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Development of Creative Problem Solving-Based Student Worksheets on the Pythagorean Theorem to Facilitate Mathematical Creative Thinking Skills

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ABSTRACT The low level of students' mathematical creative thinking skills indicates persistent problems in mathematics instruction, including the limited suitability of the learning materials used. This study aimed to develop a valid and practical Creative Problem Solving (CPS)-based student worksheet on the Pythagorean theorem to facilitate the mathematical creative thinking skills of Phase D students. The study employed a research and development approach using the 4-D model, comprising the define, design, develop, and disseminate stages. The participants were eighth-grade students at SMPN 4 Siak Hulu. Product validation involved three mathematics education lecturers, while the developmental trials consisted of a one-to-one evaluation with three students, a small-group trial with six students, and a field trial with 30 students. The development process was informed by observations and a literature review, while validity and practicality data were collected using validation sheets and student practicality questionnaires. The worksheet obtained an average validity score of 84.89%, meeting the valid criterion. The practicality score was 85.76% in the small-group trial and 86.58% in the field trial, both categorized as very practical. These findings indicate that the CPS-based student worksheet met the validity and practicality criteria for use in mathematics instruction; further research is required to examine its effectiveness in improving mathematical creative thinking.

Keywords: Creative Problem Solving, mathematical creative thinking, student worksheets, Pythagorean theorem

INTRODUCTION

The Merdeka Curriculum identifies creative thinking as one of the competencies that mathematics learning should develop (Wicaksono et al., 2022). Mathematical creative thinking encompasses fluency, flexibility, originality, and elaboration (Munandar, 2014). These abilities enable students to address unstructured and open-ended mathematical

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problems, generate innovative ideas, and organize their mathematical reasoning during learning (Suherman & Vidákovich, 2022; Suripah & Sthephani, 2017). Consequently, developing mathematical creative thinking is an important objective of mathematics instruction.

Despite its importance, students' mathematical creative thinking remains relatively low. Kamalia and Ruli (2022) reported that 43.75% of the assessed students were in the low category, while Robiah and Rahmawati (2021) found that students had difficulty producing systematic solutions using their own approaches. Similarly, Alvionita et al. (2022) reported an overall achievement of only 22.22%, with originality reaching 0%. This condition is partly associated with conventional instruction and inappropriate learning methods, which often cause students to depend on a single solution procedure (Heleni et al., 2025; Sitinjak et al., 2022). Preliminary observations at SMPN 4 Siak Hulu revealed a comparable pattern: students relied heavily on demonstrated procedures rather than exploring their own strategies. Improving the learning process is therefore essential for strengthening mathematical creative thinking.

The Pythagorean theorem is closely related to everyday situations and requires both logical and creative thinking (Wahusna et al., 2022). However, Febrian et al. (2022) found that students' creative thinking on this topic was predominantly low: 86.7% were in the low category, 6.7% were in the moderate category, and 6.7% were in the very low category, with no students in the high or very high categories. These findings indicate that instruction on the Pythagorean theorem needs to be designed more effectively to support creative mathematical thinking.

One instructional resource that can increase student participation and deepen conceptual understanding is the student worksheet (Riwayati et al., 2022; Rosliana, 2019). Student worksheets can help learners discover and integrate concepts (Safitri et al., 2025), while providing opportunities for active involvement and creative exploration (Luthfi & Rakhmawati, 2022). Previous studies have shown that worksheet-supported learning can improve mathematical creative thinking more effectively than conventional instruction (Mahendrawan et al., 2022; Nurmala et al., 2021). Nevertheless, many available worksheets contain only summaries and routine exercises and therefore do not fully support creative thinking (Astuti, 2021; Elvionika et al., 2023). At SMPN 4 Siak Hulu, students primarily relied on teacher explanations and textbook exercises, limiting opportunities for independent exploration.

To address this limitation, student worksheets can be integrated with the Creative Problem Solving model (Sulistyawati, 2025). CPS directs students to understand problems, develop problem-solving strategies, and generate alternative solutions (Malisa et al., 2018). It combines divergent and convergent thinking, encouraging students to propose multiple alternatives and select the most appropriate solution (Nurdin et al., 2020;

Solihin et al., 2021). Its stages can facilitate fluency, flexibility, originality, and elaboration (Panuntun Hsm et al., 2021). These characteristics directly address students' dependence on a single method by encouraging them to explore multiple strategies and construct their own solutions. Previous findings also indicate that CPS can facilitate mathematical creative thinking (Munafiah et al., 2019; Munthe et al., 2023).

