



# Teachers' Perspectives and Proposed Assessment Framework in Implementing Open-Ended Tasks in Mathematics Classrooms

**Alexis Michael B. Oledan\***, **Crispin D. Ebal Jr.**, **Rovic E. Perocho**, **Dante Joma P. Zabala**, **Mary Joy F. Luga**, **Maria Rebecca O. Flores**, and **Grace P. Liwanag**  
 Integrated Development School, College of Education, Mindanao State University -  
 Iligan Institute of Technology, Iligan, Philippines

\*Corresponding author email: alexismichael.oledan@g.msuiit.edu.ph

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**Abstract.** This research examines the experiences of three secondary school mathematics teachers in developing, conducting, and evaluating open-ended mathematical tasks. It examines their instructional approaches, difficulties faced, and perceived benefits of employing such tasks to promote critical thinking, creativity, and conceptual understanding among students. Data was gathered through tasks, rubrics, and reflective feedback, analyzed using descriptive and thematic analysis. Findings indicate that although open-ended tasks enhance pedagogical insight and facilitate learner-centered learning, instructors have trouble in task construction, time planning, and the provision of feedback. This study proposed a framework for evaluating open-ended tasks, which included criteria of understanding, representation, communication, and creativity that are grounded on divergent thinking concepts. The study underscores the importance of professional development and strong support mechanisms to enable teachers to maximize the transformational capabilities of open-ended tasks in teaching mathematics.

**Keywords:** Open-ended Mathematical Tasks, Mathematics Instruction, Teacher Perceptions, Assessment Framework, Divergent Thinking

## 1. Introduction

An innovative and effective approach to enhancing students' conceptual understanding, critical thinking, and problem-solving skills is the integration of open-ended tasks in the mathematics classroom. Unlike conventional closed-ended problems that require a single correct solution, open-ended tasks allow students to explore multiple pathways and apply creative mathematical thinking. These tasks not only strengthen students' mathematical proficiency but also encourage them to generate diverse answers, promoting creativity through fluency, flexibility, and originality in problem-solving (Levenson, Swisa, & Tabach, 2018). Moreover, successfully engaging with open-ended tasks requires the development of both problem-solving abilities and communication skills, which are crucial for productive collaboration in group work (Chan & Clarke, 2017).

The nature and potential of open-ended tasks can be traced to their structure and forms. Literature describes open-ended tasks as questions, problems, or activities that permit multiple solutions leading to a common answer, or multiple correct answers derived

through varied methods or procedures. Yılmaz and Köse (2015) characterize multiple-solution tasks as mathematical problems that can be approached through different strategies, enabling students to achieve the same result in diverse ways. Similarly, Bingölbali and Bingölbali (2021) utilized open-ended questions with multiple correct answers in their study, while also noting that the use of such tasks may increase the workload and planning demands on teachers. This means that despite the recognized benefits, the successful implementation of open-ended tasks heavily depends on the perspectives and instructional approaches of teachers. As central figures in designing, facilitating, and guiding these learning experiences, teachers play a pivotal role in ensuring that students are supported as they engage in open-ended mathematical exploration. Consequently, there is a growing emphasis on the need for targeted teacher training and sustained professional development to build teachers' capacity and confidence in employing open-ended tasks effectively (Luong & Evans, 2021).

This study investigates teachers' perspectives on the use of open-ended tasks in mathematics classrooms. Specifically, it aims to examine the factors that influence the successful integration of open-ended tasks by exploring the challenges, benefits, and experiences reported by teachers. It also considers how professional development programs and support structures can facilitate teachers' adoption of this pedagogical approach. Understanding teachers' views is essential for addressing potential barriers and promoting the effective use of open-ended tasks to create dynamic, engaging, and student-centered mathematics learning environments. Previous research by Chick and Pierce (2017) has shown that open-ended tasks can significantly shift teachers' instructional beliefs, leading to a stronger emphasis on student-centered and problem-solving-oriented approaches to mathematics teaching.

