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THE EFFECT OF AN OPEN-ENDED APPROACH ON MATHEMATICAL PROBLEM-SOLVING ABILITY AND LEARNING MOTIVATION REGARDING PLANE FIGURES AMONG GRADE VI STUDENTS AT UPT SD NEGERI 064037, MEDAN TEMBUNG DISTRICT

Conceptual Article on the Development of an Open-Ended Learning Model

Diani Sari Siregar[1], Tua Halomoan Harahap[2]
[1,2] Universitas Muhammadiyah sumatera Utara

ABSTRACT

This article develops a conceptual open-ended learning model to explain and examine its effects on mathematical problem-solving ability and learning motivation in plane geometry for sixth-grade students. An integrative literature review was conducted using publications from 2021–2026 on open-ended tasks, problem solving, motivation, geometry learning, and elementary mathematics education. The synthesis produced the Open-Ended Problem-Solving and Motivation model (OE-PMM), consisting of six phases: contextual orientation, exploration of open problems, individual strategy construction, collaborative solution comparison, justification and generalization, and reflection with motivational reinforcement. Problem-solving ability is represented by understanding the problem, devising a plan, carrying out the plan, and reviewing the solution. Motivation is embedded through autonomy, competence, and relatedness support. Four propositions are formulated: OE-PMM positively affects problem-solving ability; OE-PMM positively influences learning motivation; motivation is positively related to problem solving; and motivation partially mediates the effect of OE-PMM on problem solving. Because this conceptual article does not report experimental data, the proposed relationships require expert validation, feasibility testing, and empirical examination through a quasi-experimental or mixed-methods study in Grade VI of UPT SD Negeri 064037, Medan Tembung.

Keywords: open-ended learning, mathematical problem solving, learning motivation, plane geometry, elementary school

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Corresponding Author:
Diani Sari Siregar,
Master of Mathematics Education,
Universitas Muhammadiyah Sumatera Utara,
Jalan Kapten Muktar Basri No 3 Medan 20238, Indonesia.
Email: dianisarisiregar5@gmail.com

1. INTRODUCTION

Mathematics at the elementary school level serves not only to develop numeracy skills but also to develop logical, flexible, and systematic thinking when students face problems. In Phase C, which covers grades V and VI, mathematics learning is directed at strengthening conceptual understanding and the use of reasoning in various contexts. Material on plane figures is relevant to this goal because students need to connect the properties of shape, size, circumference, area, and visual representation with situations encountered in everyday life. The national curriculum references place grade VI within Phase C and provide a flow of learning objectives that need to be adapted to the conditions of students and educational units (Kemendikdasmen, 2024).

These demands are not always met by learning that provides sufficient space for students to develop their own strategies. Mathematics learning can still focus on teacher examples, the use of a single formula, and exercises that require a single final answer. This pattern risks making students view problem-solving as an activity of imitating procedures, rather than a process of understanding the situation, selecting a strategy, testing steps, and assessing the reasonableness of the answer. Studies of

elementary school students show that problem-solving abilities for plane figures vary, and students with lower abilities do not meet all problem-solving indicators (Achadiyah et al., 2022).

Problem-solving difficulties are not solely related to mastery of formulas. Students also need cognitive flexibility to view problems from multiple perspectives and switch from one strategy to another when the first doesn't work. Research on elementary school students found that pattern-finding, estimation, guided trial and error, and the use of diagrams are essential components of cognitive flexibility in solving math problems (Rahayuningsih et al., 2021). Therefore, learning activities need to be designed so that strategy variation is seen as a learning resource, not as a deviation from the teacher's example.

The open-ended approach offers a learning style that meets these needs. Open-ended problems allow for more than one solution, more than one acceptable answer, or more than one possible development of the problem. This openness encourages students to explain ideas, compare representations, and make mathematical decisions. Research on the affordance of open-ended mathematics questions shows that open-ended problems generate more diverse answers and are associated with divergent thinking skills, although a high degree of openness can also increase the task's difficulty for students (Bingölbali & Bingölbali, 2021).

