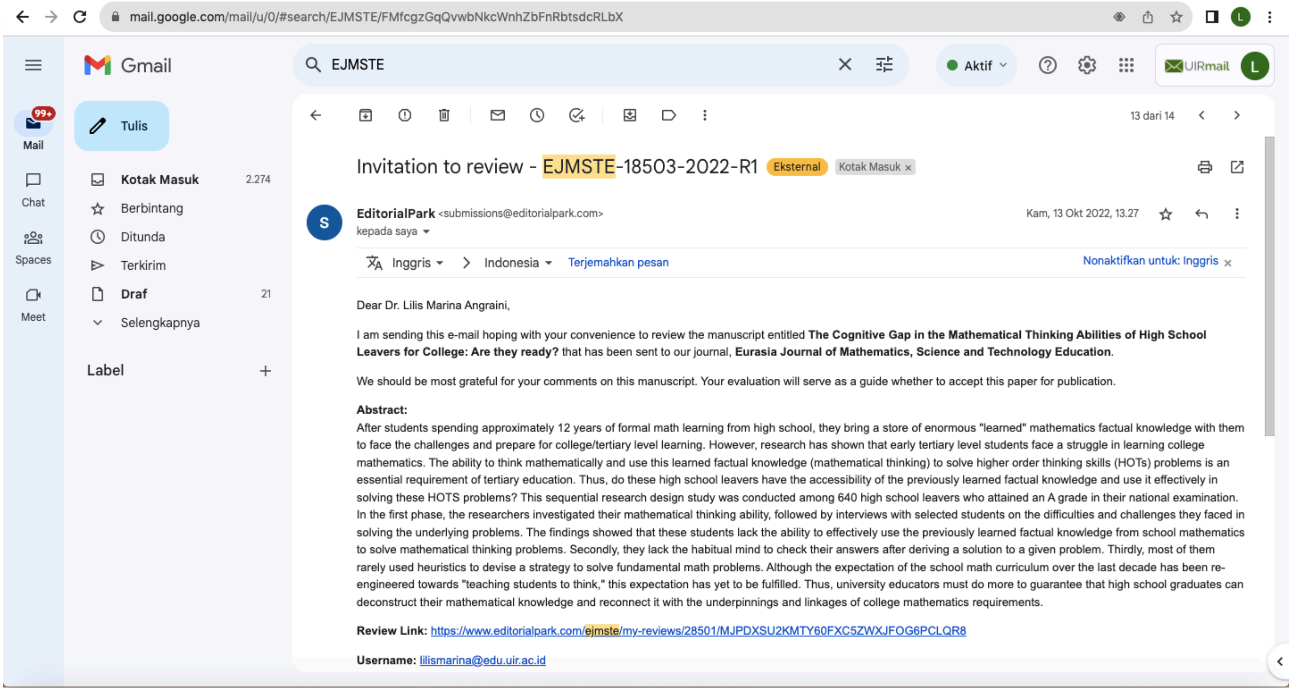
1. Permintaan review (13 October 2022)



Invitation to review - EJMSTE-18503-2022-R1

EditorialPark <submissions@editorialpark.com>

Kam, 13 Okt 2022, 13.27

Dear Dr. Lilis Marina Angraini,

I am sending this e-mail hoping with your convenience to review the manuscript entitled **The Cognitive Gap in the Mathematical Thinking Abilities of High School Leavers for College: Are they ready?** that has been sent to our journal, **Eurasia Journal of Mathematics, Science and Technology Education**.

We should be most grateful for your comments on this manuscript. Your evaluation will serve as a guide whether to accept this paper for publication.

Abstract:
After students spending approximately 12 years of formal math learning from high school, they bring a store of enormous "learned" mathematics factual knowledge with them to face the challenges and prepare for college/tertiary level learning. However, research has shown that early tertiary level students face a struggle in learning college mathematics. The ability to think mathematically and use this learned factual knowledge (mathematical thinking) to solve higher order thinking skills (HOTs) problems is an essential requirement of tertiary education. Thus, do these high school leavers have the accessibility of the previously learned factual knowledge and use it effectively in solving these HOTS problems? This sequential research design study was conducted among 640 high school leavers who attained an A grade in their national examination. In the first phase, the researchers investigated their mathematical thinking ability, followed by interviews with selected students on the difficulties and challenges they faced in solving the underlying problems. The findings showed that these students lack the ability to effectively use the previously learned factual knowledge from school mathematics to solve mathematical thinking problems. Secondly, they lack the habitual mind to check their answers after deriving a solution to a given problem. Thirdly, most of them rarely used heuristics to devise a strategy to solve fundamental math problems. Although the expectation of the school math curriculum over the last decade has been re-engineered towards "teaching students to think," this expectation has yet to be fulfilled. Thus, university educators must do more to guarantee that high school graduates can deconstruct their mathematical knowledge and reconnect it with the underpinnings and linkages of college mathematics requirements.