This study is anchored in two complementary theoretical perspectives. First, the concept of mathematical creativity (Silver, 1997) frames open-ended tasks as opportunities to cultivate fluency, flexibility, and originality in students' problem-solving processes. Second, a sociocultural perspective on learning (Vygotsky, 1978; Cobb, 1994) emphasizes that knowledge construction occurs through social interaction, dialogue, and collaborative engagements, which are elements that open-ended tasks are designed to promote. These frameworks collectively underscore the cognitive and social dimensions of mathematics learning that open-ended tasks aim to enhance, providing a theoretical lens through which teachers' experiences and instructional practices can be examined.

Integrating open-ended tasks into mathematics instruction offers considerable potential to deepen students' understanding and foster essential mathematical competencies. However, the realization of these benefits is contingent upon teachers' readiness and support. By centering the teacher's perspectives, this study seeks to contribute valuable insights into how open-ended tasks can be more effectively implemented, ultimately enriching the mathematics classroom and enhancing students' learning experiences.

#### *Open-Ended Mathematical Tasks in Mathematics Classroom*

Open-ended mathematical tasks have become a popular approach to instruction in math classes because they motivate students to use their critical thinking skills, collaborate, and experiment with various methods to solve problems.

There is agreement in the literature about the definition and characteristics of open-ended mathematical tasks. These tasks are characterized by researchers as challenges involving a variety of potential responses and methods, frequently lacking a single correct answer. In mathematics education, open-ended problems are typically non-routine tasks that can be interpreted in different ways, allow for multiple correct solutions, and support a range of problem-solving approaches (Rizos and Gkrekas, 2023).

According to Bingölbali and Bingölbali (2021), “the terms such as open-ended problem, open-ended task and open-ended question are mainly employed to refer to the openness of an item. The term 'open' in the open-ended question, where the term question includes problem and task as well, refers to diversity. Openness allows for different definitions of the term open-ended by nature.

However, Yeo (2017) characterized openness according to being well-defined or ill-defined, and task-inherent or subject-dependent. Tasks variables were investigated such as goal, method, complexity, answer and extension. He defined that a task could have an open method, which may be well-defined or ill-defined. A well-defined method implies that students can be taught a specific procedure that consistently leads to the same correct answer. In contrast, an ill-defined method suggests that even when the same method is taught, different students may arrive at different answers. Moreover, an open method may be either task-inherent or subject-dependent. A task-inherent method indicates that the openness of the method is embedded in the task itself and does not rely on the individuals involved like teachers or students.

The effect of open-ended mathematical tasks on student learning outcomes has been the subject of several research. Studies show that students' problem-solving, mathematical reasoning, and metacognitive skills have been shown to improve when they engage in open-ended tasks. Additionally, open-ended tasks help students develop better attitudes about arithmetic, which promotes a pleasant learning environment. One way to address distinct student traits is with questions that are unrestricted. According to research on the use of open-ended questions in mathematics education, students become more active in expressing their ideas, have more opportunities to use knowledge and skills comprehensively, and gain rich experience in the process of discovering and obtaining approval from other students against their ideas. (Surya, et al., 2021).

The assessment of open-ended mathematical tasks is an important component of their implementation. The difficulties and new approaches for evaluating students' performance on open-ended tasks are discussed in some studies. When offering students open-ended tasks, there are a variety of methods of assessment and instruments that may be employed, according to Al-Absi (2013). In addition to the paper and pencil method, the teacher may observe the student as they work through the task and evaluate each of the parts of the problem using a checklist or a rating scale. To gather the reactions and works of the students, the teacher might utilize a portfolio.

#### *Teacher's Viewpoints in Utilizing Open-ended Mathematical Tasks*

Open-ended mathematical tasks have grown in popularity as successful instructional techniques for encouraging students' critical thinking, problem-solving, and grasp of concepts. While much research emphasizes the benefits of open-ended tasks for students, understanding how teachers perceive, design, and assess these tasks is equally vital. Hence, this study focuses on teachers' experiences. Understanding the views of teachers is crucial to maximizing the efficacy of this strategy as educators increasingly include these tasks into their classroom instruction.

Many researchers have investigated how teachers feel about open-ended mathematical tasks. According to research, teachers often have a positive attitude toward these tasks because they understand how they can help students develop their creativity, independence, and higher-order thinking skills. According to the secondary school teachers that participated in the study by Sariay (2017), open-ended questions/tasks may indicate the depth of knowledge that students need, i.e. high-level cognitive skills including comprehension, interpretation, and sophisticated decision-making. However, some teachers may be reluctant to include open-ended tasks because they have issues with evaluation, classroom control, and curriculum alignment.