Based on these considerations, this study developed a CPS-based student worksheet on the Pythagorean theorem to facilitate the mathematical creative thinking skills of Phase D students. The product was designed to satisfy validity and practicality requirements before wider classroom use.

RESEARCH METHODS

This research employed a research and development approach based on the 4-D model proposed by Thiagarajan et al. (1974). The model consists of four stages: define, which identifies learning needs and objectives; design, which develops the initial product; develop, which involves evaluation and revision; and disseminate, which packages and distributes the final product.

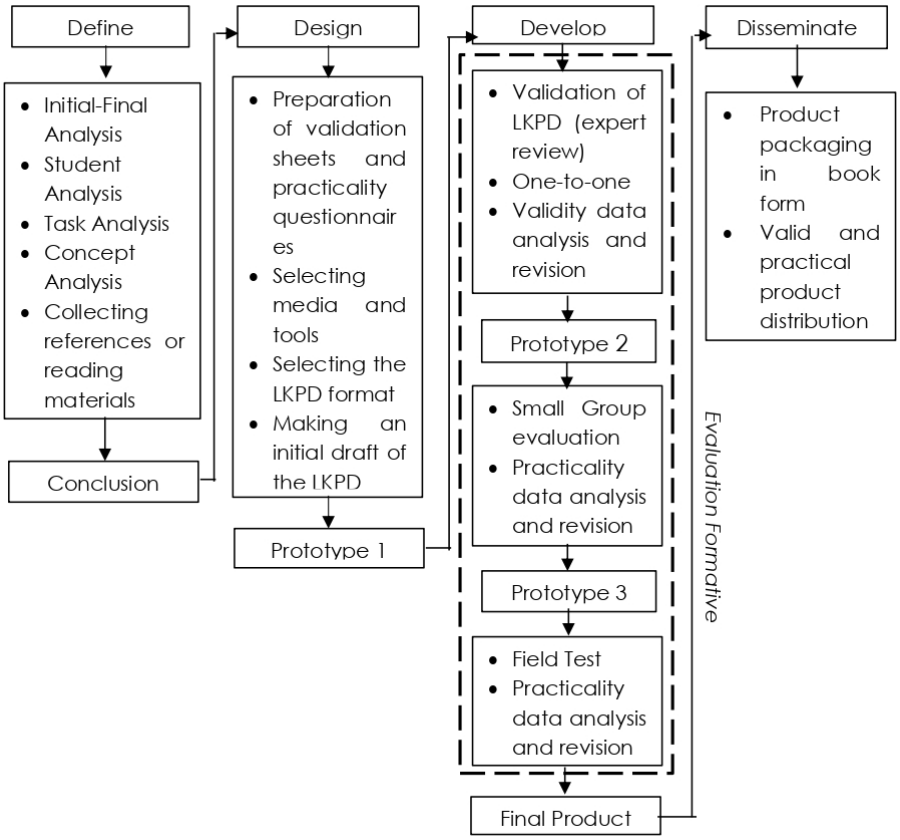


Figure 1. Flowchart of the 4-D development process for student worksheet design

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During the define stage, the researchers conducted preliminary, student, task, and concept analyses and specified the learning objectives. The design stage involved developing assessment standards, selecting media and formats, and preparing the initial worksheet draft. The assessment instruments comprised expert-validation sheets and student-practicality questionnaires. During the develop stage, formative evaluation followed the framework proposed by Tessmer (1993). The worksheet was evaluated by experts and tested with students, and the results guided revisions until a valid and practical final product was obtained. The disseminate stage involved packaging and distributing the completed worksheet.

The participants were eighth-grade students at SMPN 4 Siak Hulu. The one-to-one and small-group trials involved students from Class VIII.13, selected purposively to represent low, moderate, and high academic ability. The field trial involved 30 students from the heterogeneous Class VIII.11. This selection was intended to evaluate the worksheet's practicality under regular classroom conditions.