Recent empirical evidence supports the potential of this approach. A meta-analysis of 32 quasi-experimental studies reported a high effect size of applying an open-ended approach to general mathematical skills (Dewi & Juandi, 2024). In an elementary school context, the application of open-ended learning to the perimeter of plane figures was also associated with improved problem-solving skills from one cycle to the next (Ramadhan et al., 2022). These findings strengthen the basis for designing a more structured open-ended model that is tailored to the characteristics of sixth-grade students.

However, challenging learning doesn't automatically generate motivation. Open-ended problems can spark curiosity, but also confusion and frustration when students feel a lack of control or don't see opportunities for success. Research on third- to sixth-grade students shows that emotions during impasses are related to appraisals of control, use of metacognitive strategies, and problem-solving achievement (Munzar et al., 2021). Therefore, open-ended designs need to regulate the level of challenge, incremental support, and classroom climate to maintain student engagement.

Learning motivation in this article is understood as a drive manifested through interest, a desire to engage, persistence, confidence in one's abilities, and a willingness to complete a task. The Self-Determination Theory framework emphasizes the need for autonomy, competence, and relatedness. Educational interventions based on this theory generally support students' autonomy, competence, and intrinsic motivation (Wang et al., 2024). The application of the principles of autonomy, competence, and relatedness to fifth-grade mathematics learning also resulted in more positive attitudes and better mathematics achievement compared to comparison learning (Knopik & Oszwa, 2023).

The relationship between an open-ended approach, motivation, and problem-solving skills forms the basis for developing the model in this article. Freedom to choose strategies can fulfill the need for autonomy. Opportunities to receive feedback and refine solutions can strengthen competency. Discussions that value different approaches can build connectedness. These three conditions are thought to increase student engagement and encourage them to persist in the problem-solving process.

This article focuses on the development of an open-ended learning model for the material of plane figures in grade VI of UPT SD Negeri 064037, Medan Tembung District. The article does not report experimental results and does not present data on influences that have not yet been obtained. The term influence in the title is placed as a relationship that will be tested through further research. The objectives of the article are: (1) to formulate the conceptual basis of the open-ended approach; (2) to develop a model syntax that integrates problem solving and motivational support; (3) to explain the

mechanism of relationships between variables; and (4) to design the implications of implementation and empirical testing in grade VI.

2. RESEARCH METHOD

This article uses a conceptual model development method through an integrative literature review. This method was chosen because the study's goal is not to calculate the magnitude of influence based on field data, but rather to integrate the latest findings into a logical, operational, and testable learning model design. The development process is carried out through four stages: identifying the learning problem, selecting a theoretical basis, synthesizing model components, and formulating propositions about the relationships between variables.

The study sources were limited to publications from 2021–2026 to ensure that the arguments are in line with the latest research developments. Literature was selected from reputable journal articles, accredited or indexed national journals, meta-analyses, and official government websites related to the curriculum. Keywords used included open-ended approach, open-ended learning, mathematical problem solving, learning motivation, self-determination, elementary mathematics, geometry, plane figures, and grade six. Literature was used if it discussed at least one of four focuses: the character of open-ended problems, the mathematical problem-solving process, motivation to learn mathematics, or geometry learning in elementary schools.

The analysis was conducted by examining the objectives, subjects, designs, results, and implications of each source. The findings were then grouped into themes: task openness, strategy flexibility, mathematical discussion, psychological support, problem-solving indicators, and assessment. Citations are presented singly for the main idea to avoid overlapping citations. The synthesis results are presented in an Open-Ended Model Based on Problem Solving and Motivation, hereinafter abbreviated as OE-PMM.

The limitation of this method lies in the lack of expert validation, implementation testing, and statistical testing on sixth-grade students at UPT SD Negeri 064037. Therefore, the resulting model remains a conceptual model. Its effectiveness, practicality, and magnitude of influence still require field research with ethical procedures and validated instruments.

3. RESULTS AND DISCUSSION

1) Synthesis of Recent Literature

The main sources that shape the OE-PMM model are summarized in Table 1. This table shows that the model design does not rest on a single study, but integrates evidence on task openness, flexibility, geometry, collaboration, emotions, and motivation.

Source	Context/Method	Relevant Findings	Model Implications
Rahayuningsih et al. (2021)	Elementary school students; qualitative study	Cognitive flexibility is seen through patterns, estimation, trial and error, and diagrams.	Models need to allow for alternative strategies.
Bingölbali & Bingölbali (2021)	Grade VI; comparison questions	Open-ended questions produce more diverse responses, but generalization is more challenging.	Openness needs to be gradual and targeted.