Researchers have investigated the many ways used by teachers to successfully implement open-ended mathematical activities considering the difficulties in incorporating open-ended tasks that have been discussed. These techniques include task selection, creating relevant prompts, and organizing class activities to promote meaningful student engagement. From the literature review of Pınar Karaman & Serap Büyükkıdık (2023) study, cited Badger and Thomas (1991); Darling-Hammond (2017); Vercellotti and McCormick (2021), teachers need to follow some general guidelines for developing and accessing open-ended questions/tasks effectively in classrooms:

A. Questions which ask for written discussion and require students to elaborate on their thoughts. Open-ended questions may have more than one possible response.

B. Questions that encourage students to use higher-order thinking abilities like reflection, judgment, and reasoning.

C. Although open-ended questions may yield multiple valid solutions, they should nevertheless have a clear objective. Students must be aware of what to expect from the questions' explicit instructions. It is essential to create a well-structured scoring process to produce more accurate and consistent task outcomes.

D. Clear criteria detailing the characteristics of tasks at various levels of student performance should be included in scoring instruments (rubrics, checklists, scripts, etc.). In particular, rubrics are effective scoring tools for open-ended tasks that may be used to evaluate student achievement as well as provide teachers and students with feedback.

As teachers incorporate open-ended tasks into their method of instruction, a number of difficulties arise. Commonly cited barriers include time restraints, difficulty differentiating education for various learners, and limited access to appropriate resources. Teachers may also find it difficult to lead discussions and offer comments on a variety of students' responses. When creating open-ended questions/tasks, teachers believed that various elements, such as clearly explaining questions, offering content validity, and properly developing scoring rubrics, were significant. On the other hand, the majority of teachers thought that they had some issues with their open-ended assessment techniques. Lack of time, poor design and grading skills, and reluctant students are some of the difficulties teachers have (Karaman and Büyükkıdık, 2023).

There are studies exploring the function of professional development and support for teachers in fostering the efficient utilization of open-ended tasks. Increased self-assurance and success in executing open-ended tasks have been connected to effective professional development programs that give teachers access to resources, collaboration opportunities, and ongoing support. In order to properly generate and assess open-ended questions/tasks in classrooms, it has been suggested that professional development be provided for both preservice and inservice teachers (Karaman and Büyükkıdık, 2023).

In the present study, participating teachers were tasked with designing and implementing open-ended mathematical tasks and implementing them in their respective classrooms. Some of the teachers are not well-versed with incorporating open-ended mathematical tasks.

## 2. Objectives of the Study

While the educational value of open-ended tasks in fostering deep mathematical understanding and supporting student-centered instruction is increasingly recognized, much of the existing research has predominantly focused on student outcomes and broad pedagogical advantages. However, there remains limited empirical investigation into how teachers implement these tasks in everyday classroom practice and the specific instructional strategies they employ to maximize their effectiveness. Furthermore, although open-ended tasks are widely recognized for encouraging flexible and creative thinking, relatively little attention has been devoted to the development of systematic

assessment frameworks that can accurately capture the richness, depth, and originality of students' mathematical responses.

The specific objectives of the study are:

*i. Explore Teachers' Challenges, Strategies, and Perceived Benefits in Implementing Open-Ended Tasks in Mathematics*

This study aims to explore the design, characteristics, and implementation challenges of open-ended mathematical tasks as developed and utilized by teachers. It seeks to examine how these tasks influence teaching practices and to capture teachers' perceptions of the benefits of open-ended tasks on student learning, particularly in enhancing critical thinking, creativity, and conceptual understanding.

*ii. Proposed a Framework for Assessing Open-Ended Mathematical Outputs*

Another key objective is to design a systematic assessment framework for evaluating students' outputs when engaging in open-ended tasks. This framework will establish clear criteria for assessing the variety, depth, and creativity of student responses, ensuring that the evaluation process aligns closely with the goals of open-ended learning and supports meaningful feedback.

