning theory, which emphasizes that coordinated visual and verbal information can strengthen conceptual comprehension and learner engagement [19], [20].

The instructional design also incorporated motivational principles derived from the attention, relevance, confidence, and satisfaction or ARCS framework, which highlights attention, relevance, confidence, and satisfaction as key components of learner engagement [10]. Through contextual examples and interactive hypercontent resources, the model aimed to strengthen both conceptual understanding and learning motivation among vocational students. Figure 2 illustrates the complete structure of the CPPH model, while Table 2 summarizes the integration of hypercontent materials within the eight-chapter learning sequence.

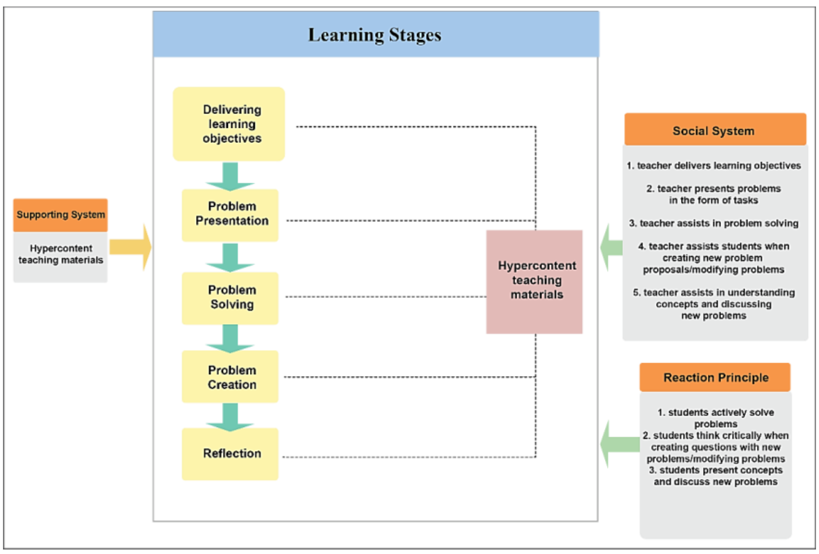

Figure 2. The CPPH model

Table 2. Eight-chapter circle learning progression with hypercontent integration

Chapter	Topic	Industrial application	Hypercontent components
1	Circle concepts and elements	Identification of circle elements in machine components and precision manufacturing applications	1. Video interviews with metal fabrication industry 2. Educational game for circle component identification
2	Circle equations	Coordinate systems in computer numerical control (CNC) programming and circular component positioning	Contextual supporting journal on pipe connections
3	Central and inscribed angles	Using a dividing head on milling machines for gear manufacturing and indexed components	Video on dividing head operations in milling machines
4	Angle relationships in circles	Quality control and precision measurement using protractors and measuring tools	1. Game on arc usage in measurement procedures 2. Learning video on angles between two chords
5	Arc length and apothem	Cutting plan optimization and material calculation for curved components	1. Supporting journal on required materials 2. Material optimization calculator tools
6	Circle area and circumference	Material requirement planning and production efficiency calculations	1. Earth circumference and Moon orbit simulation 2. Material requirement calculator applications
7	Sector area	Design and manufacturing of specialized components with sector shapes	Learning video on sector area applications
8	Circle tangent lines	Technical drawing and computer-aided design (CAD) applications for component design with tangent relationships	Learning journal on circle tangent lines

3.1.3. Expert validation

Expert validation results indicated strong agreement regarding the theoretical validity of the CPPH model. Across all evaluation domains—including instructional design, media design, and mathematics content—Aiken's V coefficients exceeded the accepted validity threshold, demonstrating that the model components were considered appropriate and relevant by the expert panel. Table 3 summarizes the validation results across domains. The mathematics content domain received the highest rating, indicating that the contextual integration of mathematical concepts with vocational applications was considered particularly strong. Overall, the validation results confirm that the CPPH model demonstrates satisfactory theoretical validity and alignment between instructional objectives, learning materials, and pedagogical strategies. The reliability analysis of the learning assessment instruments also indicated strong internal consistency, with Cronbach's alpha values exceeding the commonly accepted reliability threshold. These results suggest that the developed instruments were suitable for evaluating student learning outcomes within the implementation phase.