The study used validity and practicality instruments. Data were collected through learning observations, expert-validation sheets, and student questionnaires. Students' written responses and the researchers' observations during the trials were reviewed descriptively to examine how the worksheet activities elicited fluency, flexibility, originality, and elaboration. This descriptive review was exploratory and was not treated as an effectiveness test. The Guttman and Likert scales were used for scoring. Tables 1 and 2 summarize the validity and practicality assessment aspects.

Table 1. Validity assessment aspects

Assessment Aspect	Assessment Indicators	Number of Items
Face validity	Completeness of worksheet components; accuracy of word choice and language; worksheet appearance	12
Content validity	Alignment with learning outcomes and the learning objective flow; presentation of learning topics; suitability for students' thinking levels	8
Construct validity	Alignment between the worksheet and the four CPS stages; alignment of activities with mathematical creative thinking indicators	8

Source: Adapted from Akbar (2013) and Fitni et al. (2023).

Table 2. Practicality assessment aspects

Assessment Aspect	Number of Items
Ease of use	5
Presentation	5
Readability	3
Time	2

Source: Adapted from Akbar (2013) and Ariani (2022).

During dissemination, the valid and practical CPS-based worksheet was printed and packaged as a book. It was then distributed to SMPN 4 Siak Hulu for use in mathematics learning.

The validity and practicality data were analyzed using the percentage criteria adapted from Akbar (2013). A worksheet was considered valid or practical when its percentage exceeded 70%. Products that did not meet this threshold were revised and retested. The classification criteria are presented in Table 3.

Table 3. Validity and practicality criteria

Interval	Validity Criterion	Practicality Criterion
$85.01\% \leq V \leq 100\%$	Very valid	Very practical
$70.01\% \leq V \leq 85.00\%$	Valid	Practical
$50.01\% \leq V \leq 70.00\%$	Less valid	Less practical
$0\% \leq V \leq 50.00\%$	Invalid	Impractical

RESULTS AND DISCUSSION

Define Stage

During the define stage, the researchers collected and analyzed information through a literature review and preliminary observations at several schools. The analysis showed that no student worksheet had been specifically designed to facilitate mathematical creative thinking on the Pythagorean theorem, even though students' creative thinking remained relatively low.

The student analysis examined learners' characteristics during instruction. Observations showed that students were generally passive, tended to listen to teacher explanations, and imitated demonstrated methods without fully understanding the underlying concepts. Consequently, their mathematical creative thinking did not develop optimally.

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The concept analysis was based on the learning outcomes stipulated in Decree of the Head of the Agency for Standards, Curriculum, and Educational Assessment (BSKAP) No. 046/H/KR/2025 (BSKAP, 2025), which require students to demonstrate the validity of the Pythagorean theorem and apply it in problem-solving. The content was organized into four topics: the Pythagorean theorem, Pythagorean triples, special triangles, and applications of the theorem. The concept analysis informed the task analysis, learning objective flow, and objectives for each worksheet.

Design Stage

During the design stage, the researchers developed expert-validation and student-practicality instruments. The selected medium was a printed worksheet designed using Canva. The worksheet consisted of a cover, a main content section, and a closing section. The cover contained the worksheet identity, topic, student identity, learning objectives, illustrations, and instructions. The main section incorporated the CPS stages to support mathematical creative thinking, while the closing section contained conclusions and practice questions. The resulting prototype-1 comprised four topics: the concept of the Pythagorean theorem, Pythagorean triples, special triangles, and applications of the theorem.

Develop Stage

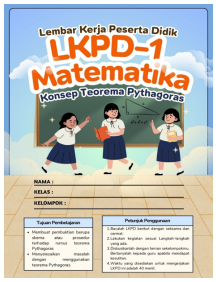
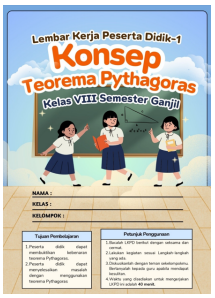
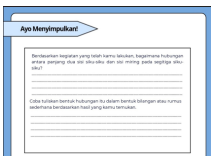
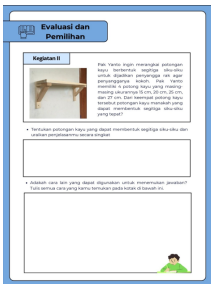
Prototype-1 underwent formative evaluation during the develop stage. Three mathematics education lecturers assessed its validity. The validation results are presented in Table 4.