The findings of this study are expected to offer valuable contributions to the field of mathematics education. They will illuminate the practical applications of open-ended tasks in classroom settings and demonstrate their potential to transform traditional teaching dynamics. Additionally, the study underscores the critical role of robust assessment practices and targeted professional development in equipping teachers to successfully integrate open-ended mathematical tasks into their instructional approaches, ultimately fostering more dynamic and engaging learning environments for students.

### **3. Methodology**

#### *Research Design*

The study employed a multiple case study design involving three cases. A multiple case study approach is a qualitative research methodology that allows for the comparison and contrast of individual cases. This method enables researchers to explore a range of perspectives, extremes, and nuances to gain a comprehensive understanding of the phenomenon, while still preserving the individuality and context of each case (Baxter & Jack, 2008; Thomas, 2011, as cited by Adams, Barrio Minton, Hightower, & Blount, 2022).

Compared to other case study or experimental designs, multiple case studies yield data that is typically richer and more detailed. This study draws inspiration from Jia and Leung's (2019) research, which also utilized multiple case studies to investigate how teachers adopt open-ended mathematical tasks. By examining three distinct cases, the study provides a holistic perspective on how open-ended tasks are developed, implemented, and assessed in the context of secondary mathematics education.

#### *Participants*

Three teachers, designated as T1, T2, and T3, participated in the study. They implemented the open-ended mathematical tasks in their respective grade levels: Grade 12, Grade 9, and Grade 10 students at a Laboratory High School in Lanao del Norte, Philippines. T1 and T2 were both experienced teachers who incorporated open-ended tasks occasionally, typically once per quarter. In contrast, T3, a relatively new teacher, reported integrating open-ended tasks into classroom instruction more frequently, using them monthly.

### *Data Collection*

To prepare for the study, the participating teachers attended a series of sessions focusing on mathematical creativity and the use of open-ended mathematical tasks. During these sessions, they discussed key concepts related to mathematical creativity, analyzed sample open-ended tasks, and collaborated to develop their own open-ended mathematical problems tailored to their classroom contexts. The developed open-ended mathematical tasks were then implemented once in their respective classes. At the end of each implementation, the teachers answered a validated researcher-developed perception and reflection questionnaire, which consists of open-ended questions to share their experiences, insights, and challenges regarding the implementation of open-ended tasks. Each teacher used an adapted rubric to assess the outputs produced by their students. In summary, the study gathered the following data:

1. Teachers' self-developed open-ended mathematical tasks.
2. Teachers' Perceptions and reflections on utilizing open-ended mathematical tasks in their classrooms.
3. Rubrics used to assess students' outputs.

### *Data Analysis*

This study employed both descriptive and thematic analysis to address the research objectives. Descriptive analysis was used to document the designing process of the open-ended mathematical task, the development considerations, and the assessment criteria, where scores were assigned based on predefined criteria, and mean percentage scores were calculated to summarize overall performance. Also, thematic analysis was conducted to examine teachers' perceptions of implementing open-ended tasks in mathematics classes. Following Braun and Clarke's (2006) framework, responses were coded, and recurring themes were identified to capture common experiences, challenges, and perceived benefits of utilizing open-ended tasks in a mathematics classroom. The combination of descriptive and thematic analyses provided a comprehensive understanding of both student outcomes and teacher insights.

## **4. Results and Discussion**

This study underscores the potential of open-ended mathematical tasks as powerful instructional strategies that positively influence both student learning and attitudes toward mathematics. The findings point to three key areas that support effective implementation: (1) the development of appropriate learning materials and resources, (2) the process of classroom integration, and (3) the assessment and evaluation of student outputs. In terms of assessment, the study proposes a set of criteria that may guide teachers in evaluating students' work on open-ended tasks. These include: (i) understanding of the task, (ii) appropriateness of mathematical representations, (iii) clarity and effectiveness of communication, and (iv) creativity and originality of the output. Influence to teaching practice involved enhanced instructional insight, a shift in assessment practices, and professional growth.

The results highlight how open-ended tasks can enhance students' motivation, cognitive engagement, and creative thinking in mathematics. However, to realize these benefits more fully, it is essential to provide teachers with the necessary tools, instructional resources, and professional support. The following section discusses these findings in greater detail, examining their implications for classroom practice and future professional development.

