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The Quantum Learning Model's View of Mathematical Logical Intelligence from the Point of View of Creativity in Mathematics Learning

T.S. Hadi[1*], S.B. Waluya[2], Mulyono[3] and A. Suyitno[4]

[1]*Students of Doctoral Department of Mathematics, Faculty of Mathematics and Science, 50223, Universitas Negeri Semarang, Indonesia.*

[2]*Department of Mathematics, Faculty of Mathematics and Science, 50223, Universitas Negeri Semarang, Indonesia.*

[3]*Department of Mathematics, Faculty of Mathematics and Science, 50223, Universitas Negeri Semarang, Indonesia.*

[4]*Department of Mathematics, Faculty of Mathematics and Science, 50223, Universitas Negeri Semarang, Indonesia.*

Intelligence is highly important to observe as it will impact students' thinking processes. Additionally, the thinking process can be further elevated through collaboration with creativity. The research aims to conduct an analysis of the levels of logical-mathematical intelligence and creativity through the quantum learning model, conduct an analysis of mathematical logical intelligence and creativity through the quantum learning instructional model and to analyse the effectiveness of the quantum learning model in terms of mathematical logical intelligence viewed from the perspective of creativity. The research employs a mixed methods approach, grounded in a combination of positivism and post-positivism. Research results utilising the quantum learning model indicate that students with high levels of logical intelligence are capable of applying mathematical concepts and analysing the interconnectedness between concepts. Students in the moderate category sometimes exhibit doubt and a lack of confidence when solving problems. Students in the low category tend to make larger errors compared to students in other categories. Creative indicators possessed by high-category students include classification, generalisation, hypothesis formulation, calculation, and conclusion. In the moderate category, these indicators involve classification, calculation, and conclusion. In the low category, the primary purpose is to seek instant solutions. The relationship between logical-mathematical intelligence and creativity in students categorised as high is that these students are able to apply concepts and analyse the connections between concepts, enabling them to classify, calculate, and draw conclusions. The effectiveness of the quantum learning instructional model in terms of creativity and logical intelligence is placed in the moderately effective category.

Keywords: intelligence; creativity; quantum learning; mathematics

I. INTRODUCTION

Mathematics is often linked to everyday life, and this connection fosters creativity. The key component in the process of developing advanced thinking abilities is creativity, thus it needs to be nurtured as early as possible to ensure the fulfilment of learning outcomes (Aini *et al.*, 2017). If learning outcomes are achieved and students are able to comprehend the instructional material, it will indirectly enhance learning achievements (Aini *et al.*, 2017). For students to be able to explore knowledge, thinking processes, and develop thinking abilities, creativity is necessary. In creativity, when viewed from the affective aspect, several factors are needed to support its attainment. These factors include a sense of curiosity where learners possess constructive curiosity and can demonstrate it through answering given questions, open-mindedness,

*Corresponding author's e-mail: budiw@mail.unnes.ac.id

where learners are receptive to new ideas and can exhibit this by using open and divergent thinking, flexibility, hypothesis formation, learner's imagination that allows them to harness their imagination and demonstrate exploration, synthesis, refinement of ideas, and creation, and self-confidence, which is the ability to reassure oneself of the abilities possessed or the ability to develop positive assessments for oneself and the surrounding environment (Arum *et al.*, 2018). By considering the supportive factors in creative thinking skills, it will result in improved learning abilities for students (Prastika R. S., 2020).

To make the learning activities engaging and enjoyable, instructors must possess high creativity and be capable of generating creative ideas in delivering the material (Baaquie, 2013). Engaging instruction will stimulate students' creative ideas in solving the given problems, making the learning environment lively and fostering interaction between instructors and students (D. Bolden, 2012). Nurturing students' creative thinking abilities is closely tied to other factors of students' capabilities, one of which is the intelligence possessed by students (Miranda & Mamede, 2022).

Based on the results of the preliminary study conducted by the author through a meta-analysis of several reputable journals, the aim was to understand the creative thinking skills of students (Corrigan *et al.*, 2013). Reputable journals reviewed in relation to creative thinking skills. The results indicated that students' creative thinking skills are still in the low category, or their impact on the application of technology is minimal. This is attributed to the fact that the technology used serves merely as a bridge between students and instructors, without granting students the freedom to explore alternative references (Sya'Roni *et al.*, 2020).

The results indicate that students' creative thinking skills need to be continually explored. Besides the correlation between creative thinking skills and technology, another intriguing aspect is the connection between students' creative thinking skills and mathematical logical intelligence (Widodo *et al.*, 2021). Students with creative thinking skills are at level 3 (creative), possessing high logical intelligence. Students with moderate creative thinking skills are at level 2 (moderately creative), having average logical intelligence. Furthermore, students with creative thinking skills at level 0 (not creative) exhibit low logical intelligence (Prastika *et al.*, 2021). Based on data analysis, it was found that subjects characterised by classification, comparison, performing basic numerical operations, deductive and inductive reasoning generally fulfil the components of creative thinking: curiosity, open-mindedness, imagination, and problem-solving (D. S. Bolden *et al.*, 2010). Subjects with the characteristics of hypothesis formation and testing fulfil four components and novelty (Aini, 2017).

Logical intelligence as an intellectual attitude encompasses the ability to quickly provide answers, solutions, and problem-solving capabilities (Prastika *et al.*, 2021). The concept of intelligence as a general capacity of individuals to act, think rationally, and interact with the environment effectively (Syaiful, 2020). In concept, creative thinking is almost similar to the logical-mathematical intelligence of students, so when students' creativity is enhanced, it will also enhance their logical-mathematical intelligence. One of the steps that can be taken to enable students to discover a method in problem-solving is by training their intelligence (Salam *et al.*, 2019).