Source	Context/Method	Relevant Findings	Model Implications
Munzar et al. (2021)	Class III–VI; mixed methods	Control and emotions during deadlocks regarding strategy and achievement.	Teachers need to maintain both challenge and support.
Klang et al. (2021)	Class V; 15-week intervention	Cooperative learning impacts problem solving and geometry.	Group discussions should be structured.
Ramadhan et al. (2022)	Grade IV; PTK flat shapes	Open Ended Learning enhances problem solving across cycles.	Open-ended is suitable for development in elementary geometry.
Achadiyah et al. (2022)	Class IV; descriptive study	Students' abilities vary in fulfilling the area and perimeter indicators.	The rubric needs to assess the process per indicator.
Knopik & Oszwa (2023)	Class V; experiment	Support for autonomy, competence, and relatedness improves attitudes and outcomes.	Motivation needs to be built into the syntax.
Dewi & Juandi (2024)	Meta-analysis of 32 studies	The open-ended approach had a high effect size on mathematical skills.	There is an empirical basis for testing the model.
Alawiyyah et al. (2024)	Class III; R&D LKPD	Open-ended based LKPD is considered valid and increases problem solving scores.	Activity sheets should guide the process, not provide a single answer.
Yusnita et al. (2025)	Junior high school; quasi-experimental	Open-ended improves problem solving and correlates with representation.	Representation needs to be part of the activity.

Table 1. Literature synthesis as a basis for developing OE-PMM

2) OE-PMM Model Structure

The study results in the OE-PMM model as a development of open-ended learning that explicitly links problem openness, problem-solving stages, and motivational support. This model does not replace the basic principles of open-ended learning, but rather clarifies how teachers manage open-ended problems to suit the development of sixth-grade students and not simply provide questions with multiple answers.

The OE-PMM model has five main characteristics. First, problems start from a context that students can visualize or experience. Second, openness is provided in a measurable way through variations in

strategies, answers, or development of forms. Third, individual processes are conducted before group discussions so that each student has the opportunity to develop ideas. Fourth, comparisons of solutions are directed at mathematical reasoning, not simply selecting the fastest answer. Fifth, reflection always includes elements of strategy evaluation and motivational reinforcement.

This model uses four indicators of problem-solving ability: understanding the problem, planning a solution, implementing the plan, and reviewing. These four indicators are translated into observable actions in the geometric figure material. In the understanding stage, students identify relevant information, questions, units, and shapes. In the planning stage, students select representations and strategies. In the implementing stage, students perform calculations and provide reasons. In the review stage, students compare answers with the problem conditions, check units, and find alternatives.

Problem-solving skills are viewed as a process that requires both conceptual and procedural knowledge. A purely instrumental understanding can lead students to apply procedures without understanding the rationale and limits of their use. Recent studies confirm that elementary school students' mathematical understanding can still be trapped in the use of procedures without a strong conceptual foundation (Mytra et al., 2026). Therefore, each stage of the OE-PMM requires students to explain the relationships between shape, size, operations, and results.

Learning motivation is integrated through three forms of support. Autonomy support is provided through the choice of tools, methods, sequence of strategies, or product form of answers. Competence support is provided through tiered problems, initial representation examples, guiding questions, and feedback indicating progress. Connectedness support is provided through safe discussion rules, role assignments, and recognition of diverse contributions. These supports are relevant because Self-Determination Theory-based interventions have been shown to be the most consistent in supporting the needs for autonomy and competence (Wang et al., 2024).

The OE-PMM syntax consists of six phases: context orientation, open-ended problem exploration, individual strategy construction, collaborative solution comparison, justification and generalization, and reflection-motivational reinforcement. Each phase has cognitive and affective objectives. The syntax is designed for one 2 x 35-minute session or can be expanded to two sessions when the problem requires model or product creation.

