E-ISSN: 2621-4296

Exploration of Lithner's Creative And Imitative Mathematical Reasoning Analysis Based on High School Student's Mathematical Anxiety in Trigonometry Class

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Abstract

This study aims to explore the creative and imitative reasoning process of high school students based on their mathematics anxiety (MA) level. The research method used was descriptive qualitative research. The subjects were 62 students, with the criteria of high/medium/low MA questionnaire results. Data collection techniques were conducted by written tests, field observations, and interviews. The results of MA levels are 19.4% low level and 80.6% medium level of MA. The absence of high MA level students made the researchers investigate through the three aspects of MA, which are: Attitudinal, Cognitive, and Somatic. There were no significant differences within the other two aspects but the somatic aspect shows 36% amongst the medium level MA are having high category on this aspect: 1) Creative reasoning process is only owned by students with medium level MA; 2) Students with high level and low level MA are considered vulnerable to misconceptions, rely heavily on available information, and tend to find it difficult to make new approximation; 3) The process of Imitative reasoning is possessed in each MA category, judging from the performance of solving Algorithmic and Memorized type problems. Thus, it can be concluded that the type of reasoning of a student will differ between types of MA categories and with different processes according to their particular interest in learning.

Keywords: Reasoning, Mathematics Reasoning, Mathematics Anxiety, Lithner's Reasoning, High School Major, Natural and Social Sciences

INTRODUCTION

Mathematical reasoning is a foundational skill that underpins the acquisition and construction of mathematical knowledge. As a critical component of mathematics education, it enables students to comprehend complex concepts, solve problems effectively, and develop logical thinking (Riyanto & Siroj, 2011). Understanding mathematical principles through reasoning helps students not only in their academic pursuits but also in real-world applications, fostering analytical and decision-making skills. By engaging in mathematical reasoning, students learn to formulate hypotheses, construct proofs, and communicate their ideas clearly (California High School Exit Exam [CAHSEE], 2008). Overall, this ability is critical for both lifetime learning and academic achievement, emphasising the need for early curricular integration.

In fact, many learners do not have good mathematical reasoning skills or at least able to meet the standards that must be possessed by the level of education they are currently undergoing, causing feelings of frustration in learners which can be a source of mathematics anxiety (MA) (Anggraeni et al., 2014; Iswadi, 1999; Scarpello, 2007). A survey by Kessler at al. (2005) suggests that MA is a major problem for numerous students, which in this case defined as an anxiety that can disrupt the process of manipulating numbers and solving mathematical problems in everyday life and school questions (exercises and exams). In addition, some studies also suggest that students with high MA levels tend to have low mathematical reasoning skills, whereas students with low reasoning have a high MA (Anita, 2014; Aryani & Hasyim, 2018; Ashcraft & Krause, 2007; Syafri, 2017).

When experiencing MA, students may have thoughts that they do not know enough about the content (knowledge), experience physical changes such as sweating or rapid heartbeat (somatic), have the inability to think straight or forget things that they would normally remember (cognitive), or feel insecure about doing what they are asked to do or unwilling to do it (attitude) (Cooke et al., 2011). While it is possible for teachers to analyse students' MA levels and then strategise approaches to help their students by using the Mathematics Anxiety Rating Scale for Adolescents (MARS-A) which was designed by Richardson and Suinn to classify adolescents' MA levels. Suinn and Edwards also included that the MARS-A can be used as a foundation for objective counselling and guidance for junior and senior high school students as these are the times when mathematics learning behaviours are formed, the mindset about career choices are formed, and the times when MA can greatly impact student achievement (Richardson & Suinn, 1972).

Senior High School students are in the consideration as a quick escalation level of MA, where mathematics may becomes so complicated in terms of real numbers, algebra, trigonometry, and other materials that require various skills and excellent working memory (Raggam, 2021). To some extent, MA has a major impact on the development of a student's working memory, which may affect their arithmetic skills, especially on tasks that involve multi-digit, conceptual and high levels of calaculation (Dowker et al., 2016). One of the high school mathematics main topics that are conceptual, have a high level of difficulty, and require students to use working memory is trigonometry (Khairunnisa et al., 2023).