Table 4. Student worksheet validation results

Aspect	Average
Face validity	91.62%
Content validity	85.69%
Construct validity	77.36%
Overall worksheet validity	84.89%
Criterion	Valid

The overall validity score was 84.89%, placing the worksheet in the valid category. Although every component met the validity criterion, the validators recommended several revisions. Table 5 summarizes the feedback and the corresponding changes.

Table 5. Validator feedback and product revisions

Validator Feedback	Before Revision	After Revision
Add complete identification, including class, semester, and time allocation, to each worksheet.		
Make the final reflection more explicit by adding guiding questions to the ``Let's Conclude'' section.		
Replace the apartment-fire context in Worksheet 1 with a context that is more familiar to students.		
Strengthen the flexibility indicator in Worksheet 2 by explicitly asking students to use multiple strategies and provide open-ended responses.		

Alongside expert validation, a one-to-one evaluation was conducted with three students from Class VIII.13 to assess readability and identify weaknesses. The students considered the worksheet visually appealing and understandable, although several aspects still required improvement. Prototype-1 was revised in response to the validators' and students' suggestions, producing prototype-2.

A small-group trial was then conducted with six students from Class VIII.13 who represented high, moderate, and low ability levels. Table 6 presents the results.

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Table 6. Small group practicality results

Aspect	Average
Ease of use	83.75%
Presentation	86.88%
Readability	87.50%
Time	84.90%
Overall worksheet practicality	85.76%
Criterion	Very practical

The average practicality score in the small-group trial was 85.76%, categorized as very practical. Student feedback was used to revise prototype-2, resulting in prototype-3 for the field trial.

The field trial involved 30 students from Class VIII.11 with heterogeneous abilities. It was conducted over four meetings, with worksheet activities completed in 40-minute sessions. The results are presented in Table 7.

Table 7. Field trial practicality results

Aspect	Average
Ease of use	86.63%
Presentation	86.75%
Readability	87.02%
Time	85.94%
Overall worksheet practicality	86.58%
Criterion	Very practical

The field-trial practicality score was 86.58%, also categorized as very practical. The validation and practicality results therefore confirmed that the CPS-based worksheet met the criteria for classroom use.

Disseminate Stage

During dissemination, the researchers printed and delivered the completed student worksheet to SMPN 4 Siak Hulu. The product was intended to support Phase D students' mathematical creative thinking on the Pythagorean theorem. Figure 2 presents the final packaging cover.

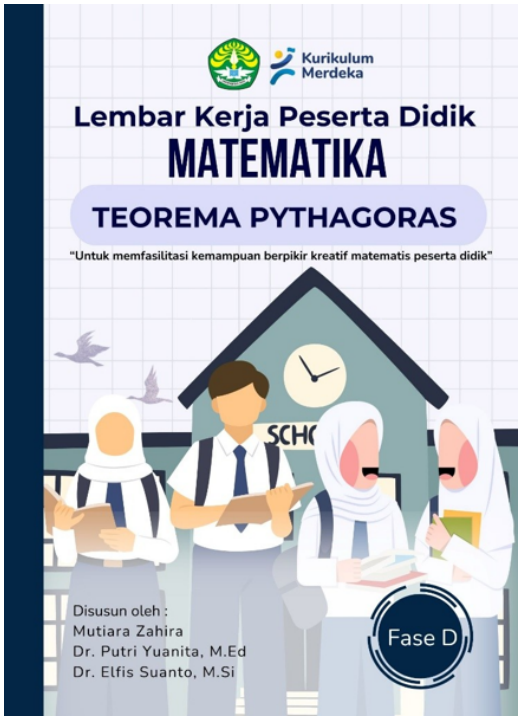


Figure 2. Final student worksheet packaging cover

The results from the four stages were subsequently interpreted in relation to previous research. During the define stage, the literature review and preliminary observations indicated that low mathematical creative thinking is a recurring problem in mathematics education (Alvionita et al., 2022; Kamalia & Ruli, 2022; Robiah & Rahmawati, 2021). Students often focus on procedures without developing a deep conceptual understanding, encouraging convergent thinking and dependence on a single presumed correct answer (Rosliana, 2019). The observations in this study similarly showed limited engagement and dependence on teacher explanations. CPS was therefore selected to promote creativity and learning outcomes (Sulistyawati, 2025), while worksheets were used to increase student involvement (Riwayati et al., 2022; Rosliana, 2019).