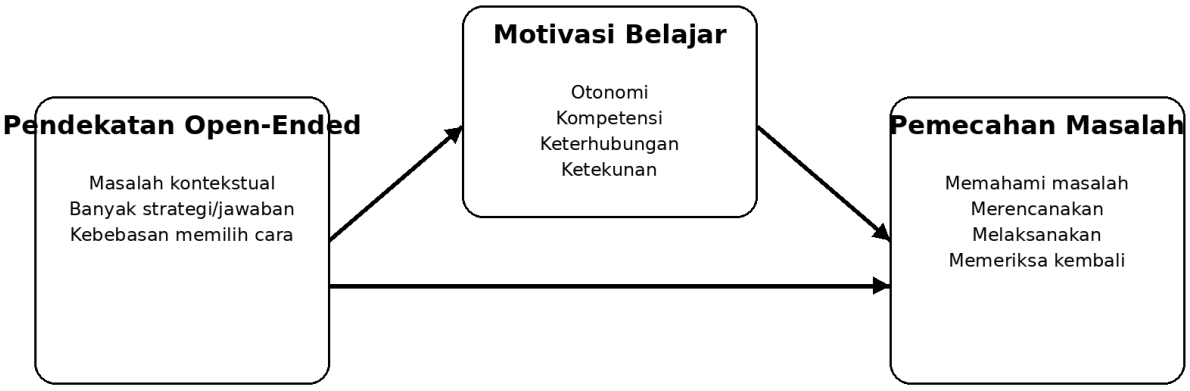


Figure 1. Conceptual relationship framework of OE-PMM, learning motivation, and problem-solving ability

3) Learning Syntax

The first phase is context orientation. The teacher presents a situation familiar to the students, such as arranging tiles, designing a garden, making a frame, dividing areas on a floor plan, or using cardboard.

The teacher does not immediately write formulas but instead invites students to observe the shapes and ask questions. The goal of this phase is to build the usefulness of the task and activate prior knowledge.

The second phase is open-ended problem exploration. The teacher presents problems that allow for multiple strategies or multiple correct answers. The level of openness should be tailored to the students' readiness. Questions that are too open-ended can elicit diverse responses but also increase the demand for generalization (Bingölbali & Bingölbali, 2021). Therefore, the teacher can provide constraints such as minimum size, specific area, quantity of materials, or shape requirements to keep the problem focused.

The third phase is individual strategy construction. Students write down what they know, what they are asking, the image or model they are using, and a solution plan. The teacher provides sufficient thinking time before the discussion. This stage is important to prevent students from simply copying their peers' ideas and to provide space for free mathematical expression. Problem-posing activities with elementary school students demonstrate that freedom to construct contexts can support understanding and the ability to generate solvable problems (Bevan & Capraro, 2021).

The fourth phase is collaborative solution comparison. Students work in small groups to compare methods, identify similarities, and assess the strengths of each strategy. Cooperative learning can provide opportunities to explain, clarify, and strengthen problem understanding. Research in fifth-grade students found a significant effect of cooperative learning on overall problem-solving scores and geometry problem solving (Klang et al., 2021). In OE-PMM, teachers ensure each member has a role, such as problem reader, image maker, calculation checker, and reasoner.

The fifth phase is justification and generalization. Several groups present different solutions. The teacher guides the class to assess whether the strategies meet the requirements of the problem, rather than determining one method as the only correct one. Students then develop general conclusions, such as the relationship between changes in side length and perimeter, the equality of areas of different shapes, or why a particular arrangement is more efficient. This stage transforms the diversity of answers into shared knowledge.

The sixth phase is reflection and motivational reinforcement. Students answer questions such as: what strategies do I understand best, when do I struggle, what kind of support keeps me going, and what method do I want to try next? The teacher provides feedback on the process, persistence, and quality of reasoning. This reflection is important because impasses can spark curiosity or frustration, and students' responses to impasses are related to their perceived sense of control (Munzar et al., 2021).

The conceptual mechanism of the model can be explained through two pathways. The direct pathway states that the open-ended approach provides richer problem-solving practice opportunities, thereby enhancing learners' abilities. The indirect pathway states that strategy choice, successful experiences, and rewarding interactions enhance motivation; this motivation, in turn, encourages persistence, monitoring of steps, and a willingness to try alternative strategies. The relationship between these two variables is not viewed as a simple one-way relationship, as successful problem-solving can also strengthen feelings of competence.