Thus, the main focus of this research is to obtain data and interpretation of students' mathematical reasoning after an assessment based on the MA category amongst students at a private school in Jakarta. The elaboration of students' mathematical reasoning focuses on how the students processing a mathematical problems refers to Lithner's (2008) dimensions of mathematical reasoning by mapping the aspect of Imitative Reasoning (IR) and Creative Reasoning (CR) after they are classified based on their level of mathematics anxiety using MARS-A (Suinn & Edward, 1982). In short the goals of this research is the exploration and elaboration of reasoning profile in highschool students based on their mathematics anxiety (MA) level.

Mathematical Reasoning

Mathematical reasoning skills have been a topic that has been extensively developed by philosophers and mathematicians. Reasoning by Euclid of Alexandria 2300 years ago was introduced with 'proof' as a tool to prove that a truth is absolute and unquestionable (Krantz, 2007). Euclid also assigned definitions, axioms, and theorems consecutively to every problem that required reasoning (Franklin, 1996; Krantz, 2007). This shows that reasoning requires a process by choosing the right tools to solve it.

In the following time, Lithner (2008) successfully developed a method to analyse students' reasoning by classifying into two types and dividing them based on each characteristic that the student shows in each answer and their behaviour. Lithner's classification of reasoning includes:

Creative Reasoning (CR). Lithner neither defined creative as a specific thing, nor did he emphasise creative reasoning as 'doing something extraordinary'. Rather, he refers to the process of creating a simple solution that the creator thinks is original. In the field of education, students are given a sequence of tasks as access to solutions, and here are some criteria for reasoning someone can be said to be creative. (1) Novelty, this means that a new set of solutions must be created in problem solving or a solution set that has been forgotten, must be recreated. Therefore, an answer that simply copies a procedure from another problem is not a type of CR; (2) Flexibility, this means students must use different approaches and adapt to suit the problem situation. So the usage of a fixed rule does not include the type of CR; (3) Plausible, means that there must be reasons that support the choice or strategy to strengthen the conclusion they made is correct or plausible. So guessing the answer is not included in the type of CR. (4) Mathematical Foundation, which means the argumentation given in the previous point must have intrinsic mathematical properties. Therefore, reasoning that is purely based on experience is not a type of CR.

Imitative Reasoning (IR) is basically a type of reasoning that is formed by copying task solutions (Bergqvist, 2007). For example, by looking at examples in books or remembering answers thatthe teacher has given. Some types of IR include: (1) Memorised Reasoning: This reasoning happens when the selection of a strategy exists and discovered by recalling a complete answer on another problem and the strategy is simply to write it down (or say it, draw it, etc.). So the student is allowed to explain a part of the process without needing to explain what the previous part means. (2) Algorithmic Reasoning: This reasoning happens when the strategy is chosen and found by recalling but not the whole answer, after the rules / algorithms are known then answering the question will not be an issue for the student. It is also important to realise that the clarity or rationalisation of the method the student uses is not important to know in this classification.

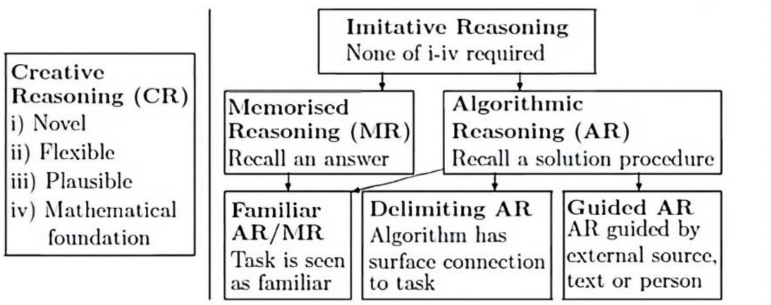

FIGURE 1. An Overview of Empirically Established Reasoning Types (Lithner, 2006)

Mathematics Anxiety

Maths anxiety (MA) is a psychological and physical condition where a person feels pressured and discomfort when manipulating numbers or solving mathematical problems, either at school or in everyday life (Cooke & Hurst, 2012; Spielberger & Vagg, 1995; Wang, 2019). MA also defined as the fear and unpleasant feelings that interupt a person when solving maths problems in real life or schoolwork problems, e.g., exercises and exams (Ashcraft, 2002; Utami & Warmi, 2019).