*Explore Teachers' Challenges, Strategies, and Perceived Benefits in Implementing Open-Ended Tasks in Mathematics*

*i. Designing the Open-ended Mathematical Tasks*

White and Rowley (2018) highlighted the difficulties and assistance needed by teachers to include open-ended tasks into their mathematics instruction. The study offers perceptions into approaches to professional development that support the effective use of open-ended tasks in the classroom.

Upon analysis of teachers' process in developing their open-ended mathematical tasks, the following are what they considered in successful implementation of open-ended tasks in their classrooms.

**Table 1: Considerations in implementing open-ended tasks**

Case 1	Case 2	Case 3
Previous knowledge of students	Set objectives of the lesson	Anticipate what possible answers from the students
Resources	Evaluation of peers	Review existing open-ended tasks
Assessment	Assessment	Assessment
Students' to have their own view and interpretations		Students give their own and give many possible answers.
Relate to other fields		

Through a focus group discussion and analyzing the processes of the three teachers in developing their open-ended tasks, the paper would like to propose the following to be considered:

*A. Development of Appropriate Learning Materials/Resources*

During the discussion of mathematics teachers, the developed open-ended mathematical tasks should be helpful in attaining the objectives of the lesson. It should also include searching for existing or related open-ended tasks that were found to be effective. This will be a basis for neophyte teachers in terms of experience of implementing open-ended tasks. Also, preparation of learning materials to be used in the implementation of the developed/adapted open-ended tasks should also be taken into consideration. Since it is an open-task, teachers should consider how students might provide different interpretations to the given open-ended tasks.

*B. Process of Implementation*

Some of the open-ended mathematical tasks were implemented individually or by groups. The task should ensure students can provide multiple possible answers which may include the application of previous concepts in Mathematics. Also, it provides opportunities for students to use the open-ended tasks to relate the concept to other fields in order to provide more meaning.

### C. Assessment/Evaluation of Students' Outputs

Assessing students' output involves developing/adapting an assessment tool in evaluating the multiple and varied solutions of the students. The group also suggested that the teacher should provide an opportunity for peers to evaluate students' outputs for them to see other possible answers and help in determining correct and wrong answers. This is also essential to address misconceptions.

#### ii. Characteristics of the Open-ended Mathematical Tasks

In the study of Bennevall (2015), a 70-source literature study reveals 17 different forms of open-ended tasks, which are then defined, categorized, examined, and discussed from a teacher's point of view. The open-ended mathematical tasks are categorized into five (5): (1) Insight tasks: which are tasks that require overcoming of mental fixation; (2) Problem-Solving Tasks (Investigation Tasks): Rather than asking for as many solutions as possible to a multi-solution problem, an investigation task asks for the best solution. While in the end, only one method is chosen, problem-solvers still have to consider other approaches to persuade themselves (and others) that their approach is indeed the best; (3) Problem-posing tasks students construct as many problems as possible based on specific criteria; (4) Redefinition Tasks - request the problem-solver to consider a mathematical object from as many perspectives as possible, either by itself or concerning other things; (5) Open Classical Analogy Tasks - there are more than one unknown in a task; and (6) Generative Tasks - students generate an output base on the situation given.

**Table 2: Type of open-ended tasks implemented per case**

Case 1	Case 2	Case 3
Problem Posing	Problem Posing	Generative Tasks

The teachers were exposed to different samples of open-ended mathematical tasks. They then decided to plan and develop their own tasks. Upon examining the three teachers' tasks, two employed problem-posing tasks, while T3 used generative tasks. According to Silver (1997), in various fields of human endeavor, the ability to pose or find problems has long been seen as a sign of creativity or outstanding talent. Most of the open-ended mathematical tasks by the teachers were used as assessments. T1 developed a task in which students summarize the lesson and insights about the topic. She then asked students to create word problems relating to differential equations.

On the other hand, T2 utilized an open-ended mathematical task implemented as a project where students could work on it individually or in pairs. The task is to create real-life word problems involving arc length and the area of the sector. However, students are restricted to utilizing  $2/5$  rad as their central angle. Both tasks of T1 and T2 required students to provide complete solutions. T3 implemented open-ended mathematical tasks, which could be considered generative tasks. Students were asked to give the sum, difference, product, and quotient of a specific number of functions whose answer is 1, 2, 3, and 4, respectively. T3 also gave another task of the same strategy incorporating the topic of the composition of functions.