Logical-mathematical intelligence is the ability to calculate, consider propositions and hypotheses, and perform complex mathematical operations. This intelligence enables students to comprehend relationships, connections, as well as abstract and symbolic ideas employed, reasoning skills, and patterns of inductive and deductive thinking (Salam *et al.*, 2019). The study on the relationship between creativity and logical-mathematical intelligence is based on data analysis, and it is found that subjects characterised by categorisation, comparison, basic numerical operations, deductive and inductive reasoning generally fulfil components of creative thinking: problem sensitivity, curiosity, imagination, open-mindedness, and problem-solving (Ernest, 2005).

The level of intelligence among students does indeed vary from one to another, and not many students possess a high level of intelligence (Kontro & Palmgren, 2020). Just like in the mathematics class of the civil engineering study program, the intelligence level needs to be enhanced. There are only a few students who have a moderate level of intelligence, as evidenced by the examination scores at the end of each learning session.

Examining the indicators of mathematical creativity, there exists a mutually fulfilling relationship between logical-mathematical intelligence and the pattern of creativity, as viewed from the affective aspect of mathematics (Faulkner, 2008). The intended connection is that creativity, observed from the affective aspect of mathematics, can contribute directly or indirectly to logical-mathematical intelligence (Fauziyah *et al.*, 2021). Based on indications rooted in theory and prior studies, it is necessary to conduct research concerning the connection between mathematical creativity and students' logical-mathematical intelligence, so that the desired achievements can be met (Gridos *et al.*, 2022).

The urgency of research on the relationship between logical intelligence as viewed from creativity can occur in subjects characterised by categorisation, comparison, basic numerical operations, deductive reasoning, and inductive reasoning, fulfilling indicators of creative thinking skills. By considering creativity from the affective aspect, it will have an impact on students' inherent logical-mathematical intelligence and lead to improvement (Isyrofinnisak *et al.*, 2020).

The connection between logical-mathematical intelligence and creativity can be supported by a learning model that shares similar characteristics, namely the quantum learning model (Jaramillo *et al.*, n.d.). The quantum learning model is a vibrant transformation of learning that encompasses all nuances, interactions, and differences that maximise learning moments, focusing on dynamic relationships within the classroom environment. Quantum learning is a joyful learning process that creates educative interactions between teachers and students, optimising an effective learning environment (both physical and mental) in education (Baaquie, 2013).

According to Rusnilawati *et al.* (2020), quantum learning is a new perspective that facilitates students' learning process by transforming learning into a lively experience, incorporating all the nuances within and around the learning environment through interactions in and around the classroom. The urgency of using the quantum learning model in education stems from its ability to support students' logical-mathematical intelligence by transforming the usually monotonous or teacher-centred learning into an engaging process. The novelty of the upcoming research lies in establishing the connection between each indicator of logical-mathematical intelligence and students' creativity, and its potential to strongly contribute through education using the quantum learning model. The objectives of this research include analysing logical-mathematical intelligence to optimise mathematics education through the quantum learning model, analysing students' mathematical creativity in mathematics education using the quantum learning model, and analysing the connection between logical-mathematical intelligence as viewed from creativity in mathematics education through the quantum learning model.

II. METHOD

A. Type Research

This research employs a mixed methods research design, which is based on a combination of positivism and post-positivism. According to Jayantika *et al.* (2019), mixed methods research is an approach that combines quantitative and qualitative forms of research. This approach involves the integration of the functions of both research approaches collectively, making its overall strength greater than that of individual qualitative and quantitative research, and more comprehensive than merely collecting and analysing two types of data (Johansen *et al.*, 2022). This approach also involves both quantitative and qualitative methods, and the blending of these two approaches in a single study and timeframe (Joklitschke *et al.*, 2022).

B. Design Research

The research design utilised in this study is the Embedded Strategy Model, a mixed methods design that combines primary methods, either quantitative or qualitative, with secondary methods, which can be either qualitative or quantitative, used simultaneously (Kasman, 2014). By integrating both sets of data, a comprehensive analysis is obtained. This research was conducted as a single-phase research study (Khine & Areepattamannil, 2019).

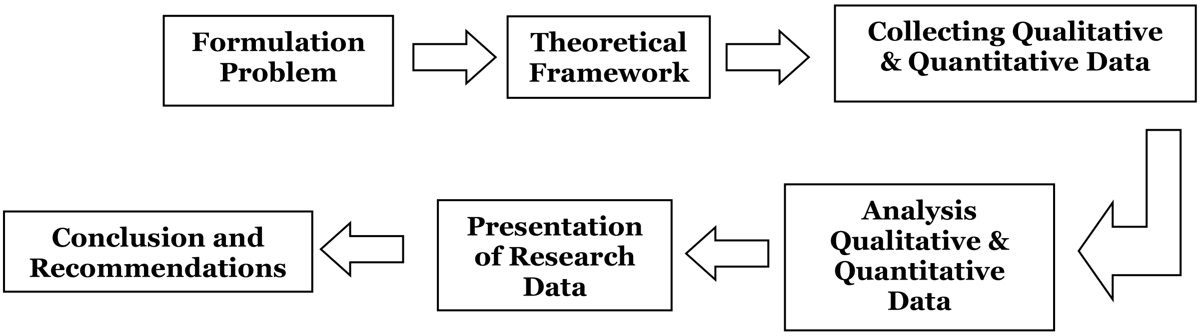

Figure 1. Design Research

Based on Figure 1, it can be explained that the research begins with identifying a problem or a potential. Once the problem and its background have been identified, they are then presented with facts. Subsequently, a problem statement is formulated in the form of research questions. The researcher then selects relevant theories to clarify the problem. Next, hypotheses are formulated, and research instruments are developed. Before testing the validity and reliability of the instruments, they must be prepared. Once the instruments are proven valid and reliable, they are then used to collect data in order to address the quantitative research questions, which are the focus of the study. Additionally, qualitative data collection is also conducted.

C. Research Sample

Sample is a portion of the population that is selected as the subject of the research. A sample, also often referred to as an example, represents the population's characteristics and is used to estimate population characteristics. The sampling technique used in this study employs probability sampling, which is a method of sample selection that provides an equal opportunity for every element (member) of the population to be chosen as a sample member.