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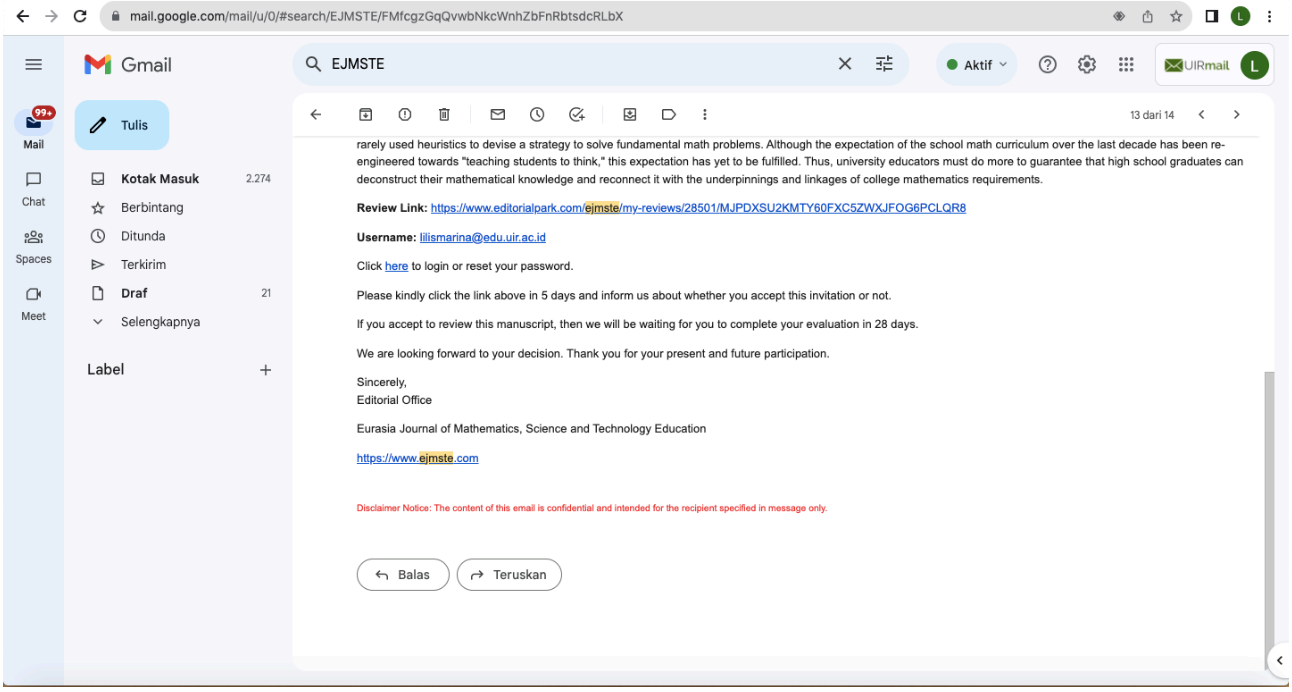

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If you accept to review this manuscript, then we will be waiting for you to complete your evaluation in 28 days.

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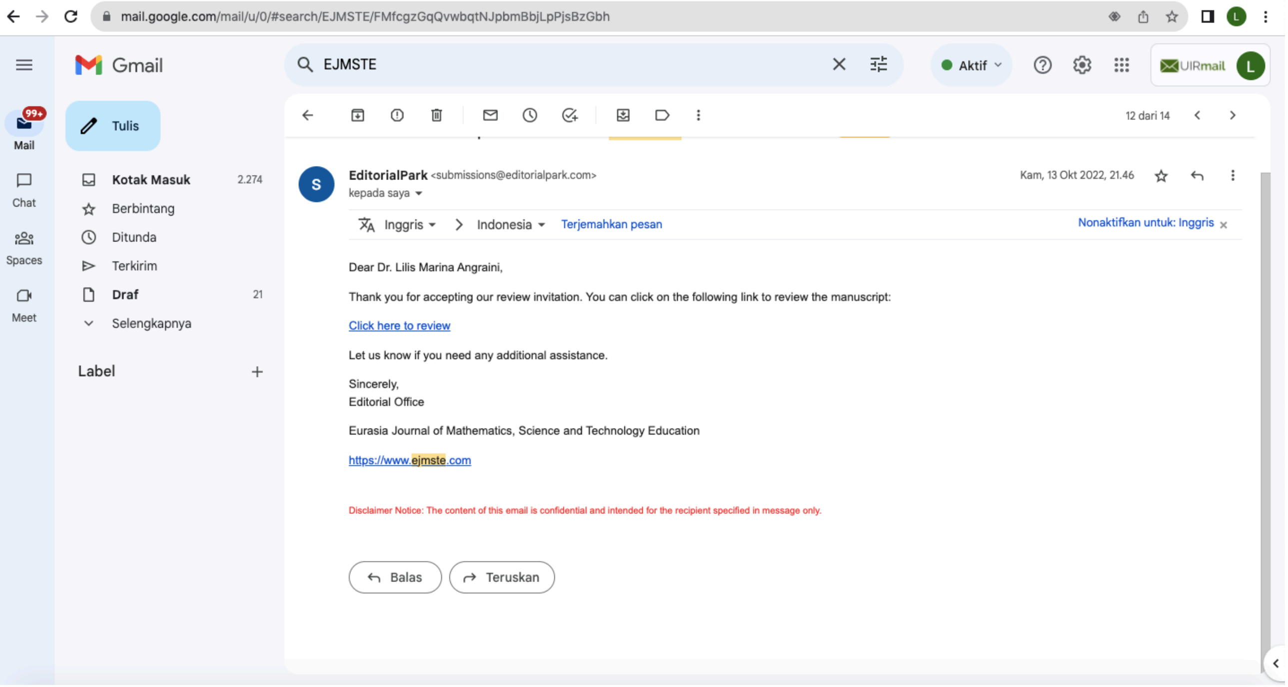