Phase	Objective	Teacher Activities	Student Activities	Motivational Support
1. Context orientation	Activate prior knowledge and use value	Presenting local situations, objects, pictures, or plans; asking initial questions	Observing, stating information, connecting experiences	Task value and connectedness

Phase	Objective	Teacher Activities	Student Activities	Motivational Support
2. Exploration of open problems	Understanding the conditions and possible solutions	Provide semi-open/open problems and clear boundaries	Marking information, interpreting conditions, making assumptions	Autonomy through choice
3. Individual strategies	Building a self-plan	Provide minimal thinking time and assistance	Make a drawing/model, choose a strategy, calculate the start	Competence through scaffolding
4. Collaborative comparison	Testing and expanding strategies	Organize groups and roles; ask for comparisons	Explain, ask, check, revise	Connectedness and sense of security
5. Justification-generalization	Building general reasons and concepts	Selecting representative solutions; guiding argumentation	Presenting evidence, assessing conditions, drawing patterns	Competence and meaning
6. Reflection-reinforcement	Checking the process and cultivating perseverance	Provide process feedback; guide reflection	Assess strategy, emotions, progress, next plans	Internalization of motivation

Table 2. OE-PMM model syntax

4) Influence Mechanisms and Propositions

Based on this mechanism, four propositions are formulated. The first proposition, the application of OE-PMM is estimated to have a positive effect on mathematical problem-solving ability. The second proposition, the application of OE-PMM is estimated to have a positive effect on mathematics learning motivation. The third proposition, learning motivation is estimated to have a positive relationship with problem-solving ability. The fourth proposition, learning motivation is estimated to partially mediate the effect of OE-PMM on problem-solving ability. These four propositions must be tested through empirical research and should not be treated as proven results at the research site.

Plane geometry material was chosen because it supports the use of concrete, visual, symbolic, and verbal representations. Students can use gridded paper, rulers, cut-out shapes, floor plans, or simple applications. The variety of representations helps students explain relationships between measurements. Recent research on open-ended strategies shows that representational skills have a positive relationship with problem-solving abilities (Yusnita et al., 2025).

The first example problem is: 'A garden has an area of 96 square meters. Create at least three rectangular garden designs of different sizes. Calculate the perimeter of each design and determine the one that requires the least amount of fencing.' This problem has multiple correct answers and encourages students to connect the factors of number, area, and perimeter. Teachers can expand on this by including paths or planters.

H1: The application of the OE-PMM model is estimated to have a positive effect on students' mathematical problem-solving abilities.

H2: The application of the OE-PMM model is estimated to have a positive effect on students' motivation to learn mathematics.
H3: Learning motivation is estimated to be positively related to mathematical problem solving ability.
H4: Learning motivation is estimated to partially mediate the effect of OE-PMM on mathematical problem solving ability.

5) Examples of Open-Ended Plane Problems

The second example problem is: 'A rectangular cardboard measuring 40 cm x 30 cm is available. Make a photo frame design from the cardboard with a square or rectangular photo hole. Determine the size of the hole so that the remaining cardboard used as the frame has a certain area.' This problem can be solved by drawing, reducing the area, or dividing the plane. Openness lies in the choice of size and modeling method.

A third example problem is: 'Arrange two or more geometric shapes so that the total area is 72 square units. Create two arrangements that have different perimeters and explain the reason for the difference.' This problem develops an understanding that equal areas do not always produce equal perimeters. The task also provides an opportunity for students to prove their answers through calculations and visualization.

The OE-PMM assessment uses an analytical rubric. Problem-solving ability scores can be arranged on a scale of 0–4 for each indicator. A score of 0 indicates no relevant response; a score of 1 indicates very limited information or steps; a score of 2 indicates a partially correct but incomplete process; a score of 3 indicates a correct process with minor deficiencies; and a score of 4 indicates a complete, correct process with reasons or alternatives. The rubric needs to be tested for content validity by mathematics education experts and elementary school teachers before use.

Learning motivation can be measured using a Likert-scale questionnaire that covers interest, persistence, preference for involvement, belief in competence, and comfort in discussion. Questions should be tailored to the language of sixth-grade students. Measurement should not rely solely on questionnaires but should be combined with behavioral observations and reflective notes. A triangulation approach helps distinguish between positive questionnaire responses and actual engagement during learning.