D. Research Step

The following are the research steps that were carried out:

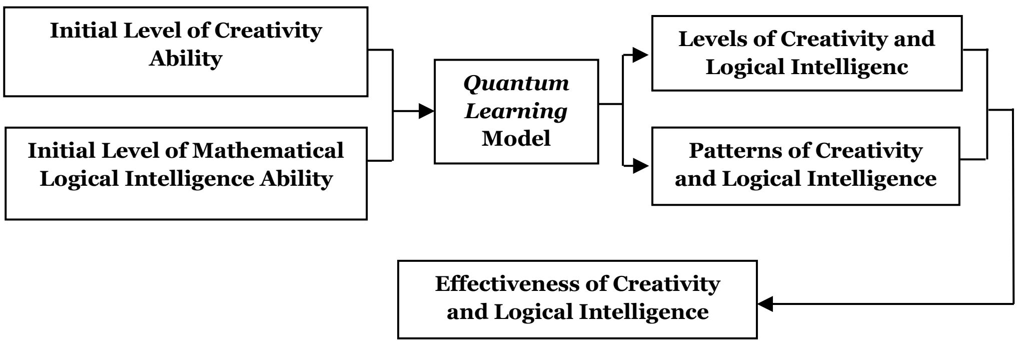

Figure 2. Research Step

In order to achieve the desired results, research requires well-structured steps, leading up to the discovery of innovations. The findings of this study include the level of creativity in the affective aspect, the level of logical-mathematical intelligence, patterns of creativity in the affective aspect, patterns of logical-mathematical intelligence, the effectiveness of creativity in the affective aspect and logical-mathematical intelligence, as well as the correlation between creativity in the affective aspect and logical-mathematical intelligence within the quantum learning model through the open-ended strategy.

E. Data Source

The source of primary research data is the type and origin of research data obtained directly from the first-hand source, whether individuals or groups, without intermediaries. This means that the data is collected directly. Primary data specifically addresses the research questions. The author gathered primary data using survey methods as well as observation methods (Arum *et al.*, 2018). The survey method involves the collection of primary data using oral and written questions. The author conducted interviews with students to obtain the necessary data or information. Additionally, data collection was conducted through observation methods. The observation method involves the collection of primary data by observing specific activities and events. Secondary data is a source of research data that the researcher obtains indirectly through intermediaries (collected or recorded by others). Secondary data takes the form of evidence, historical records, or reports that are organised in archives or documentary data (Jayantika *et al.*, 2019).

F. Data Collection Techniques

Data collection techniques are the most strategic steps in research, as the researcher's goal is to gather data. Without data collection techniques, researchers will not obtain data that meets the established data standards. Data collection technique using research triangulation includes the use of interview techniques. In this research, primary data consists of thoughts, ideas, feelings, and perspectives of those being interviewed. The interview technique is employed to understand what is in the minds and feelings of the respondents. Hence, one approach the researcher will undertake is conducting in-depth interviews with research subjects while adhering to the research direction, objectives, and focus.

Observation is a complex, structured process involving various biological and psychological processes. Two of the most important processes are observation and memory. The observation research instrument is deemed necessary by the researcher to enrich or complement the data already obtained from interviews. Through observation, the researcher can directly witness students' learning activities or their activities during classroom sessions. Subsequently, data collection involves pre-test and post-test assessments to determine the extent of students' achievement in the teaching material (both knowledge and skills) after participating in the learning activities. The pre-test and post-test assessments are conducted at the beginning and end of the learning period, respectively.

G. Data Analysis Techniques

Data Analysis Techniques in qualitative research are conducted before entering the field, during the fieldwork, and after completing the fieldwork. Before explaining the various data analysis techniques, it's important to first understand the concept of data analysis. Data analysis is the systematic process of organising data obtained from interviews, field notes, and documentation. This process involves categorising the data, breaking it down into units, synthesis, forming patterns, selecting what's important and should be studied, and drawing conclusions to make it easily understood by oneself and others (Sugiyono, 2014).

Activities in data analysis include:

1. Data Reduction: The data obtained from the field can be extensive, thus necessitating careful and detailed recording. As the researcher spends more time in the field, the amount of data increases, becomes more complex, and intricate. Therefore, data analysis through data reduction should be conducted promptly. Reducing data means summarising, examining essential elements, focusing on important aspects, identifying themes and patterns.

2. Data Display: In qualitative research, data presentation can take various forms such as brief descriptions, charts, inter-category relationships, flowcharts, and similar visualisations. The most common method for presenting data in qualitative research is through narrative text. In this context, researchers present data in textual form, potentially enhancing the clarity by including tables or figures.

3. Data Interpretation: This process involves reviewing data and arriving at relevant conclusions using various analysis methods. Data analysis assists researchers in categorising, manipulating, and summarising data to address critical questions.

4. Conclusion Drawing/Verification: Conclusions in qualitative research might address the research questions formulated initially, but they might also not fully capture the evolving nature of qualitative research problems and formulations during fieldwork. Conclusions in qualitative research represent novel findings that have not existed previously. Findings can include descriptions or

representations of objects that were previously vague or obscure and become clear through research. They can also involve causal or interactive relationships.

The Quantitative Data Analysis Technique of Calculating N-Gain aims to determine the effectiveness of using a specific method or treatment in one-group pre-test and post-test research. The N-gain score test is conducted by calculating the difference between the pre-test score (test before the application of the quantum learning model through the open-ended strategy) and the post-test score (test after the application of the quantum learning model through the open-ended strategy). By calculating the difference between the pre-test and post-test or gain score, the effectiveness of applying the quantum learning model through the open-ended strategy can be determined.

III. RESULT AND DISCUSSION

A. Research Results: Level of Creativity using the Quantum Learning Model

The research steps using the quantum learning model through the open-ended strategy are as follows: preparing equipment such as instruments, speakers, projectors, and room fragrances. Before starting the class, the researcher ensures that the air conditioning is functioning properly so that students can be comfortable in the classroom. The seating arrangement is adjusted to enhance student focus on the presented material, with seating arranged in U-shapes, circles, and other configurations, ensuring that students can concentrate on the instructor and the content being delivered. The room is also scented with room fragrances to create a pleasant environment.