A debate continues about the beginning of maths anxiety in a person's mind. Many researchers and educators argue that the first appearance of maths anxiety occurs when children begin to learn complex mathematics (Sokolowski & Ansari, 2017). On the contrary, a research has examined 154 children aged 6 years old, who were in first or second grade of primary school and had not yet learnt complex mathematical concepts, and resulting almost half of the children said that they felt a little nervous when doing maths (Ramirez et al., 2013). In summary, MA develops from a relatively varied age of children and undoubtedly nomerous responses will be obtained whereas a teacher is expected to handle this matter well after knowing the symptoms that students have by providing guidance and counselling as a method (Sari, 2017).

Numerous methods are known exist to determine the level of MA, such as the Mathematics Anxiety Rating Scale for Adolescents (MARS-A). This programme is a revision of the previous version of the Mathematics Anxiety Rating Scale (MARS) which centering the contents made are relevant to teenagers' experiences. For instance, the situations include: " Collecting money for tickets," "Playing cards with numbers on them," "Counting down result in a vote," "Decide how much to tip to give," etc. MARS-A is also easy to use as it consists of five items likert scale that are easily understood by adolescents and has been validated in many studies (Suinn & Edward, 1982).

Cooke and Hurst (2012) provided an alternative approach to measure mathematics anxiety using MARS-A by considering three categories of indicators: somatic, cognitive, and attitude, in which the cognitive category will be further elaborated in terms of knowledge. The knowledge aspect needs to be elaborated because it was shown that MA can arise in situations that require mathematical skills and knowledge such as completing self-assignments and examinations (Cavanagh & Sparrow, 2010). Cavanagh and Sparrow (2010) added that levels of MA can be measured by the same indicators, meaning that all levels of anxiety (low, medium, and high) are characterised by a combination of the three indicators.

TABLE 1. Model of Mathematics Anxiety

Dominant trait model of mathematics anxiety			
Indicators / Anxiety Level	Attitudinal	Cognitive	Somatic
High anxiety	e.g. Scared about what s/he has to do	e.g. Worried about other thinking s/he is stupid	e.g. Having difficulty breathing
Medium anxiety	e.g. Not wanting to be doing what has to be done	e.g. Mind going blank	e.g. Heart beats more quickly
Low anxiety	e.g. Expecting to have difficulty doing what is required	e.g. Being confused	e.g. Feeling uncomfortable
Note: Applicable to	**In-class instruction** For example, independent work, group work or working in a class group **In-class assessment** For example, formal examinations or tests, informal tests **Out-class application** For example, another subject, at home, at work, or social life		

METHOD

This research describes students' mathematical reasoning profile based on the type of mathematics anxiety that students experience. This research is using the descriptive qualitative research. Qualitative research method is a type of research that emphasises the process and untested understanding, or measured precisely with data in the descriptive format (Strauss & Corbin, 2003). This qualitative research was conducted to gain an understanding of reality through an inductive thinking process (Adlini et al., 2022).

This research was conducted in 10 grade of SMAS Manbaul Ulum Asshiddiqiyah Jakarta. The research was conducted offline in the even semester of the 2023/2024 academic year, to be precise in January 2024 - March 2024. The determination of research subjects was carried out using purposive sampling technique which is a technique of selecting subjects with certain considerations (Sugiyono, 2008). The research subjects consisted of 6 students based on the test results with criteria that must represent each mathematical anxiety level, willing and able to answer reasoning test questions with the type of reasoning they have, and willing to be interviewed.