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Kam, 13 Okt 2022, 21.46

Dear Dr. Lilis Marina Angraini,

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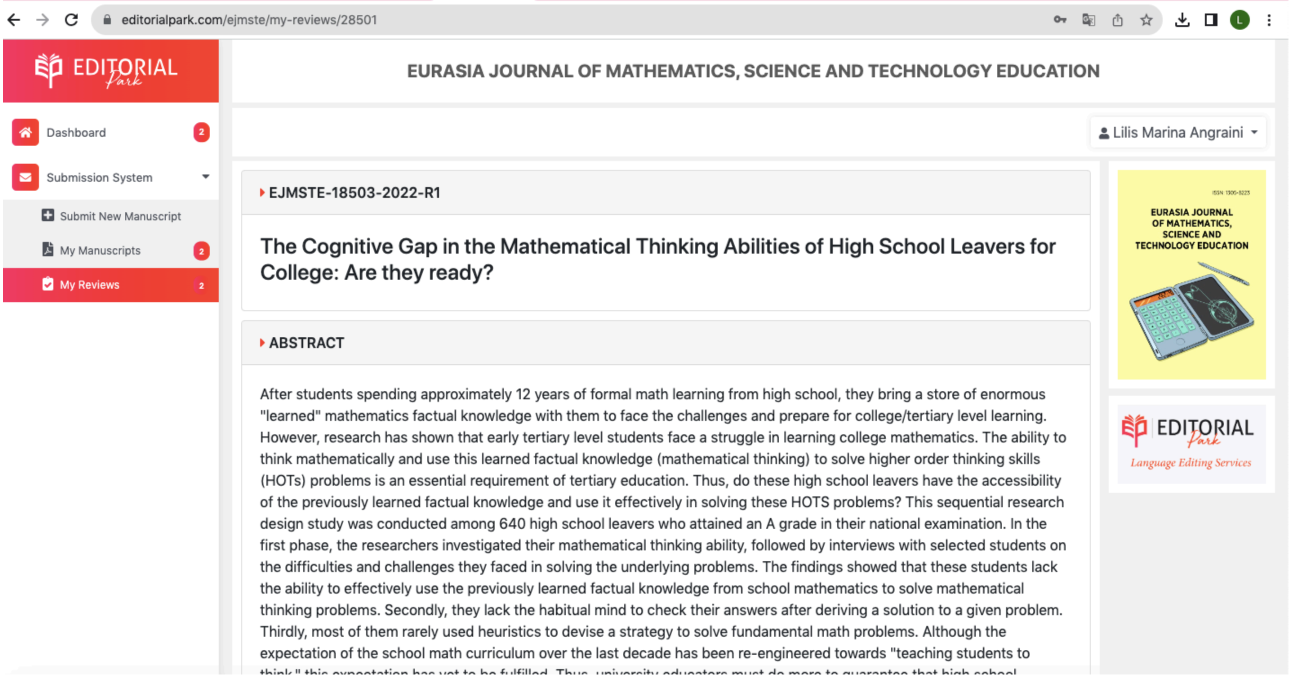
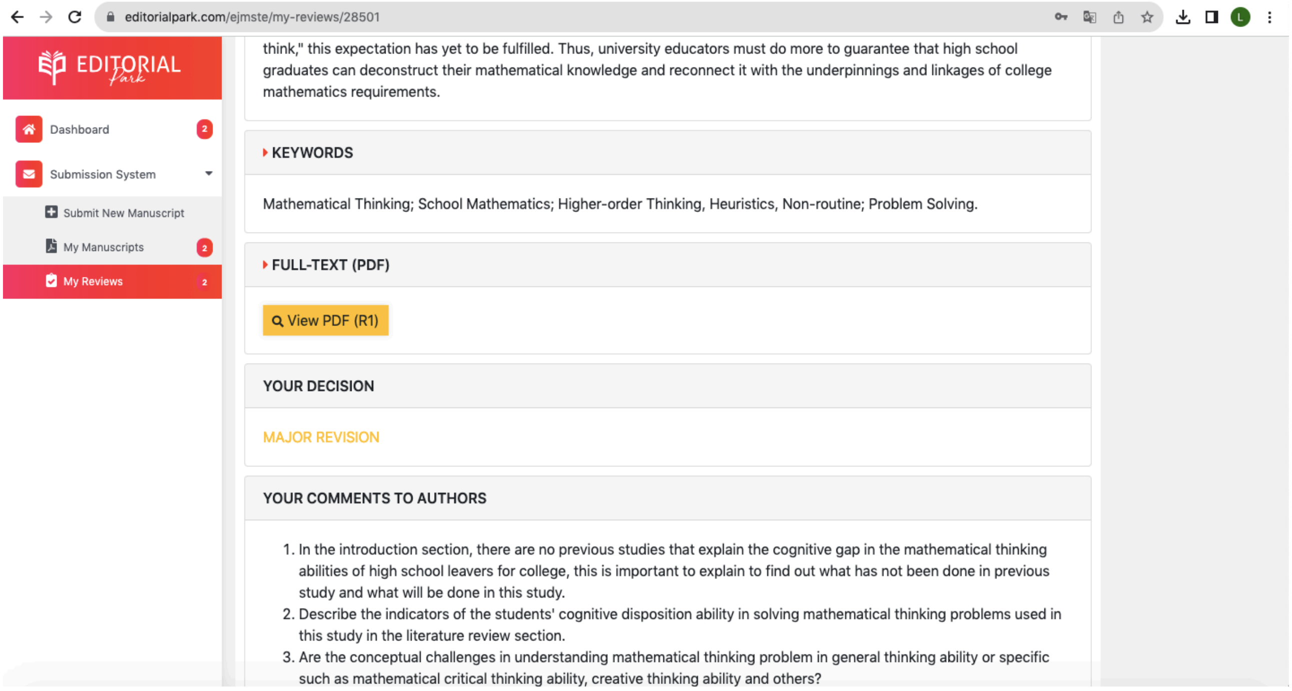


EJMSTE-18503-2022-R1

The Cognitive Gap in the Mathematical Thinking Abilities of High School Leavers for College: Are they ready?