Furthermore, before the class begins, the instructor takes attendance from the students while playing soft music to boost their learning enthusiasm. This practice is based on initial interviews with students, indicating that they are more motivated to learn when music is integrated. After attendance is taken, students are given 7 minutes for relaxation to allow those who have travelled long distances to rest briefly. Background music is played during this break. During the research activities, pre-test and post-test questions are administered to observe the development of creativity from the affective aspect or mathematical logical intelligence of the students during the course. The pre-test is given before students receive the material from the instructor, and they have 15 minutes to answer the questions.

While delivering the material, the instructor poses unexpected questions to students to enhance two-way interaction between the instructor and the students, creating a livelier learning atmosphere. The purpose of these spontaneous questions is to maintain student focus on the explanation. In summary, the research procedure involves a sequence of actions that encompass setting up the learning environment, engaging students through interactive techniques, and assessing creativity and intelligence growth through pre-test and post-test evaluations

During the course of delivering the material, the instructor also provides students with the opportunity to ask questions, as there is concern that students may not fully understand the steps of the presented material. If students request a repetition of the material explanation, the instructor revisits the explanation. After concluding the material explanation, the instructor gives students another chance to ask questions about the presented material, particularly focusing on matrices, including their definition, types, order, and matrix arithmetic.

Several sessions incorporate instructional videos from YouTube. After playing the video, the instructor further clarifies the content, as students reported not fully comprehending the material or finding the pace too fast. Additionally, discussion sessions are held with students, allowing them to ask questions related to the material covered. Following the completion of the material presentation, structured practice exercises are assigned to students in each session. These assignments are collected to assess the extent of the students' understanding on a daily basis.

The submitted assignments are reviewed and assessed by the instructor, providing feedback for improvement in subsequent sessions. Moreover, an observer from the mathematics education program student assists the instructor in classroom observations. Equipped with observation sheets, this student observes the responses of students to the applied treatment during the course. The analysis utilised to uncover creativity from the affective aspect of students is based on data obtained from a questionnaire distributed to students through Google Forms. Below are the results of the student responses regarding creativity:

Table 1. Creative Questionnaire Results

No	Indicator	Mean	Std. dev.	Percentage (%)
1	Curiosity	3.96	0.934	79
2	Open Mindedness	3.58	0.672	72
3	Imagination	4.36	0.489	87
4	Self Confidence	3.89	0.416	78

Based on the results of statistical data analysis conducted to analyse the effectiveness of the quantum learning model through the open-ended strategy, the highest average score was obtained in the imagination indicator at 4.36 with a percentage of 87% in the excellent category. In other words, the quantum learning model significantly impacts the imagination indicator in creativity from the affective aspect. Furthermore, the mean value for curiosity was 3.96 with a percentage of 79% in the good category, aligned with the self-confidence indicator, which had an average score of 3.89 with a percentage of 78% in the good category. As for open-mindedness, it achieved an average score of 3.58 with a percentage of 72%, falling into the fairly good category.

To ensure the validity of the statistical analysis data, the next step will involve presenting the results of structured interviews with students categorised based on their mathematical abilities: low, moderate, and high. To reveal the novelty value of the research conducted, we will start by considering several previous studies. This data will be reduced with statistical results from the research and validated through interviews. The explanations are as follows.

Research on the implementation of the quantum learning model has been conducted in the context of analysing the characteristics of middle school students in the development of mathematics learning tools based on the Quantum Learning Model and Teaching with the result stating: 'The results of this study are expected to improve students' interest in learning mathematics and make them more active in the learning process' (Pratama *et al.*, 2020). A similar study on the quantum learning model titled 'The Role of Mathematics and Self-efficacy in Quantum Mechanics Learning' explains the difference in mathematics skills between first-year and second-year physics students, revealing that second-year physics students showed slightly better results in exercises and exams compared to first-year physics students (Kontro & Palmgren, 2020). However, this difference is not significant as the first-year physics group also includes individuals with lower performance (Krumphals, 2019). Nevertheless, the difference is not significant because the first-year physics group also includes individuals with lower performance (Kynigos *et al.*, 2020).

Furthermore, it was found that second-year physics students recorded lower scores compared to first-year physics students and theoretical physics students in all conducted measurements. An explanation for this difference is likely due to a selective effect, as first-year mathematics students tend to be more comfortable and have a better understanding of physics and mathematics content compared to second-year students. This can influence their learning outcomes in mathematics and physics subjects (Kontro & Palmgren, 2020).

Based on several studies related to the implementation of the quantum learning model, it is evident that research related to creative thinking skills in mathematics learning has been conducted. Therefore, the researcher assumes that there is still novelty when it comes to applying research related to quantum learning in the context of creativity from the affective aspect. The following framework outlines the research results:

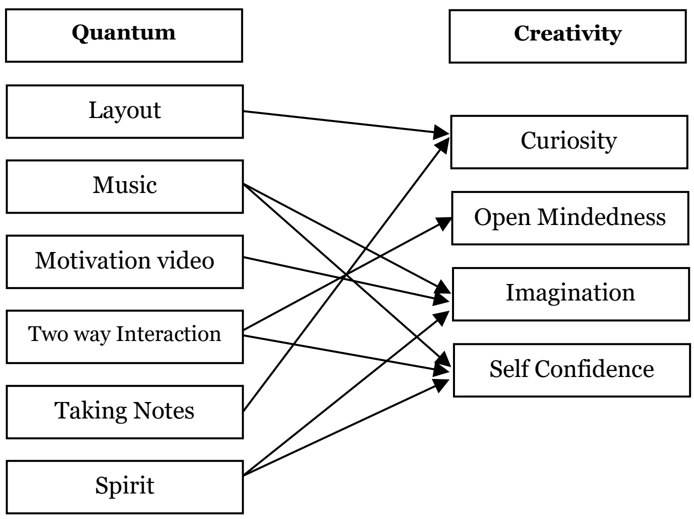

Figure 3. Research Findings Framework

Based on the research findings presented in the aforementioned framework, the relationship between the quantum learning model and creativity from the affective aspect in mathematics education is depicted. In the context of quantum learning-based instruction, the arrangement of seating positions is continuously altered, aiming to create a more meaningful and diverse classroom atmosphere. From observations and interviews, a connection is established between the arrangement of seating positions and the curiosity aspect of creativity from the affective dimension. The use of music in the learning process is linked to imagination and self-confidence, as instrumental and student-preferred music is incorporated into the teaching. Motivational videos played before the start of lessons are found to relate to students' imagination.