6) The Role of Learning and Assessment of Ability and Motivation

The teacher plays the role of problem designer, strategy observer, minimal support provider, and discussion facilitator. Support is not provided in the form of a complete solution. Teachers can use questions such as "Which information is not used?", "Can a different picture be drawn?", "What happens if the size is changed?", or "How do you ensure the answer meets the requirements?". Such questions maintain autonomy while strengthening competence.

Students play the roles of problem solver, representation maker, reasoner, solution evaluator, and process reflector. These roles need to be introduced gradually. Initially, teachers can use semi-open-ended problems with limited options. Once students become accustomed to explaining and comparing strategies, the level of openness can be increased.

Variables	Indicator	Expected Evidence	Instrument
Problem solving skills	Understanding the problem	Write down information, questions, units, and draw relevant shapes	Open-ended test; rubric 0–4
Problem solving skills	Plan	Selecting a formula/representation and explaining the reasons for the selection	Open-ended test; rubric 0–4
Problem solving skills	Carry out	Perform operations, organize steps, and obtain consistent results	Open-ended test; rubric 0–4
Problem solving skills	Check back	Checking units, fairness, conditions, and offering alternatives	Open-ended test; rubric 0–4
Motivation to learn	Interest and value of assignments	Enthusiasm, contextual relevance, willingness to initiate	Questionnaires and observations
Motivation to learn	Perseverance	Try again, find the right help, complete the task	Questionnaire, observation, reflection
Motivation to learn	Competence	Believe in finding strategies and correcting mistakes	Questionnaire
Motivation to learn	Autonomy and connectedness	Choose a way and feel comfortable conveying ideas in a group	Questionnaires and observations

Table 3. Assessment indicators and design

7) The Role of Teachers, Social Systems, and Supporting Facilities

The social system in OE-PMM demands the norm that errors provide information for improving strategies. Different answers are not automatically considered wrong as long as they meet the problem's conditions and are justifiable. Teachers need to prevent the dominance of highly capable students. Scheduling turns, role cards, and the obligation for each member to present one idea can support more equitable participation.

The principle of teacher response consists of five actions. First, accept diverse strategies before evaluating. Second, ask for evidence or reasons. Third, provide gradual assistance based on difficulty. Fourth, connect student strategies to formal concepts. Fifth, provide feedback that emphasizes progress and persistence. This principle prevents open-ended freedom from becoming directionless activity.

Supporting materials for the model include open-structured activity sheets, measuring tools, gridded paper, cut-out shapes, presentation boards, and rubrics. Activity sheets should not only contain answer spaces. They should also include columns for problem understanding, images or models, plans, calculation steps, checks, alternatives, and motivational reflections. The development of open-ended problem-based worksheets at the elementary level showed an increase in problem-solving scores and met valid criteria according to expert assessment (Alawiyyah et al., 2024).

The targeted instructional impacts are improved problem-solving skills, strategic flexibility, implementation accuracy, and answer verification. Expected accompanying impacts include increased confidence in expressing ideas, appreciation for diverse approaches, persistence, and a positive attitude toward mathematics. These accompanying impacts need to be assessed realistically and should not be inferred solely from the perceived active classroom atmosphere.

Implementation at the UPT SD Negeri 064037 needs to begin with a context analysis. Teachers need to map prerequisite mastery, learning habits, time availability, student population, and facilities. Examples of contexts can be adapted to the Medan Tembung environment, such as classroom layouts, schoolyards, floor plans, kiosks, parks, or fields. Local context is used to enhance meaningful connections, not simply by changing the names of objects in questions.

8) Implementation in Class VI of UPT SD Negeri 064037

Initial implementation is recommended using three to four limited trial sessions. The first session could focus on the area and perimeter of rectangles. The second could compare shapes with the same area. The third could use a combination of plane shapes. The fourth could include a mini-project in the form of a floor plan design. After each session, the teacher records the type of strategy, difficulty, time, and students' motivational responses.

Differentiation occurs through varying support, not by excessively lowering the objectives. Students who need support can receive a starter image, a list of information, formula cards with explanations, or an example of a strategy. More prepared students can receive additional requirements, be asked to find common patterns, or create new problems. In this way, all students work on the same mathematical ideas at an appropriate level of complexity.