Table 3. Expert validation results summary

Validator domain	Total aspects	Total items	Consensus
Instructional design	3	21	80% valid
Media	4	25	80% valid
Mathematics materials	6	24	85% valid
Overall total	13	70	82% theoretical validity

3.1.4. Teacher acceptance evaluation

Teacher responses indicated strong acceptance of the CPPH instructional model. Educators consistently rated the model positively across multiple instructional dimensions, particularly in relation to student motivation, creativity development, and active learning engagement. Table 4 presents the detailed evaluation results. Overall ratings indicate that teachers perceived the model as highly supportive of student-centered learning and critical thinking development. Motivation and creativity emerged as the most strongly endorsed aspects, suggesting that the contextual problem-posing activities and hypercontent resources successfully increased student engagement. Importantly, positive evaluations were consistent across teachers from different STEM disciplines. This cross-disciplinary endorsement suggests that the CPPH model has potential applicability beyond mathematics classrooms and may support broader STEM learning integration within vocational education contexts.

3.1.5. Implementation effectiveness

The quasi-experimental implementation demonstrated clear improvement in students' mathematical learning outcomes following the application of the CPPH model. Overall results indicate that most students experienced moderate to high learning gains, suggesting that the instructional approach effectively supported conceptual understanding of circle geometry. Statistical analysis confirmed that the improvement between pre-test and post-test scores was highly significant. In addition, the calculated effect size indicated a very strong practical impact of the intervention, although the magnitude of the effect may be influenced by the relatively small sample size and within-group design.

Table 4. Teacher acceptance evaluation results

No	Evaluation aspects	Average score	Approval rate	Category
1	Increase motivation	4.45	93.4%	Excellent
2	Student-centered learning	4.29	86.1%	Excellent
3	Critical thinking skills	4.37	90.4%	Excellent
4	Creativeness	4.39	91.2%	Excellent
5	Interesting activities	4.32	89.0%	Excellent
6	Perceived improvement in critical thinking	4.41	90.4%	Excellent
7	Increased creativity	4.42	92.6%	Excellent

Table 5 summarizes the results of the small-group practicality evaluation. Student responses indicated that the developed learning materials were highly practical and easy to use. Participants also provided constructive feedback regarding additional hyperlinks, clearer explanations, and improved visual presentation. These suggestions were incorporated during the final revision stage, contributing to improved usability of the instructional materials.

Table 6 presents the distribution of normalized learning gains. The results indicate that the majority of students achieved moderate to high improvement levels, while only a small proportion demonstrated limited improvement. This pattern suggests that the CPPH model was effective for most learners across different achievement levels.

Overall, these findings indicate that the integration of contextual problem posing with hypercontent learning resources can significantly enhance students' mathematical understanding in vocational education settings. Similar positive outcomes have been reported in previous studies examining the effectiveness of problem-based and problem-posing instructional approaches in mathematics education [18], [21], [22].

Table 5. Analysis of practicality criteria

Criteria	Standard	Result	Status
Very practical	≥85%	95.67%	✓ Achieved
Consistency	CV<15%	5.17%	✓ Excellent
Feedback participation	≥70%	80%	✓ Achieved
Minimum score	≥80%	87.8%	✓ Achieved

Table 6. Distribution of N-gain categories

Category	Range	Count	Percentage	Interpretation
High	>0.7	9	45.0%	Highly effective
Medium	0.3-0.7	9	45.0%	Quite effective
Low	<0.3	2	10.0%	Less effective
Total		20	100.0%	

3.2. Discussion

The CPPH model produced statistically significant and practically meaningful gains in vocational mathematics learning (N-gain=0.628; Cohen's d=3.674; $p<0.001$). The medium N-gain is consistent with meta-analytic benchmarks for problem-posing interventions, which report moderate effect sizes (g=0.47-0.58) across controlled studies [7], [18]. The notably large Cohen's d should be interpreted cautiously given the single-group design and small sample (n=20); nonetheless, it signals strong practical significance within this context. The primary innovation of this study lies in positioning problem creation as a structured instructional phase rather than a supplementary activity—a design shift that transformed students from passive problem solvers into active problem designers. This structured integration aligns with evidence that systematic problem-posing interventions yield stronger learning effects than incidental implementations [23]. The integration of hypercontent further amplified these effects by providing multimodal, adaptive scaffolding consistent with multimedia learning principles [10], [24]. Extending prior evidence on digital tool effectiveness to a vocational education context [25], [26].