Regarding the indicators of the quantum learning model, the two-way interaction is associated with open-mindedness and self-confidence. This interaction involves bidirectional communication between students and teachers, fostering an environment of active engagement. Additionally, the activity of notetaking during lectures is correlated with the curiosity dimension of creativity from the affective aspect. The final indicator within the quantum learning model, enthusiasm, is linked to imagination and self-confidence within the creativity dimension from the affective aspect. The following section will delve deeper into the interconnectedness and impact of the quantum learning instructional model on creativity from the affective aspect.

a. Curiosity with the Quantum Learning Model

Curiosity refers to the desire to investigate and seek understanding of the mysteries of nature (Samani *et al.*, 2012). It continuously motivates individuals to explore and comprehend novel concepts, thereby expanding knowledge and experiences within the realm of learning. An alternative definition of curiosity, according to (Leech & Onwuegbuzie, 2009), characterises it as an attitude and action that persistently strives to gain deeper and broader insights from what is learned, seen, and heard.

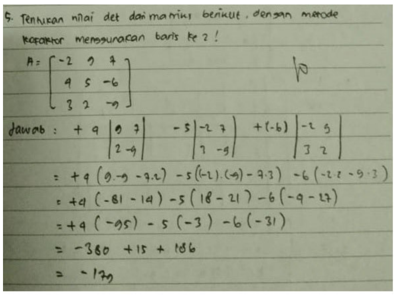

Figure 4. Students Response

It can be concluded that curiosity is the drive or desire of an individual to investigate and seek understanding about the mysteries of nature or unknown phenomena. It consistently motivates individuals to continuously search for and discover new things, thereby enhancing knowledge and experience in the learning process. Additionally, curiosity involves the attitude and action of consistently striving to comprehend in-depth and broadly about something learned, observed, or heard. This means that individuals with curiosity will continuously strive to delve deeper into topics or objects that capture their interest, thus enriching their knowledge in a more profound and comprehensive manner.

Based on the observations and interviews conducted with students regarding the implementation of the quantum learning model on curiosity, it was found that indicators that support curiosity are the arrangement of seating and the process of notetaking. The impact of seating arrangement on curiosity is not very significant according to students. Changes in seating arrangement contribute to a different classroom atmosphere and facilitate better discussions between students of low and high abilities, as well as interactions between high-ability students. Psychologically, seating position enhances learning enthusiasm, making students feel more relaxed and comfortable. However, students with lower abilities still tend to avoid occupying front or centralised seats.

According to (Leikin & Sriraman, 2022), seating positions affect students' learning concentration. Some students can focus better when sitting in the front and engaging closely with the instructor, while others may concentrate better when sitting at the back. This implies that expert opinions on this matter are relative and vary depending on individual students. However, other experts indicate that 25% of students sitting at the back tend to be more easily distracted, thus impacting their focus on grasping the material and leading to lagging behind in their studies. This phenomenon is also evident among the students in this research.

The above opinion is also similar to the statement by (Leikin *et al.*, 2013) that students sitting in the front feel more responsible for listening to the teacher's instruction, compelling them to focus on the subject matter being presented. Conversely, students sitting at the back feel less observed, which may lead them to engage in other activities or not pay attention to the material. According to (Lev-Zamir & Leikin, 2013) and the findings of conducted research, it is indeed true that the seating arrangement has an impact on curiosity, including students' understanding of the presented material.

Another factor that impacts curiosity within the quantum learning instructional model is notetaking. Notetaking remains one of the learning processes that continue to yield positive outcomes, particularly in terms of learning outcomes. According to interviews with students, they still find notetaking necessary for reviewing material at home. Through their notes, students can review their learning at anytime and anywhere, enabling them to prepare for exams based on their recorded notes.

For other fields, note-taking might not be an effective learning approach, as is the case for memorisation-based subjects, arts, and social sciences. However, for exact or calculation-related subjects, notetaking remains a significant method to enhance abilities and effectively impact learning outcomes. In the research, students from high, moderate, and low categories, when asked about the continued need for notetaking, provided similar responses. They expressed the need for notes because reviewing the material that has been presented and delving deeper into it helps them prepare for exams and gain a more profound understanding of the subject matter, potentially leading to new insights.

B. *Open-Mindedness in the Quantum Learning Model*

According to Malucelli and Fantinati (2022), being open-minded is the ability to pay close attention to a willingness to respond to anything that others say and to answer if questioned again. Another understanding of open-mindedness is an attitude where there is a willingness to consider different perspectives or viewpoints, thus having empathy for others even when not agreeing with their opinions (Miranda & Mamede, 2022). The open-minded attitude helps students to be receptive to new ideas and experiences, even though encountering something new might confuse and make students doubtful about its correctness when solving problems provided by the instructor (Munakata *et al.*, 2021).