The first potential obstacle is lengthy discussion time. The solution is to select two or three representative strategies to discuss in class and showcase the others through a gallery of work. The second potential obstacle is students waiting for examples. Teachers can provide opening problems with concrete objects and tiered questions. The third potential obstacle is varying response assessments. Analytical rubrics and examples of anchor responses need to be developed to ensure consistent assessment.

A fourth potential obstacle is decreased motivation when problems become too difficult. Teachers need to adjust the level of challenge and provide incremental guidance. Motivation isn't built through general praise alone, but through the experience that effort and strategies lead to progress. Mathematics programs that prioritize autonomy, competence, and connectedness have shown positive changes in student attitudes and achievement (Knopik & Oszwa, 2023).

A fifth potential obstacle is that discussions can become divisions of labor without an exchange of ideas. Teachers need to assess the group process, not just the product. Each group can be asked to write down two strategies: one for differences, one for similarities, and one for questions. This structure keeps collaboration focused on reasoning.

The OE-PMM model has the advantage of integrating cognitive and affective objectives within the same syntax. It also provides space for individual solutions before discussion, thus fostering student creativity. Another advantage is its compatibility with visually rich geometric materials and the possibility for variations in size and shape.

This model also has limitations. Teachers need the ability to design open-ended problems that remain objective. Assessments take longer than objective questions. Furthermore, not all topics or learning objectives require the same level of openness. Mastery of basic facts and procedures still requires appropriate training to ensure students have the resources to solve problems.

Empirical testing can use a quasi-experimental pretest-posttest control group design. The experimental class receives the OE-PMM, while the comparison class receives the school's usual learning approach or another approach described in detail. Class assignments should consider initial equivalency,

schedules, teachers, and materials. Research can also use a mixed methods design to explain changes in scores through student strategies, interactions, and experiences.

The independent variables are the application of an open-ended approach through the OE-PMM syntax. The first dependent variable is mathematical problem-solving ability. The second dependent variable is learning motivation. If the sample size is sufficient, motivation can be tested as a mediator. If the sample size is limited, the analysis can focus on differences in improvement and descriptions of relationships without imposing inappropriate statistical models.

9) Empirical Test Design

The problem-solving ability instrument should consist of three to five open-ended problems on geometric shapes. Each problem should have more than one strategy or answer, a graded level of difficulty, and scoring guidelines. Content validity can be tested using an expert agreement index. Scoring reliability should be checked by two raters on a subset of student responses.

The learning motivation instrument needs to undergo a readability test on sixth-grade students. Positive and negative items can be used sparingly to avoid confusing students. Initial analysis includes item validity and internal reliability. Observational data is used as support, not mixed directly with questionnaire scores without a clear procedure.

Data analysis can include descriptive statistics, assumption checks, score difference or gain tests, and effect sizes. Results are not adequately reported through significance values. Effect sizes and confidence intervals help assess the practical significance of the application. Qualitative analysis of sample responses can reveal a shift in strategy from a single, rigid approach to a more justifiable one.

Research ethics must be considered because the subjects are elementary school-aged children. Researchers must obtain school permission and parental or guardian consent, as per institutional regulations. Student identities are kept anonymous, activities do not diminish their right to learn, and learning treatments must not disadvantage the comparison class. Research results are reported as is, including any insignificant effects.

Overall, the OE-PMM model positions open-ended problems as triggers, individual strategies as sources of diversity, discussions as spaces for negotiating meaning, justifications as reinforcements for reasoning, and reflection as a link between learning experiences and motivation. This arrangement makes the open-ended approach more operational and provides a clear basis for research on influence in sixth grade.

4. DISCUSSION

The development of the OE-PMM demonstrates that the open-ended approach needs to be understood as a learning system, not simply as a type of problem. Asking questions with multiple answers without fostering discussion and reflection can result in diverse responses, but it doesn't necessarily reinforce concepts. Therefore, the model's syntax places justification and generalization after comparing solutions. This stage ensures that the variety of answers leads to a more organized mathematical understanding.