During the design stage, the assessment standards, expert-validation instruments, practicality questionnaire, printed medium, and worksheet format were developed in accordance with validity and practicality requirements (Thiagarajan et al., 1974). This process produced prototype-1 as the basis for formative evaluation.

During development, expert appraisal and one-to-one evaluation indicated that prototype-1 was valid but required several improvements. The validators recommended adding complete worksheet identification, clarifying potentially ambiguous terms, and strengthening instructions related to CPS stages, fluency, and flexibility. Students also indicated that the response spaces needed to be enlarged. These revisions produced prototype-2.

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After prototype-2 was declared valid, small-group and field trials were conducted. Students in the small-group trial could understand the instructions, recognize the problem contexts, and follow the sequence of activities. Their feedback informed the production of prototype-3. In the field trial, no substantial implementation obstacles were identified. Each worksheet activity followed the CPS sequence and was designed to facilitate mathematical creative thinking.

The CPS sequence comprised four principal activities. First, during problem clarification, students identified the problem and relevant information, supporting fluency. Second, during idea generation, students proposed multiple alternative solutions and original ideas, supporting fluency and originality. Third, during evaluation and selection, students reviewed their strategies and selected the most appropriate solution, supporting flexibility. Fourth, during implementation, students presented the chosen solution systematically and in detail, supporting elaboration. This structure is consistent with findings that CPS can promote active and creative problem-solving (Nurmalasari et al., 2025).

Students were generally able to identify known and unknown information and propose more than one strategy. This result is consistent with Saputra and Fajriah (2024), who reported that opportunities for free thinking and alternative exploration can stimulate fluency. Putri and Suripah (2022) similarly associated originality with distinctive answers and strategies. Thus, problem clarification supported fluency, while idea generation supported both fluency and originality.

During evaluation and selection, students solved activities in more than one way and produced varied solution steps. This finding is consistent with Munandar's (2014) description of flexibility as the ability to generate and express multiple approaches. During implementation, most students presented systematic and detailed solutions, although some provided answers without sufficient elaboration. Rakhmawati et al. (2022) reported a similar difficulty, with several students failing to explain their answers in detail. Thus, the implementation stage supported elaboration, but continued practice in explaining solutions remains necessary.

Overall, the CPS-based worksheet has the potential to facilitate mathematical creative thinking, although elaboration requires further attention. This interpretation is consistent with studies showing that CPS-based learning can support mathematical creative thinking (Munafiah et al., 2019; Munthe et al., 2023; Septian et al., 2019). The descriptive trial findings illustrate how the four CPS stages can be operationalized through student worksheets to elicit fluency, flexibility, originality, and elaboration; however, their effectiveness remains to be tested.

CONCLUSION AND RECOMMENDATION

The CPS-based student worksheet on the Pythagorean theorem met the validity and practicality criteria and demonstrated potential to facilitate students' mathematical creative thinking. Expert assessment yielded an average validity score of 84.89%. The small-group and field trials produced practicality scores of 85.76% and 86.58%, respectively, both categorized as very practical. Descriptive observations suggested that students readily generated multiple ideas and problem-solving strategies, whereas some students did not present their solution procedures systematically and in sufficient detail. Nevertheless, the developed worksheet is suitable for use as a mathematics learning resource, although its effectiveness has not yet been established.

This development was limited to the Pythagorean theorem and focused on facilitating mathematical creative thinking. Future studies should develop CPS-based worksheets for other mathematical topics and continue evaluation through an effectiveness-testing stage. Such research would provide stronger evidence regarding the effect of CPS-based worksheets on students' mathematical creative thinking.

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