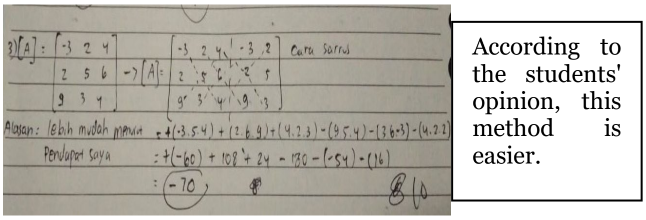

Figure 5. Students Response about Open Mindedness

Based on the research results by confirming with students regarding one of the steps in the quantum learning instructional model, which is the two-way interaction between instructors and students, it has an impact on the creativity indicator from an affective aspect, namely open-mindedness. The interaction between instructors and students in relation to explaining the provided material and providing direct feedback through questioning directly opens up students' minds about the conveyed material. One way to open students' minds to new concepts or topics being learned is by asking questions that lead to something new. Students are given the freedom to express something new, supported by brief explanations. For example, when determining the determinant of a matrix using the cofactor method, which typically involves using the first row, instructors motivate students to experiment with other rows to determine if the results are the same or different from the presented method. By conducting such experiments, students discover new insights into solving problems presented by the instructor. Only students in the high category are capable of doing this, which means conducting experiments and finding new methods to solve determinant problems.

For students with lower capabilities, sometimes even with the existing explanations, they still struggle to apply them to different problems. When the values in the problem are changed, low-ability students may experience confusion in applying the concepts. However, by maintaining an approach and motivation, students try to address this by discussing with the instructor or fellow students. Based on this, it can be concluded that the two-way interaction between instructors and students has a positive impact on students' open-mindedness, enabling them to discover alternative approaches to problem-solving.

C. *Imagination in the Quantum Learning Model*

According to Newton *et al.* (2022), imagination is the ability to create mental images of things that are not visible, making them seem as if they were real. Meanwhile, according to Suwarno *et al.* (2020), imagination is the ability to form images and ideas about something previously unknown.

According to Pasaribu (2018), imagination is the work of the mind in developing thoughts that are broader than what has been seen, heard, and felt. Through imagination, humans develop something from simplicity into something more valuable in their minds. It can develop something from God's creation in their minds, with the aim of making something more valuable in the form of an object or simply a thought that comes to mind (Pitta-Pantazi *et al.*, 2022).

Based on these definitions, it can be concluded that fundamentally, imagination is a mental power that enables humans to transcend physical limitations and develop creativity and deeper insights into the world around them (Pratama *et al.*, 2020). In the research conducted on creative thinking skills, specifically imagination, through learning by implementing the quantum learning model with open-ended strategies, based on student responses obtained through interviews, indicators from the quantum learning model that have an impact on imagination include music, motivational videos, and enthusiasm (Arum *et al.*, 2018).

In detail, regarding the impact of implementing the quantum learning model on imagination, there are some students who feel happy and even motivated to come up with new ideas when answering given questions. Similar to the researcher's own experience, when working on something, having music playing in the background helps inspiration and imagination flow smoothly, even leading to the emergence of ideas that were not initially present. Psychologically, music can positively influence the brain, allowing it to function effectively and even beyond its usual capabilities. Moreover, music can also enhance motivation directly or indirectly, leading to changes in thought patterns and overall motivation improvement.

Motivation can be provided directly by instructors or through motivational videos, especially those related to learning. However, compared to music, motivational videos do not have a significant impact on enhancing imagination during learning. Motivation is temporary, as without continuous verbal reinforcement or video stimuli, its effects quickly fade. Music and motivational videos can have an impact on students who enjoy music, yet some students might not be enthusiastic about music that is too loud or not aligned with their preferences. In other words, music can influence students' learning experiences as long as the music played aligns with their preferences.

D. *Confidence with the Quantum Learning Model*

Self-confidence is an individual's ability to take appropriate and effective actions in any situation, even challenging ones (Salam *et al.*, 2019). Overall, these two perspectives underscore the importance of human ability to address problems with directed and systematic thinking, but they have different emphases in their approaches and levels of detail. While Polya prioritises systematic and in-depth steps for problem-solving, (Sánchez *et al.*, 2022) might emphasise efficiency and quick solutions. The choice of approach depends on the complexity of the problem and individual preferences in solving it. Referring to various opinions on problem-solving in mathematics education, research utilising the quantum learning teaching model has an impact on problem-solving, as perceived by students during the learning activities.

Indicators that have an impact include music, two-way interaction, and motivational videos. Similar to how imagination benefits from music, problem-solving is also positively impacted by music, especially for students who enjoy it. Music can encourage students to think and solve problems. Listening to music provides the brain with support for thinking and discovering new aspects to solve the given problems.

Music does not discriminate between low or high ability students but rather depends on whether the student enjoys music or not. Two-way interaction between the instructor and students can also prompt students to engage with the problems given by the instructor. The interaction established goes beyond students asking questions; it involves discussions between students and the instructor about the work done in answering the given problems.

Based on interviews with students and observations conducted during the research activities with students, the level of creativity, as viewed from an affective aspect, refers to the theory of levels of student creativity (Pasaribu, 2018). The levels are as follows:

Table 2. Level Creativity

Indicator	**Level 0 (no creative)**	**Level 1 (insufficient creative)**	**Level 2 (sufficient creative)**	**Level 3 (creative)**	**Level 4 (very creative)**
Curiosity	-	√	√	√	√
Imagination	-	-	√	√	√
Open-Mindedness	-	-	-	-	√
Self Confidence	-	-	-	√	√

The results of creativity viewed from the affective aspect of students in learning using the quantum learning model through open-ended strategies were obtained based on categories: high, moderate, and low. In-depth structured interviews were conducted with these students. In the high creativity category, as viewed from the affective aspect, students fulfilled all indicators. The first indicator possessed by these students was curiosity towards the learned material. This was manifested by their ability to identify patterns and solve problems based on the instructions provided by the instructor. In other words, they followed the problem-solving approach as explained by the instructor. Additionally, they relied on existing knowledge gained from prior materials, which allowed them to generate new ideas by leveraging this knowledge. They were capable of developing and refining their knowledge by revisiting their learning.