The high teacher acceptance across STEM disciplines (86.1%-93.4%) indicates that the CPPH model's pedagogical approach resonates beyond mathematics instruction. Notably, motivation and creativity received the highest ratings, reflecting teacher recognition of the model's capacity to address two persistent challenges in vocational education: disengagement and surface-level learning. This cross-disciplinary endorsement aligns with Hermans *et al.*'s [22]. Finding that contextual, competency-based frameworks are broadly valued in vocational STEM contexts. Embedding authentic metal fabrication scenarios reduced the abstraction barrier associated with geometry, enabling meaningful knowledge transfer to industry tasks—a critical feature identified by Vos [12] as essential for effective vocational mathematics. The hypercontent component functioned not as supplementary media but as a structural scaffolding mechanism that enabled personalized, multimodal access pathways, consistent with Clark and Mayer's [10] multimedia learning principles.

4. CONCLUSION

This study developed and validated the CPPH model as an instructional framework for vocational mathematics learning. The findings demonstrate that the model achieved strong theoretical validity through expert evaluation and received high acceptance from STEM teachers, indicating its relevance and practicality for classroom implementation. The quasi-experimental results further suggest that integrating contextual problem posing with hypercontent learning resources can effectively support improvements in students' conceptual understanding of mathematics.

The CPPH model contributes to vocational mathematics education by systematically integrating contextual learning, structured problem-posing activities, and digital hypercontent within a coherent instructional design framework. This integration helps bridge the gap between abstract mathematical concepts and authentic vocational applications while also promoting the development of 21st-century competencies such as creativity, critical thinking, and student engagement.

Nevertheless, several limitations should be acknowledged. The effectiveness evaluation was conducted using a single-group pre-test–post-test design with a relatively small sample from one vocational school, which limits the generalizability of the findings. Future research should examine the long-term impact of the model, apply the framework across different vocational disciplines, and employ larger experimental designs to further validate its effectiveness in diverse educational contexts.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Suci Haryanti	✓	✓	✓			✓		✓	✓					
Muhammad Japar		✓		✓		✓				✓		✓		
Ellis Salsabila					✓		✓			✓				

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial, personal, professional, or non-financial interests that could have appeared to influence the work reported in this paper. Authors state no conflict of interest.

INFORMED CONSENT

Informed consent was obtained from all participants involved in the study. Permission to conduct the research was also obtained from the school administration. All participants were informed about the purpose of the study, and their participation was voluntary.

ETHICAL APPROVAL

This study involved non-invasive educational research conducted in a school setting. The research procedures complied with relevant national regulations and institutional policies for research involving human participants. Permission to conduct the study was obtained from the school administration, and all participants participated voluntarily. The study posed no physical or psychological risk to participants, and all data were anonymized to ensure confidentiality and privacy protection.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [SH], upon reasonable request. The data are not publicly available due to privacy and ethical restrictions related to student participants.

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BIOGRAPHIES OF AUTHORS

Suci Haryanti is a doctoral student in Educational Technology at the State University of Jakarta and a lecturer at the Kartika Indera Persada Optical Refractive Academy, Indonesia. Her research focuses on mathematics education, instructional design, and technology-enhanced learning. She is actively involved in publishing accredited books and scientific articles in the field of educational innovation. Her current research interests include contextual learning, problem-posing pedagogy, and digital instructional media development. In this study, she contributed to the conceptualization, methodology development, and implementation of the instructional model. She can be contacted at email: betasenja1@gmail.com or suci_9902922008@mhs.unj.ac.id.

Muhammad Japar is a professor in Learning Technology of Pancasila and Citizenship Education at the State University of Jakarta. He was inaugurated as professor on December 17, 2019. He teaches in both the Pancasila and Citizenship Education Study Program and the Doctoral Program in Educational Technology. His research interests include instructional design, educational technology integration, and civic education learning innovation. He has published extensively in national and international journals and actively participates in academic conferences. In this study, he contributed to supervision, validation, and manuscript review. He can be contacted at email: mjapar@unj.ac.id.

Ellis Salsabila is a permanent lecturer in the Mathematics Education Study Program, Faculty of Mathematics and Natural Sciences, State University of Jakarta. She previously served as coordinator of the Mathematics Education Study Program (2009-2011). She earned her bachelor's degree in Mathematics Education from IKIP Jakarta (1990), master's degree in Mathematics from Institut Teknologi Bandung (1997), and doctorate in Educational Evaluation from the State University of Jakarta (2020). Her research interests include mathematics pedagogy, curriculum development, and instructional evaluation. In this study, she contributed to formal analysis and academic review. She can be contacted at email: ellis@unj.ac.id.