ABSTRACT

After students spending approximately 12 years of formal math learning from high school, they bring a store of enormous "learned" mathematics factual knowledge with them to face the challenges and prepare for college/tertiary level learning. However, research has shown that early tertiary level students face a struggle in learning college mathematics. The ability to think mathematically and use this learned factual knowledge (mathematical thinking) to solve higher order thinking skills (HOTs) problems is an essential requirement of tertiary education. Thus, do these high school leavers have the accessibility of the previously learned factual knowledge and use it effectively in solving these HOTS problems? This sequential research design study was conducted among 640 high school leavers who attained an A grade in their national examination. In the first phase, the researchers investigated their mathematical thinking ability, followed by interviews with selected students on the difficulties and challenges they faced in solving the underlying problems. The findings showed that these students lack the ability to effectively use the previously learned factual knowledge from school mathematics to solve mathematical thinking problems. Secondly, they lack the habitual mind to check their answers after deriving a solution to a given problem. Thirdly, most of them rarely used heuristics to devise a strategy to solve fundamental math problems. Although the expectation of the school math curriculum over the last decade has been re-engineered towards "teaching students to think," this expectation has yet to be fulfilled. Thus, university educators must do more to guarantee that high school



think," this expectation has yet to be fulfilled. Thus, university educators must do more to guarantee that high school graduates can deconstruct their mathematical knowledge and reconnect it with the underpinnings and linkages of college mathematics requirements.

KEYWORDS

Mathematical Thinking; School Mathematics; Higher-order Thinking, Heuristics, Non-routine; Problem Solving.

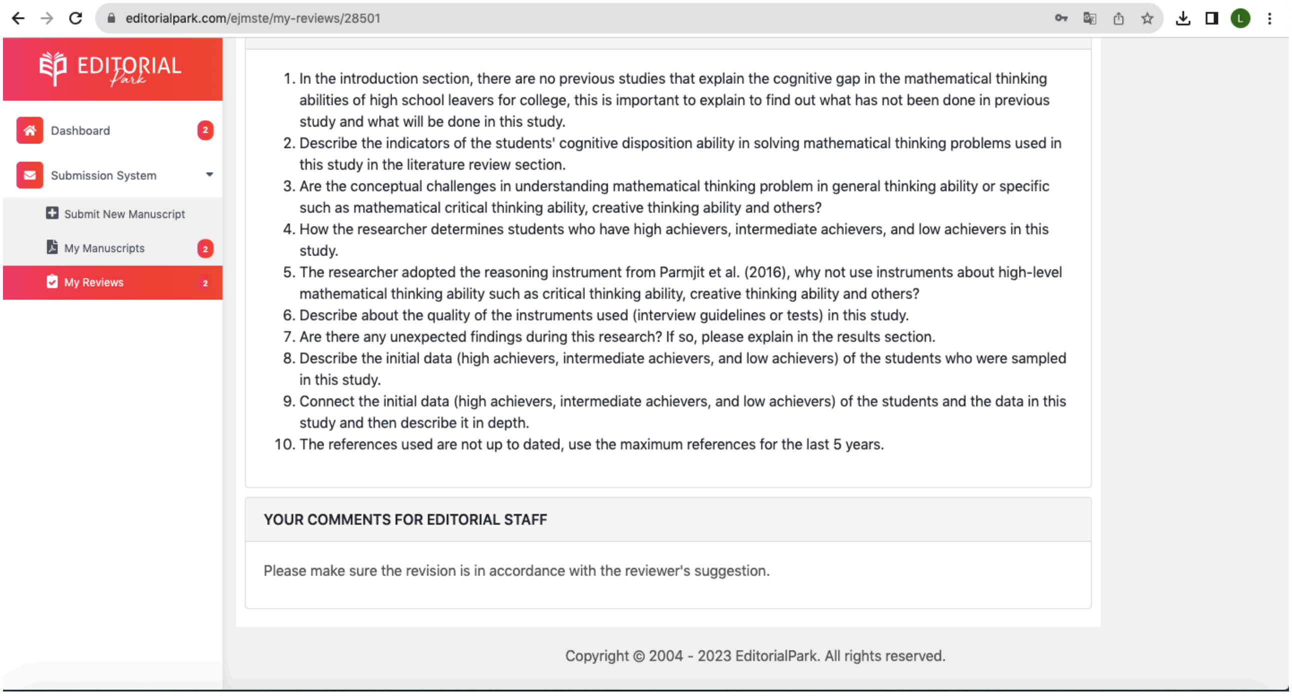
FULL-TEXT (PDF)

YOUR DECISION

MAJOR REVISION

YOUR COMMENTS TO AUTHORS

1. In the introduction section, there are no previous studies that explain the cognitive gap in the mathematical thinking abilities of high school leavers for college, this is important to explain to find out what has not been done in previous study and what will be done in this study.
2. Describe the indicators of the students' cognitive disposition ability in solving mathematical thinking problems used in this study in the literature review section.
3. Are the conceptual challenges in understanding mathematical thinking problem in general thinking ability or specific such as mathematical critical thinking ability, creative thinking ability and others?