Another indicator exhibited by high-category students was imagination. Imagination involves the cognitive ability to envision, create, and systematically solve problems. To manifest imagination, students required a well-structured mindset for exploration, devising novel methods, and refining their work through careful consideration. Through in-depth interviews and experimentation, these students could solve determinant problems using the cofactor method with modification. The modification referred to their ability to experiment with rows other than the first one when determining the determinant of a 3x3 matrix. While most students focused on the first row, these high-category students experimented with the second and third rows, leading to different results. Another indicator possessed by high-category students was open-mindedness.

According to (Arani & Mobarakeh, 2012), open-mindedness in this context referred to students' flexibility in problem-solving, avoiding fixation on a single approach, and their ability to come up with different and even simpler solutions. Furthermore, high-confidence students demonstrated a greater sense of confidence when discovering new ideas for problem-solving (Singer *et al.*, 2017). They communicated with the instructor and received motivation to solve the problem and compared their results. This level of thinking can be categorised as highly creative in mathematics learning through open-ended strategies.

For students in the moderate creativity category, based on in-depth interviews, it was found that they exhibited a satisfactory level of curiosity. These students engaged in intensive discussions with peers, particularly those in the high-category group. However, when searching independently via YouTube or browsing, they remained uncertain about the methods to be employed.

Moderate-category students also showed systematic imagination in problem-solving, although they required guidance from the instructor to introduce novel concepts. For instance, when determining the determinant of a 3x3 matrix, they needed encouragement to use a different row. Their initiatives were somewhat limited, and they still required guidance from the instructor to explore new approaches or to solve problems flexibly. Hence, students in the moderate category can be deemed moderately creative based on the affective aspect.

In the low creativity category, among the indicators used in the quantum learning and open-ended strategies for learning, only curiosity was observed. Students in this category demonstrated curiosity mainly about finding instant solutions. They sometimes participated in discussions but struggled to answer problems, often remaining passive and merely observing the outcomes. However, with motivation, they were willing to attempt all the given problems. Students in the low category faced difficulties in comprehending the taught material and required repeated explanations from peers. Researchers continually motivated them to try solving problems independently. Their creativity level can be classified as low.

E. Research Results of Mathematical Logical Intelligence with the Quantum Learning Model

To determine the effectiveness of implementing the quantum learning model through open-ended strategies, an analysis of data related to students' mathematical logical intelligence levels was conducted. The analysis of mathematical logical intelligence begins with the learning outcomes achieved by students during the learning process using the quantum learning model. The results obtained are as follows:

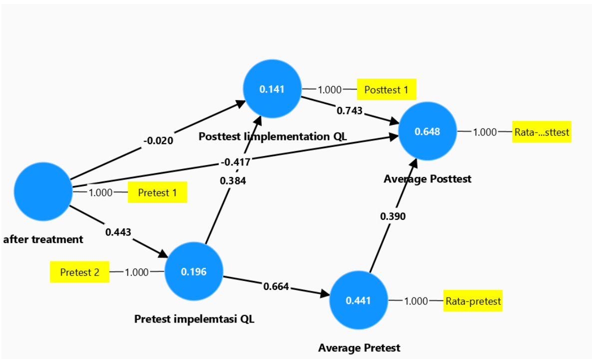

Figure 6. Output Analysis from Smart PLS

Based on the analysis, before the implementation of the quantum learning model, each student was given problems at the beginning of each learning session to assess their initial capabilities. The students' learning approach before the model was applied had a negative impact of -0.020. However, with adequate preparation, the initial impact on learning outcomes after the model was implemented was significant at 0.443, categorised as substantial. The implementation of the model had a significant effect as evidenced by the pre-test average improvement of 0.664, indicating that students were becoming accustomed to the applied quantum learning model. Furthermore, the initial post-test experienced a very substantial effect with an average of 0.743. The quantum learning model significantly enhances students' mathematical logical intelligence. Another aspect to be analysed is the level of students' mathematical logical intelligence. The results of the N-gain value analysis are as follows:

Table 3. Mathematical Logical Intelligence N-Gain Value

No	Value N-gain	Std. Dev.
1	62.30	30.21

Source: Statistic Data Processing

Based on the data analysis results conducted on pre-test and post-test scores in learning using the quantum learning model through open-ended strategies, an N-Gain value of 62.30 was obtained, categorised as moderately effective. The researcher also conducted a regression analysis due to reservations about relying solely on N-Gain values for statistical testing. The results of the regression analysis are as follows:

Table 4. Logical Intelligence Descriptive Test

Descriptive Statistics

	Mean	Std. Dev.	N
Mean Pre-test	33.0652	14.89097	23
Mean Post-test	89.0139	18.36978	23

Table 5. Logical Intelligence Summary Modelling

Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df 1	df2	Sig. F Change
1	.569[a]	.84	.292	12.52916	.324	10.076	1	21	.000

a. Predictors: (Constant), Overall Post-test

Based on the results of the model summary test, an R square value of 0.84 was obtained, indicating that the influence of the quantum learning model through open-ended strategies on mathematical logical intelligence is 84%. The remaining percentage is attributed to other factors not discussed in the conducted study. Additionally, the significance value (sig.) of 0.000 indicates that there is a significant influence of the quantum learning model through open-ended strategies on mathematical logical intelligence.

F. Analysis of Mathematical Logical Intelligence Levels using the Quantum Learning Model Through Open-Ended Strategies

Based on the results of the written test conducted among all students taking the mathematics course, the obtained results were categorised into high, moderate, and low levels. After categorisation, a more in-depth analysis will be conducted regarding mathematical logical intelligence. The analysis is based on the facts obtained from observations during the learning activities using the quantum learning model through open-ended strategies, as well as from confirmations obtained from students through interview processes.

Students in the high category, in terms of logical intelligence, are capable of applying learned mathematical concepts and analysing the interconnections between concepts, thereby opening up the idea that, for example, solving problems like matrix determinants can be approached in more than one way. Additionally, these students are capable of generalising the material provided and implementing it in the context of given problems. This means they can solve problems from a general form to a specific one or vice versa. Students in the high category are also able to hypothesise solutions for given problems due to their developed reasoning.