The first phase of the research is conducting a literature study by looking for sources, data, or information related to the problems in the research. Then, conduct a field study or observation in order to find out the problems that become the background and formulation of research problems. The research was undertaken by observing teaching and learning activities with potential subjects as the first step of observation, after the subject can be considered as a reliable source then questionnaires and written tests can be distributed to classify the type of MA and see the type of reasoning possessed by students.

The selection of subjects is done by examining the data from the written test results and the questionnaires given to several subjects as representatives of each type of anxiety. After the data is collected, then the pre-processed data is analyzed. The final phase is data summarization and report writing that has gone through the analysis stage in accordance with the formulation of the research problem. In the process of data collection, researchers used data in the form of assessments. The approach in this research is qualitative so that some additional data is needed which is explored using in-depth interviews with students and teachers. The tests and interviews were scheduled through information from the teacher or subject personally outside of school hours with the permission of the subject and the teacher in charge.

Mathematics Anxiety Questionnaire. The MA questionnaire used is an adaptation of the Mathematics Anxiety Rating Scale for Adolescents (MARS-A) with 30 items of Likert scale from 1 to 4. The description of scale 1 is "Strongly disagree" to scale 4 "Strongly Agree" with table 1 as the indicators. The total of the MARS-A scores obtained was calculated by summing all the scores. The results of this data analysis were then used to categorize students in the class into high, medium, and low categories using descriptive percentage statistics using hypothetical norms. The hypothetical norm aims to represent individual differences categories based on the defined criteria and not their relative position in the population (Hidayatullah et al., 2020). The formula for the mean of MA test score is as follows.

$$mean = \frac{max + min}{2}$$

Description:
Max = maximum score for all questions
Min = minimum score for all questions

Furthermore, the standard deviation is calculated with the formula as follows.

$$SD = \frac{max - \text{min}}{6}$$

The score boundaries for the high, medium and low categories will be set based on the mean and standard deviation. The grouping categories can be seen in the following table.

TABLE 2. Mathematics Anxiety Grouping Categories

Score (s)	Category
$(Mean + SD) \leq s$	High
$(Mean - SD) \leq s < (Mean + SD)$	Medium
$s < (Mean - SD)$	Low

The next test is the mathematical reasoning test, this test consists of 3 (three) essay questions that have been validated and based on Lithner's (2006) mathematical reasoning ability indicators in table 3. The questions on this test are mathematics story problems with moderate level trigonometry without scoring. Scoreless assessment is meant to see the mathematical reasoning ability possessed by students without looking at the correctness or incorrectness of the answer. The assessment will observe the quality of understanding of the students' reasoning by looking at the process of students solving mathematical problems, as well as the concepts, strategies, tools, and communication skills they use when answering questions (Lindquist & Gates, 1994; Rachmawati et al., 2024).

TABLE 3. Reasoning Test Indicators

Reasoning activity	Indicator
Creative Reasoning (CR)	1. Students can write down a assumption 2. Students can write conclusions, compile evidence, or write reasons for solutions; 3. Student's answer has novelty, flexibility, plausibility, and mathematical foundation .
Memorised Reasoning (MR)	1. Students can write down patterns or properties of mathematical properties to make generalizations
Algorithmic Reasoning (AR)	1. Students can write down mathematical manipulations

The amounts of data collected from the field are quite large, so it is necessary to reduce the amount. Reducing data means summarising, selecting key points, focusing on important things, finding context and patterns. If the respondent's answers were out of context, they were not used. Conversely, if there are important events that are useful for deepening research data during the interview, they are taken as research findings. In qualitative research, interview data processing is performed by categorising data in the form of keywords and grouping these keywords according to their respective classifications, the stages in processing interview data are:

a. Accumulate all data from in-depth interview obtained through data collection from the respondents.
b. After all interview data has been collected, the data is made into interview transcripts or interview notes.
c. After the transcripts are formed, the data is organised according to categories or keywords.
d. Creating a matrix of interview results in order to simplify the form of the interview transcripts displayed.