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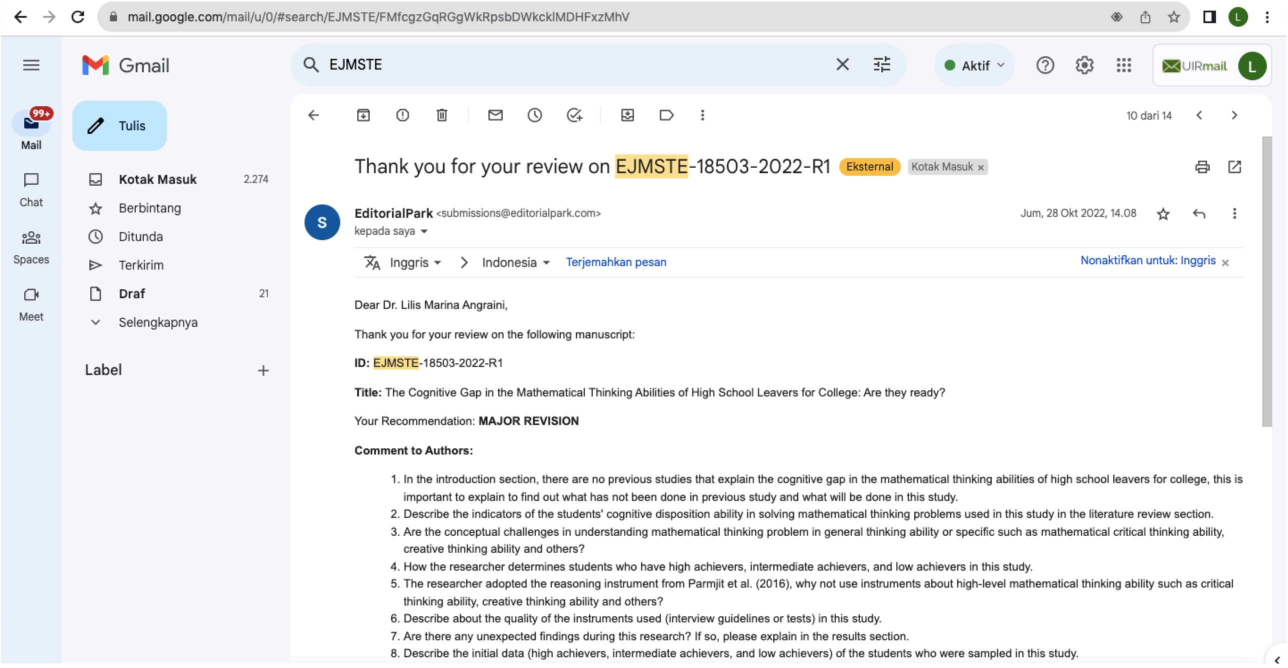
4. How the researcher determines students who have high achievers, intermediate achievers, and low achievers in this study.
5. The researcher adopted the reasoning instrument from Parmjit et al. (2016), why not use instruments about high-level mathematical thinking ability such as critical thinking ability, creative thinking ability and others?
6. Describe about the quality of the instruments used (interview guidelines or tests) in this study.
7. Are there any unexpected findings during this research? If so, please explain in the results section.
8. Describe the initial data (high achievers, intermediate achievers, and low achievers) of the students who were sampled in this study.
9. Connect the initial data (high achievers, intermediate achievers, and low achievers) of the students and the data in this study and then describe it in depth.
10. The references used are not up to dated, use the maximum references for the last 5 years.

YOUR COMMENTS FOR EDITORIAL STAFF

Please make sure the revision is in accordance with the reviewer's suggestion.

4. Ucapan terima kasih dari editor karena telah selesai mereview artikel (28 Oktober 2022)



Thank you for your review on EJMSTE-18503-2022-R1

EditorialPark <submissions@editorialpark.com>
kepada saya
Jum, 28 Okt 2022, 14.08

Dear Dr. Lilis Marina Angraini,

Thank you for your review on the following manuscript:

ID: EJMSTE-18503-2022-R1

Title: The Cognitive Gap in the Mathematical Thinking Abilities of High School Leavers for College: Are they ready?

Your Recommendation: **MAJOR REVISION**

Comment to Authors:

1. In the introduction section, there are no previous studies that explain the cognitive gap in the mathematical thinking abilities of high school leavers for college, this is important to explain to find out what has not been done in previous study and what will be done in this study.
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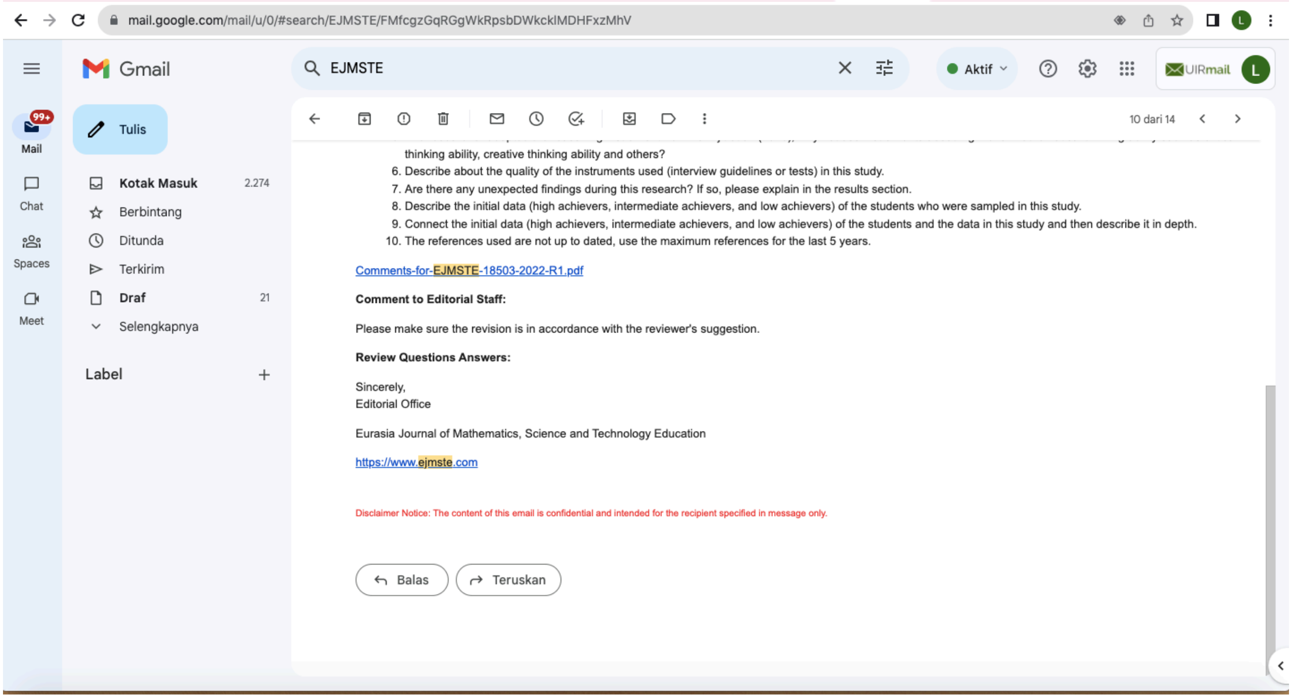

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10. The references used are not up to dated, use the maximum references for the last 5 years.