When working on assigned problems, these students are capable of performing calculations manually or using calculators, and they can draw conclusions from the problems, typically at the end of the solution process. Furthermore, they can often respond immediately when a question is posed by the instructor and, in terms of timing, they tend to complete tasks faster compared to other students.

Students in the moderate category, when solving problems, sometimes appear hesitant and lacking in confidence. In tackling problems such as matrix inverses, there are still errors in the calculation process. When solving problems, these students tend to adhere closely to the concepts provided by the instructor. When asked to try new approaches, they are hesitant and fearful of making mistakes. Errors that occur are usually due to misapplication of concepts in problem-solving.

These students tend to proceed from general to specific aspects when solving problems, as they find the former easier. However, when given problems in specific forms and asked to analyse the general forms, they face difficulties. In calculations, lack of precision leads to inaccuracies in their answers. Additionally, some students in the moderate category tend to prioritise solving easier problems first when doing exercises or tests, indicating their ability to classify tasks.

Students in the low category tend to make larger errors compared to students in other categories when answering given problems. Moreover, their understanding of concepts is limited, causing them to heavily rely on notes when solving problems. These students exhibit significant shortcomings in their basic calculation abilities. For instance, when presented with a simple calculation like '624 ÷ 3', many of them are unable to solve it. Students in the low category require different approaches in order to absorb the provided material effectively.

IV. DISCUSSION

Based on the research conducted by applying the quantum learning instructional model, the discussion of this study are as follows:

This passage describes the performance and characteristics of students in different categories of creativity.

1. Students classified in the "high" category demonstrate proficiency in various aspects of creativity related to emotions or feelings. They exhibit skills such as categorising information, making generalisations, formulating hypotheses, performing calculations, and reaching conclusions. These students are skilled at effectively applying learned concepts and frequently come up with innovative approaches when solving problems. They also possess the ability to uncover hidden or concealed concepts when addressing challenges. Students categorised as "moderate" tend to apply the concepts they have been taught when working on problems. However, there might be instances of calculation errors. Although these errors are not usually fundamental mistakes, they do occur at specific steps

of the problem-solving process, leading to partial scores. Indicators for students in this category involve tasks like classification, performing calculations, and drawing conclusions. On the contrary, students falling into the "low" category, particularly when considering emotional or affective creativity in the context of quantum learning and open-ended strategies, are identified primarily by their curiosity. This suggests that their level of engagement or interest is more pronounced, rather than displaying advanced problem-solving skills.

2. Students classified in the "high" category of logical intelligence showcase the capability to effectively use learned mathematical concepts. They are adept at analysing the relationships and connections between various mathematical concepts. This understanding allows them to recognise that complex problems, such as matrix determinant calculations, can be approached using multiple methods. Additionally, these students have the ability to generalise the concepts taught and apply them to different situations. They can seamlessly transition from solving problems in a broader context to specific instances and vice versa. Furthermore, students in the high category possess the skill to hypothesise potential solutions for problems due to their advanced reasoning abilities. Students in the "moderate" category occasionally exhibit hesitation and lack of confidence while solving mathematical problems. This hesitancy might be reflected in their approach to problem-solving and decision-making. Students in the "low" category, on the other hand, are prone to making more significant errors when attempting to solve mathematical problems compared to students in other categories. This suggests that their understanding of mathematical concepts might be less developed, leading to inaccuracies in their problem-solving processes.

3. This paragraph discusses the findings from interviews conducted with students who are classified as having a high level of comprehension. The results indicate that the quantum learning model is effective for their learning experience. This model creates a conducive and engaging learning environment characterised by a comfortable classroom atmosphere and pleasant aromas that promote relaxation during the learning process. The teaching approach is gradual and comprehensive, making it easy for students to understand the presented material. Moreover, the learning process is adaptable and flexible, enabling students to explore various references without constraints. This flexibility encourages them to actively seek out additional information that aligns with the material being taught.

Based on observational results, some students consistently focus on problem-solving, while others engage in conversations with peers. During problem-solving, a few students utilise calculators for computations. Notably, while solving problems, many students still rely on notes and specific problem-solving techniques. Based on the analysis of the effectiveness of the quantum learning instructional model with open-ended strategies in relation to affective creativity and mathematical logical intelligence, it can be categorised as moderately effective.

V. CONCLUSION

1. Students in the high category exhibit all indicators of creativity from the affective aspect, such as classification, generalisation, hypothesis formulation, calculations, and drawing conclusions. Students in the high category are capable of effectively applying concepts and frequently discover new approaches to solving given problems. Moreover, they are adept at unveiling concealed concepts when tackling problems. For students in the moderate category, when solving problems, they typically apply the given concepts, although some calculations may be incorrect. These errors, however, are usually not fundamental mistakes but occur at specific steps, resulting in partial scores. Indicators for students in the moderate category include classification, calculations, and drawing conclusions. On the other hand, students in the low category, when considering affective creativity through quantum learning and open-ended strategies, are indicated solely by their curiosity.
2. Students in the high category, with respect to logical intelligence, demonstrate the ability to apply learned mathematical concepts and analyse the interconnections between various concepts. This enables them to realise that, for instance, solving problems like matrix determinants can be approached through multiple methods. Additionally, these students can generalise provided material and

implement it in various contexts. Essentially, they can transition from solving problems in a general form to specific cases and vice versa. Moreover, students in the high category can hypothesise solutions for problems due to their well-developed reasoning skills. Students in the moderate category, however, sometimes display hesitancy and lack of confidence while solving problems. Students in the low category tend to make larger errors compared to students in other categories when addressing given problems. The relationship between logical-mathematical intelligence and creativity in students categorised as high is that these students are able to apply concepts and analyse the connections between concepts, enabling them to classify, calculate, and draw conclusions.

3. Based on interview results with students categorised as having high comprehension, it is evident that the quantum learning model is effective for learning. This method creates a comfortable and engaging learning environment, with a relaxed classroom atmosphere and pleasant aromas that facilitate relaxation during learning

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