#### iii. Challenges and Influence to Teaching Practice

After the implementation of the developed open-ended mathematical tasks, the three teachers shared the challenges they have encountered during the developing and implementing phases of utilizing open-ended mathematical tasks. Below are the challenges encountered by the teachers.

**Table 3: Challenges in implementing the open-ended mathematical tasks**

Case 1	Case 2	Case 3
Consider previous knowledge of students	Time constraints	Feedbacking
Answers may be available online	Put effort in designing the task	Time constraints
Time constraints	Addressing students' misunderstanding	Crafting comprehensive instruction
Students' lack of confidence		

The teachers' reflections reveal several challenges in the design, implementation, and assessment phases of utilizing open-ended mathematical tasks. T3 emphasized that "the biggest challenge in the implementation is the feedbacking," noting that while it was easier to discern students' authentic conceptual understanding through their outputs, the process of providing individualized feedback was tedious and demanding, especially given the variety of students' answers. T3 also stressed the difficulty of crafting task instructions that are comprehensive enough to avoid student confusion. Similarly, T2 reflected that "making the open-ended task itself takes time and more effort", explaining that thorough thought and collaboration with colleagues were required to refine the tasks before implementation. T2 further noted that some students struggled to meet the task objective, stating that "a few of them weren't able to attain the objective of formulating the word problem that would correctly match the required given," necessitating additional consultations to support student understanding. Meanwhile, T1 identified multiple design and implementation challenges, including accounting for the "varied scope of knowledge the students already have about the lesson" and ensuring that the questions were not easily searchable online, which "took quite a portion of my time." During implementation, T1 observed issues such as "limited time constraint," students' tendencies to overthink, and the lack of confidence and motivation among some learners. Collectively, these reflections highlight the complexities teachers face when integrating open-ended tasks, pointing to the need for structured support in task design, time management, and feedback processes.

In terms of influence on teaching practice, a thematic analysis of the teachers' reflections reveals three interrelated themes: enhanced instructional insight, a shift in assessment practices, and professional growth. T1 observed that the use of open-ended tasks provided a clearer view of students' conceptual understanding, stating that it allowed them to see the depth of students' grasp of the lesson or topic and also revealed that the majority of students possess strong critical thinking abilities. Building on this, T2 noted that the experience motivated him to incorporate more open-ended tasks into his lessons, reflecting that utilizing open-ended tasks forces him to include more of these types of tasks in a quarter. He emphasized the positive impact on his professional competence, stating that it enhances his pedagogical knowledge and abilities and recognized that such tasks significantly foster the growth of students' higher-order thinking abilities, particularly their creativity. This increased appreciation also led to greater motivation to integrate more tasks enhancing higher order thinking skills. Meanwhile, T3 highlighted how student responses to open-ended tasks served as a formative tool, helping him to influence what was happening in the class by determining which students still needed more time to learn the material and guiding decisions on which concepts to reinforce. Together, these

reflections illustrate how open-ended tasks not only support student learning but also serve as catalysts for instructional reflection and innovation among teachers.

With the reflection of the teachers in utilizing open-ended tasks in mathematics, improvements must be made in the ability of teachers to design and carry out learning environments that foster a safe environment where students are encouraged to take risks, make mistakes, engage with others, and express their points of view.

*iv. Benefits of Open-ended Tasks to Students*

From the teachers' perspective, who developed and implemented open-ended mathematical tasks, the following is what they perceived to be beneficial to students based on their observation and reflection.

**Table 4: Benefits of Implementing the Open-ended Mathematical Tasks to Students**

Themes	Benefit to Students
Motivation	Promote ownership Promote Communication Engaging Challenged
Cognitive	Address misconceptions Enrich conceptual understanding
Creativity	Relating to actual scenarios Unique and different ideas

In connection to the themes presented above, Bennevall (2015) mentioned that open-ended tasks provide a rare possibility to practice creativity in mathematics, so every new variation should be cherished. With the arsenal of task types that this study has accumulated, teachers have more tools to help students enhance their problem-solving, engage their imagination, and expand their reality.