RESULTS AND DISCUSSIONS

Based on the selection process, there are no students out of 62 students observed with an overall score of MA in the high category, but there are several students in the medium category of MA who have a high anxiety level in the somatic aspect. Similarly, in Ikhsan's (2019) research population, only 1 subject with low level of maths anxiety was found and 76% of the population had high levels of maths anxiety. This suggests that the number of each anxiety category will vary in different research settings. Creswell (2017) explains that this is very likely to happen in qualitative research, researchers do not need to look for subjects who fulfil all pre-defined criteria just because of limitations. Qualitative researchers focus more on analysing and interpreting the data that has been collected rather than looking for subjects who meet the specified criteria.

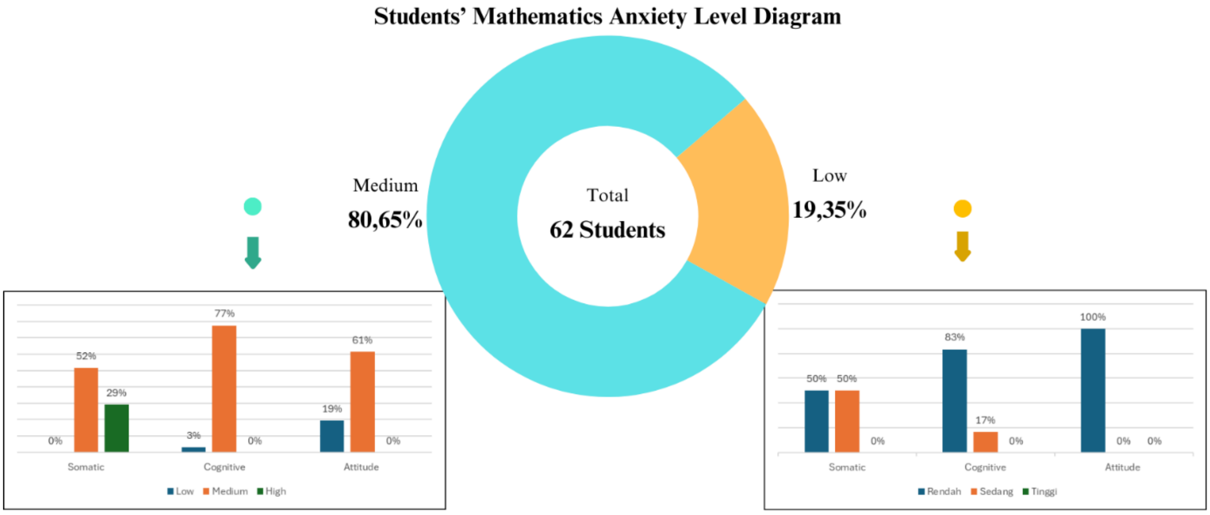

FIGURE 2. Student's Mathematics Anxiety Diagram

This diagram appears to represent the levels of mathematics anxiety among a group of 62 students, categorized into "Medium" and "Low" anxiety levels, with no mention of "High" anxiety in the central chart. The two bar charts represent a further breakdown of anxiety into three components or dimensions, somatic, cognitive, and attitudinal aspects. Each aspects analyzed in terms of students with medium or low anxiety levels. On the bottom left bar chart, shown students with medium levels of mathematics anxiety have 29% students having high category of somatics anxiety. Thus, those students were monitored daily in class (field observation) and interviews.

The analysis began with students in the category of medium MA with high somatic aspects who admitted to having several somatic symptoms indicating anxiety such as trembling, chest tightness, palpitations, and discomfort that disrupted their sleep. Students in this category have a high sense of worry and do not have strong confidence in their answers. If these symptoms frequently happened to students, it is possible that students will move to the category of high anxiety can disrupt students physically and emotionally (Ley & Yelich, 1998). The long impact on the somatic category is where students will emotionally dislike all mathematical processes or even lead to lack of emotional management at the time of facing challenge or difficulty, but the teacher certainly needs to take steps to ask for professional help (Jonas et al., 2014).