Comments-for-EJMSTE-18503-2022-R1.pdf

Comment to Editorial Staff:

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Review Questions Answers:

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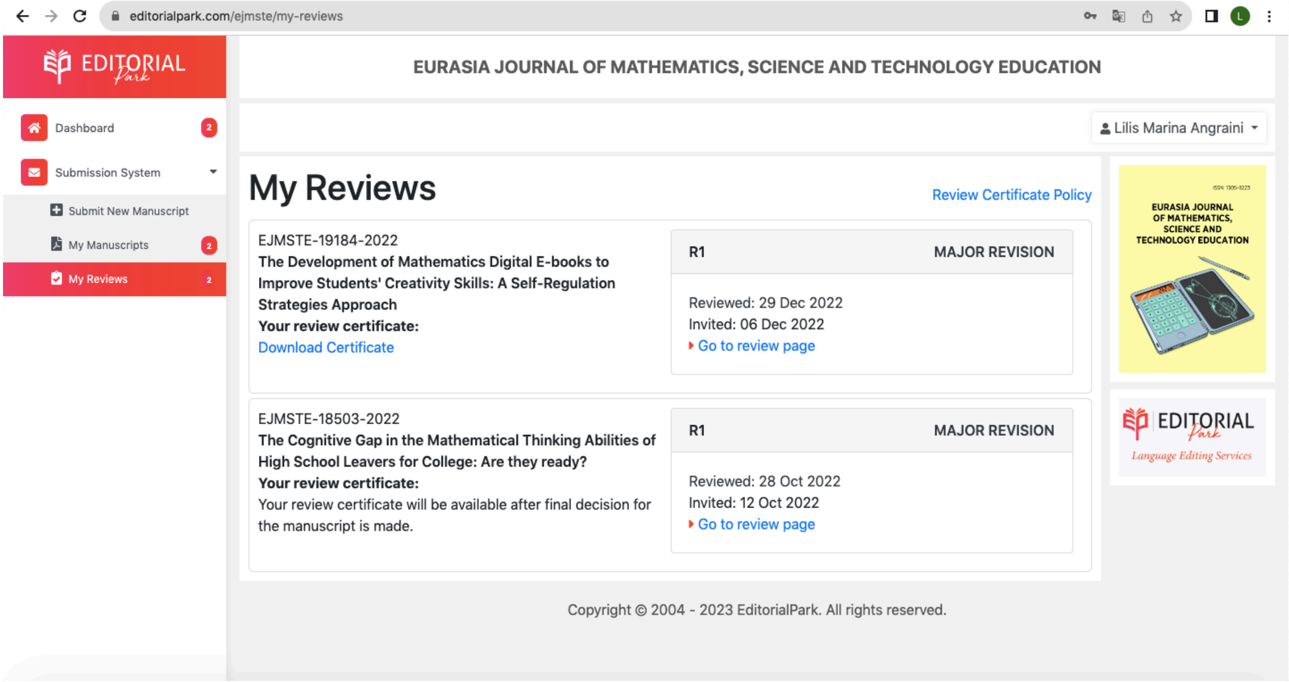

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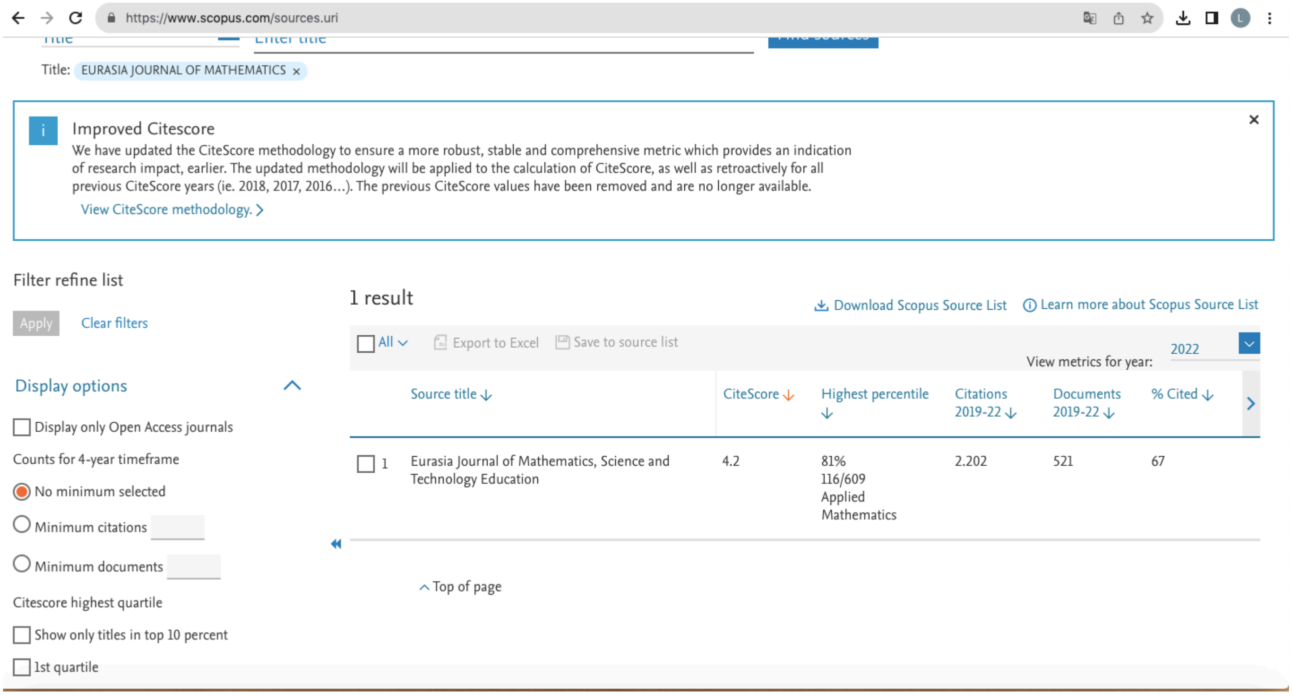