This model is consistent with meta-analytic findings that open-ended questions have a significant impact on mathematical skills, but their effectiveness can vary depending on the type of skill being measured (Dewi & Juandi, 2024). Consequently, research in sixth grade should not rely solely on general final scores. Instruments need to capture each stage of problem-solving so researchers can identify the most developed aspects and those that still require support.

Using plane geometry problems offers the advantage of a direct connection between visual objects and calculations. Students can manipulate shapes, compare arrangements, and verify results in concrete terms. Research on area and perimeter shows that students with different abilities demonstrate

differences in meeting problem-solving indicators (Achadiyah et al., 2022). OE-PMM addresses this through tiered support and mandatory answer checks.

Motivation is not positioned as an additional variable measured after learning, but as a condition established during each phase. Strategy choices support autonomy, rubrics and incremental support support competence, and safe discussions support connectedness. This framework aligns with meta-analyses of Self-Determination Theory interventions, which show strong support for autonomy and competence, as well as increased intrinsic motivation, in experimental or quasi-experimental designs (Wang et al., 2024).

The relationship between motivation and problem-solving is thought to occur through persistence and self-regulation. Students who are engaged and feel capable are more likely to try again after their first strategy fails. Conversely, students who feel out of control may quit, copy answers, or wait for the teacher. Findings on responses to impasses suggest that curiosity, frustration, help-seeking, and retrying are all integral parts of elementary school students' problem-solving processes (Munzar et al., 2021).

Group discussions in OE-PMM are not simply grouping techniques. They serve to bring together different representations and reasoning. Research in heterogeneous classes shows that structured cooperative learning can improve geometry problem-solving, but social acceptance and friendship are also related to student outcomes (Klang et al., 2021). Therefore, teachers need to establish social norms that prevent teasing, domination, and exclusion.

The model also recognizes the risk of cognitive load. Problems with infinite possible answers can be more difficult than problems with a few specific answers. Teachers need to use the principle of progression: starting with a single problem with multiple strategies, moving on to multiple answers, and then moving on to problem development. Findings on the affordance of open-ended questions show that openness encourages diversity, but students may struggle to generalize (Bingölbali & Bingölbali, 2021).

In the context of the curriculum, the model allows for adjustments to classroom conditions. The official ATP is positioned as an inspiration that needs to be restructured to suit student needs (Ministry of Elementary and Secondary Education, 2024). This allows teachers to choose the appropriate context, level of openness, and tools without altering the purpose of the plane geometry concept.

This development is novel in its explicit integration of motivational support into the open-ended syntax for sixth grade. While many open-ended studies emphasize cognitive abilities, this model explains the affective mechanisms that enable students to persist in the face of challenges. Another novelty is its inclusion of motivation as a possible mediator, allowing further research to clarify not only whether the approach has an effect, but also how that effect occurs.

However, the model's validity cannot be determined until it undergoes expert assessment and field testing. Conceptual articles only provide arguments, components, and propositions. Future research should evaluate the model's content validity, the implementation of each phase, teacher and student responses, and the consistency of results across multiple classes. Reporting should distinguish between validation results, practicality results, and effectiveness results.

5. CONCLUSION

The OE-PMM model is a development of an open-ended approach that integrates problem-solving processes and motivational support for learning in sixth-grade plane geometry. The model consists of six phases: context orientation, open-ended problem exploration, individual strategy construction, collaborative solution comparison, justification and generalization, and reflection and motivational reinforcement. Problem-solving ability is measured through the stages of understanding, planning, implementing, and reviewing. Motivation is built through support for autonomy, competence, and connectedness.

Conceptually, OE-PMM is estimated to have a direct influence on problem-solving ability and learning motivation. Motivation is also estimated to be related to problem-solving ability and partially

mediate the effect of the approach. This statement is a proposition, not an experimental result. Therefore, the model needs to be tested through expert validation, limited trials, and quasi-experimental or mixed methods research in grade VI of UPT SD Negeri 064037, Medan Tembung District.

The practical implications are that teachers need to structure open-ended but directed geometric problems, allow time for individual strategies, manage comparisons of solutions, demand mathematical reasoning, and conclude the lesson with reflection. Further research is recommended using validated instruments, analytical rubrics, effect sizes, and documentation of student strategies to accurately describe the influence of the approach

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