In another study, they put forward six principles of mathematics creative teaching as follows: 1) encourage creative thinking; 2) make full use of representations and transformation of mathematical knowledge; 3) establish motivation, self-efficacy, and self-concept within students; 4) help students become self-regulated; 5) promote group interactions; and 6) implement open learning environment (Wu et.al, 2020).

Divergent thinking is known in the literature to be the foundational proponent of creativity. However, there are many approaches to enhance creativity, notably in mathematics. Fluency ("the ability to generate a large number of different solutions obtained by the student for the same task"), flexibility ("the ability to produce a variety of different ideas about the same problem, organized in various categories"), and originality ("the ability to create and identify ideas as unique by comparing students' outputs") are the four components of divergent thinking that Guilford first proposed in the context of mathematics. Teachers should therefore modify their teachings and activities to encourage students to think in a variety of ways. According to Oledan and Limjap (2024), the quality and effectiveness of teaching strategies is a characteristic of a creative teacher.

*Proposed a Framework for Assessing Open-Ended Mathematical Outputs*

Prior to introducing a set of criteria for evaluating students' outputs in open-ended mathematical tasks, the teachers were initially allowed to use their own assessment methods and subsequently reflect on how such tasks should be assessed.

*i. Criteria for Assessing of Students' Outputs*

The three teachers employed different rubrics to rate the output of their respective students. In Case 1, the student must demonstrate not just the ability to find correct answers but also the confidence to explore multiple solution paths on their own. Their work should reflect a strong connection between mathematical tasks and real-world relevance, showing that mathematics is not just abstract but practical and meaningful. Students' approach to problem-solving should be methodical yet flexible, making careful choices about strategies and executing them efficiently. Their reasoning was assessed if it's clear and well-justified, with solutions organized logically and explained using formal mathematical vocabulary. Visual aids, such as diagrams and graphs, were thoughtfully used to support and clarify the work, creating a complete and polished final output.

Similarly, Case 2, the student should craft several approaches to the problem, each one rooted in careful reasoning and a sense of practicality. They must successfully navigate a challenging problem space, maintaining clarity in both their written and visual explanations. Their PowerPoint presentation demonstrated a deliberate effort to make mathematics accessible and engaging, using visual elements not just for decoration but to enhance understanding. Their solutions should reflect strategic thinking and an ability to articulate connections among different mathematical ideas.

For Case 3, the student not only solved the problems in multiple ways but also justified each step thoughtfully. Their solutions were scored if they highlighted a solid grasp of mathematical concepts, supported by effective visual representations such as graphs and labeled diagrams. Students must establish good communication in terms of: work should be well-organized, professional in presentation, and used mathematical language precisely. Through reflections and strategies, students must show how reasoning, representation, and creativity can come together to produce deep understanding.

*ii. Investigating Students' Output*

Using the teachers' respective rubric, the following are the results of the scores obtained by the students.

**Table 5: Scores Obtained by Students in the Open-ended Mathematical Tasks**

	Scores (For comparison, scores were converted to percentage)		
	Case 1	Case 2	Case 3
Highest	100%	100%	95%
Lowest	72.5%	55%	15%
Mean	84.64%	79.48%	60%

The open-ended mathematical task incorporated by case 1 and case 3 were implemented individually while case 2 opted to implement it in groups. It is evident that some students of case 1 and 2 have attained perfect scores in their respective open-ended mathematical tasks with a difference in students attaining the lowest score. It is also important to highlight that the two cases utilized problem-posing as an activity in their respective classes. However, a very low score was attained by a student in case 3 with average score less than the other cases. During the follow-up interview and reflection on students' output, the student did not follow the instruction stated for the task resulting in a minimum score.

However, one of the limitations of this study is that the teacher only recorded the total score and not by criteria.

*iii. Proposed criteria in assessing students outputs given an open-ended mathematical task*

The three cases provided different criteria for how they assessed the outputs of their respective students. Through a focus group discussion of mathematics teachers, this paper suggest the following four (4) criteria in assessing students outputs given an open-ended mathematical tasks:

*A. Understanding the Tasks*

Since open-ended mathematical tasks are different from usual classroom problems where students will just replicate and follow procedures in solving the problem, it is necessary that students should show understanding of what the task is all about. T1 and T3 used rubrics that incorporated assessing the skill where students understood the problem. The group of mathematics teachers agreed that for evidence that the students understood the tasks, they should plan appropriate strategies and approaches to solve the tasks at hand. This is a common criterion among the three cases. It is also suggested that this will be rated while students are doing the tasks, if not, a presentation of output must be done where students will explain how they come up with their answers.