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This document is issued to appreciate valuable efforts of

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awarded on

January 06, 2023

EDITORIAL Park

Certificate ID: EP-EJMSTE-RevCer-3966

The Cognitive Gap in the Mathematical Thinking Abilities of High School Leavers for College: Are they ready?

ABSTRACT

After students spending approximately 12 years of formal math learning from high school, they bring a store of enormous "learned" mathematics factual knowledge with them to face the challenges and prepare for college/tertiary level learning. However, research has shown that early tertiary level students face a struggle in learning college mathematics. The ability to think mathematically and use this learned factual knowledge (mathematical thinking) to solve higher order thinking skills (HOTs) problems is an essential requirement of tertiary education. Thus, do these high school leavers have the accessibility of the previously learned factual knowledge and use it effectively in solving these HOTS problems? This sequential research design study was conducted among 640 high school leavers who attained an A grade in their national examination. In the first phase, the researchers investigated their mathematical thinking ability, followed by interviews with selected students on the difficulties and challenges they faced in solving the underlying problems. The findings showed that these students lack the ability to effectively use the previously learned factual knowledge from school mathematics to solve mathematical thinking problems. Secondly, they lack the habitual mind to check their answers after deriving a solution to a given problem. Thirdly, most of them rarely used heuristics to devise a strategy to solve fundamental math problems. Although the expectation of the school math curriculum over the last decade has been re-engineered towards "teaching students to think," this expectation has yet to be fulfilled. Thus, university educators must do more to guarantee that high school graduates can deconstruct their mathematical knowledge and reconnect it with the underpinnings and linkages of college mathematics requirements.

Keywords: Mathematical Thinking; School Mathematics; Higher-order Thinking, Heuristics, Non-routine; Problem Solving.

The Cognitive Gap in the Mathematical Thinking Abilities of High School Leavers for College: Are they ready?

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After students spending approximately 12 years of formal math learning from high school, they bring a store of enormous "learned" mathematics factual knowledge with them to face the challenges and prepare for college/tertiary level learning. However, research has shown that early tertiary level students face a struggle in learning college mathematics. The ability to think mathematically and use this learned factual knowledge (mathematical thinking) to solve higher order thinking skills (HOTs) problems is an essential requirement of tertiary education. Thus, do these high school leavers have the accessibility of the previously learned factual knowledge and use it effectively in solving these HOTS problems? This sequential research design study was conducted among 640 high school leavers who attained an A grade in their national examination. In the first phase, the researchers investigated their mathematical thinking ability, followed by interviews with selected students on the difficulties and challenges they faced in solving the underlying problems. The findings showed that these students lack the ability to effectively use the previously learned factual knowledge from school mathematics to solve mathematical thinking problems. Secondly, they lack the habitual mind to check their answers after deriving a solution to a given problem. Thirdly, most of them rarely used heuristics to devise a strategy to solve fundamental math problems. Although the expectation of the school math curriculum over the last decade has been re-engineered towards "teaching students to think," this expectation has yet to be fulfilled. Thus, university educators must do more to guarantee that high school graduates can deconstruct their mathematical knowledge and reconnect it with the underpinnings and linkages of college mathematics requirements.

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INTRODUCTION

Various education systems in the world, including the Malaysian education system, have undergone various education reforms during the last decade or so in order to achieve better performance for the nation's development, especially to assure that every citizen is capable of meeting the challenges involved in getting the country ready to compete on a global scale. The issue of curricular reform in education has been a hot topic for quite some time since the early 2000s in catering to the needs of national development. Thus, curriculum reforms for primary and secondary school education were undertaken. The aim of these reforms from the mathematics perspective was for a few reasons. Firstly, due to the low performance of students in the international studies of Trends in Mathematics and Science Studies (TIMSS) and Programme for International Student Assessment (PISA). In both these studies over the decade, students' mathematics and science performance were way below the international benchmark.

Secondly, Science, Technology, Engineering, and Mathematics (STEM) affect every part of the world today, and it has been making waves in education, especially at the tertiary level, due to the low level of students' enrolment in science-related courses (The New Strait Times, May 23, 2016; UNESCO, 2016; Academy of Science Malaysia, 2018; The Straight Times, December 14, 2018). This alarming issue was further exacerbated when The Star Online (16 May 2018) reported from the World Economic Forum that as many as 65 percent of high school leavers entering the workforce now would work in new STEM-based sectors in the future. This issue was further complicated by the low enrolment of students in STEM education courses at the tertiary level (Curriculum Development Centre, 2016; Halim & Subahan, 2016). Facing this dilemma of the lack of student enrolment was probably the final straw that broke the camel's back. The Malaysian Education Blueprint 2013-2025 was introduced to enhance the STEM Education Project to encourage students to pursue secondary and higher education STEM areas. Thus, among the reform measures implemented is the inclusion of HOTS in the mathematics curriculum's teaching and learning perspective, as this subject is multidisciplinary across all STEM-related courses.