In terms of reasoning, this category did not have enough CR which allowed misconceptions to occur and relied heavily on the information available. This was all caused by hesitation of the answer and anxiety of mistake if they dig deeper into the problem information. On the other hand, this category of students have good imitative reasoning where they can perform well in solving AR and MR type problems. These include recalling concept, following strategy, modifying answers, and recalling answers that come from a trusted source (e.g. textbook or someone's words).

Second category, students with medium MA category with medium somatic aspects admitted that they sometimes experienced some symptoms that showed anxiety, including unwillingness to go to maths class, hesitance to come forward to answer in front of the class, and feeling difficult to remember some formulas. However, the symptoms in this category of students do not occur significantly when compared to students with high somatic anxiety.

In terms of reasoning, this category of students has quite good CR so that they are able to reason freely to make conjectures, reasons, and conclusions of the answers to the problems given. Despite having good reasoning, errors may also occur in this category of students but it will only be in the form of miscalculations or other minor errors that do not affect their reasoning. This may be related to the

Self-Regulated process when having a balanced or medium stress load where this is directly proportional to the increase in performance so that students have enough reasons and encouragement to regulate their minds (Aryani & Hasyim, 2018; Yerkes & Dodson, 1908). In addition, this category of students has good IR where they have good performance in solving problems with AR and MR type problems.

The last category, students with low MA category claimed to have no symptoms that indicate anxiety. In other words, they did not have significant pressure when learning or exams. Apart from their cognitive ability, this category of students has poor CR so it is difficult for them to make new guesses to explore the information in the problem. It is easy for them to make conclusions, but without a strong basis for the conclusions, it is more likely that the student's answer will result in the wrong answer. This may have happened because they had high self-confidence which led to unnecessity to make new guesses to explore the information in the problem. Furthermore, this category of students also has impressive IR, especially in problems that ask students to recall a strategy or answer, because students also have a high enough confidence even though the answers are sometimes wrong. Some other studies indicate that students with low anxiety category have high mathematical reasoning ability, yet students with low levels of alertness often experience process errors as the result of carelessness (Fatimah & Salam, 2021; Utami & Warmi, 2019; Utami et al., 2020)

CONCLUSIONS AND SUGGESTIONS

This research aimed to analyze and explore the CR and IR process of high school students based on their MA category. In conclusion, mathematical reasoning exhibits significant variability among students across different cultural and educational contexts among students, especially in the school where this research was conducted. Due to the worry of making mistakes, students with high MA levels often avoid deeper reasoning and instead rely on readily available information. This group uses IR effectively, resolving common issues such as remembering ideas or applying techniques from reliable sources. Anxiety is felt by students with medium MA, as the somatic symptoms, who may hesitate to speak in front of others or attend class. In spite of this, they show strong CR which permits them to draw inferences and hypotheses, while small errors in computation may happen. Their well-balanced stress levels aid in controlling their thought process, which improves performance. While students with low MA don't show signs of anxiousness and maintain their confidence, but their CR is poor, which causes them to draw erroneous and poorly supported conclusions. Despite this, they perform quite well in IR, particularly when it comes to recalling techniques, although at times their confidence leads to thoughtless errors.

This diversity can be systematically characterized by classifying students into categories that reflect common challenges, such as mathematics anxiety. Although mathematics anxiety is only one aspect of a student's academic identity, it has a substantial impact on their mathematical performance and overall achievement. Acknowledging the presence and effects of mathematics anxiety is a crucial step toward addressing it effectively. By comprehensively analysing this variation, educators and researchers can develop targeted interventions to reduce the negative impact of anxiety and improve mathematical understanding. This approach not only improves academic outcomes, but also contributes to a deeper understanding of both cognitive functioning and personal development. Finally, by embracing the complexity and individuality of mathematical reasoning, we can create more inclusive and supportive learning environments that empower all students to realise their potential in mathematics and beyond.

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