*B. Appropriateness of Representation*

The group of mathematics teachers during the focus group discussion agreed to utilize the definition of representation of case three which talks about utilization of appropriate symbols as well as images, diagrams, charts and graphs with labels that address the problem at hand, solution techniques and clarify or emphasize crucial details regarding the problem, mathematical connections, and/or the solution. Representation criteria is common between case 1 and case 3.

*C. Communication*

Communication is also suggested as a criterion for assessing student outputs in the open-ended mathematical tasks. Through analysis of the criteria used by the three cases, communication is defined in connection to logical flow of arguments, mathematical thinking and reasoning. The writing is simple, straightforward, and easy to understand. It is tidy, grammatically precise, and semantically accurate; it has a professional tone. It employs formal math and efficiently uses words and symbols.

*D. Creativity of Output*

Lastly, since the tasks promote divergent thinking, the creativity of output is a suggested criterion. It involves a combination of criteria from the three cases. One of which is that the students provide more than one solution which is related to fluency. The other one is the level of difficulty and connection which involves drawing direct links between various problem-solving strategies and visual aids, as well as connecting mathematical ideas and issues. This criterion is related to the flexibility component of creativity.

The group of teachers also suggested having sub criteria for creativity of output based on the components discussed above. According to Aizikovitsh-Udi (2014), the degree of aesthetic in the students' solutions can be evaluated qualitatively using Dreyfus and Eisenberg's (1986) characterization of aesthetic values of a problem solution: (a) reliance on minimum preliminary knowledge; (b) importance of clarity; (c) simplicity, brevity, and conciseness; and (d) cleverness of the solution and element of surprise.

Assessing students' outputs is essential to investigate students' learning. However, according to Varank (2021), incorporating open-ended tasks in mathematics instruction

leads to more formative assessment practices, providing teachers with a deeper understanding of students' mathematical thinking.

## 5. Conclusion

This study investigated how secondary mathematics teachers design, implement and assess open-ended mathematical tasks through case analysis and group discussion. The findings revealed that while teachers recognize the importance of open-ended tasks in conceptual understanding, higher order thinking skills, and fostering creativity, they faced challenges in designing the tasks, instruction and providing feedback. However, employing open-ended mathematical tasks in their classrooms promoted meaningful professional growth, a shift in assessment practice and enhanced instructional insight. The study recommends the development of appropriate learning resources, clear implementation guidelines, and well-defined assessment criteria—particularly in understanding tasks, representation, communication, and creativity—to support effective use of open-ended tasks in mathematics education.

## 6. Limitations and Recommendations

The limitations and recommendations of the study are as follows:

A. The study included only three teachers, which is a small sample size, even for qualitative research. While small samples are common in qualitative studies to allow for in-depth analysis, the small sample size limits the generalizability of the findings. The study was constrained by voluntariness of teachers to participate in the study, meaning that the results cannot be broadly applied to all educators. Future research should consider including a larger and more diverse sample to provide a broader understanding of teachers' perspectives.

B. Teachers developed the open-ended tasks over about a week during their available time. Implementation and student engagement spanned 2–3 class meetings, while interviews and focus group discussions lasted up to three hours. Teachers checked student outputs at their convenience. Although flexible, this timeline may limit data consistency. Future studies should use a more structured and clearly documented timeline to improve transparency and strengthen the validity of the findings.

C. The open-ended tasks were only implemented once, limiting the opportunity to observe how teachers adapted and refined their approaches over time. Reimplementation of the tasks with necessary revisions is suggested to examine the long-term effects of these tasks on both teachers' practices and students' learning outcomes. Long-term engagement with open-ended tasks would provide more insights into how they can be integrated effectively into regular teaching practices.

D. Most of the data collected in this study focused on teachers' perspectives. While this is valuable, future research should also investigate students' perspectives on open-ended tasks, particularly regarding their engagement, challenges, and learning outcomes. This could be achieved by implementing open-ended tasks over a longer duration, allowing for a deeper understanding of how students interact with such tasks and their perceptions of the process.

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