The thrust of this new curriculum reform was the embedment of a balanced set of knowledge and skills, such as the ability to think critically, creatively, and solve problems for the development of students (The Star Online, 31 Dec 2016). Since these reforms, how much or rather, are these school leavers' intellectual capacities matching with the expected level of cognitive demand at the tertiary level?

LITERATURE REVIEW

Mathematics is a cognitive skill demand for all levels of education, especially in today's rapidly changing world, particularly in terms of technological advancement, and the demand for this is unthinkable without mathematics (Hansson, 2020; Hansson, 2015). However, findings have shown that the schools are not catering to these demands (Faulkner, et al., 2020;Lasilla, Rule, Fulton, Skarda, & Torres, 2009; O’Brien & Dervarcis, 2012; Burghes, 2011). In the study by Faulkner et al. (2020), they found an over-reliance on procedural knowledge hindered students’ ability to apply the necessary skills in solving problems, which to a large extent inhibited students' cognitive growth. In the study undertaken by Lasilla et al. (2009), prompted due to US education not creating enough scientists to meet future economic demands, they elucidated that high school leavers are not prepared for the cognitive demands of college-level education. Similarly, Scott (2016) found that students’ lack of mathematical preparation prior to entering the science classroom hindered their development of meaningful learning. On the contrary, test scores are on the rise significantly in the context of math and science. Another study by O’Brien and Dervarcis (2012) entitled "Is High School Tough Enough?" found that approximately 40% of high school grads are not ready for entry-level employment or college courses. They argued for the necessity of a more rigourous curriculum requirement for high school leavers to face the cognitive challenges of a college education. Similarly, Shaugnessy (2011), a former President of the National Teachers of Mathematics, raised two pertinent issues regarding high school students' preparation for tertiary level. Are they receiving an adequate mathematics education? Furthermore, are the math alternatives comprehensive enough to facilitate a seamless transfer from high school to college? This issue was also reiterated by Padilla-Vigil and Mieliwocki (2015). They mentioned that in today's culture of rigour, students should have mathematical learning experiences that address Bloom's taxonomy to the production and sharing level to build higher order thinking skills. Students can accomplish this better when they can create links between math material and real-world applications.

These issues of concern, as mentioned above, are also prevalent in the Malaysian context of mathematics learning. Various evidence has been provided in the local literature on the low intellectual mathematics knowledge of SPM leavers. In the study by researchers (Parmjit & White, 2006; Roselainy, Yudariah, Mohammad, Soheila & Sabariah, 2013; Aida, 2015; Parmjit et al., 2016), they have concluded that these school leavers' intellectual capacity does not match with the expected level of cognitive demand at tertiary level. According to the findings of Parmjit and White (2006), the grades gained in the SPM exams do not relate to their higher-order thinking abilities. Similarly, Roselainy et al. (2013) echoed a proposal to enhance math pedagogical practises in STEM education to make them more relevant and meaningful in a way that could further develop students' capabilities. Thus, action is warranted to curb these concerns, notably in the context of learners' cognitive growth in mathematical thinking.

Mathematics is one of the "micro filters" regulating entry into tertiary education, especially in STEM education. The current model of pedagogical practises in schools is outdated (Parmjit et al., 2016; Shaugnessy, 2011; Schoenfeld, 1992). At its micro level, do the various topics of math courses learned in high schools, such as calculus, algebra, trigonometry, geometry, and statistics, cater to the higher-order thinking skills demanded at the tertiary level? The new curriculum seeks to develop learners "who can think mathematically and who can apply mathematical knowledge effectively and responsibly in solving issues and making decisions." (Ministry of Education Malaysia, 2013, p.2). The phrase "to think mathematically" was incorporated in the statement of objectives for the secondary school mathematics curriculum to emphasise the significance of mathematical thinking among high school students. Devlin (2012, as cited in Parmjit et al., 2018), asserts that mathematical thinking is a way to learn a math concept by breaking it apart and analysing it until learners find its numerical and structural roots and ways of thinking. It is a dynamic process that helps learners understand complex structures by putting together what they have already learned (Mason, Burton & Stacey, 2010). The problem must be challenging, engaging, and within the learners' proximal development zone to develop their thinking. Mathematical thinking occurs when tertiary-level problem solving requires high-level thinking skills. Schoenfeld (1992) argues that a curriculum that teaches only mathematical facts and methods is no longer valid.

The underperformance of students’ in international math studies such as TIMSS and PISA, issues related to STEM education, especially in the context of low enrolment, Mathematics pedagogical practices, and an incongruent high school leaver's intellectual capacity with the cognitive demand of tertiary level, inadvertently led to the introduction of new curricula under the Education Blueprint 2013-2025. This curriculum's thrust emphasises students' critical thinking, creative thinking, and problem-solving abilities. It sets a target of being in the top third of nations by 2025, despite the country's history of consistently being in the bottom third in Pisa and TIMSS. What impact have these reforms had on the tertiary level? Does the new math curriculum prepare high school leavers well enough for college-level cognitive readiness?

Thus, it is necessary to evaluate students' learning to assess the current impact of instructions on students' learning, especially in the context of high school leavers' preparation to face the challenges of the tertiary level math curriculum. The assessment process is inevitable as far as instruction is concerned, simply because it helps navigate the overall experience and works as a check and balance in ensuring educational goals are duly met. Through assessment, questioning takes place, and it forces one to think. For example, "Does the content taught to students in the classroom commensurate with what we think is being taught?" "What are students supposed to be learning, and are they learning so accordingly?"

Thus, this research embarked on the journey of investigating high school leavers' development of mathematical thinking in order to assess their cognitive preparedness for tertiary level education demand. The research questions posited for this study are as follows:

1) What is the extent of the students' cognitive disposition ability in solving mathematical thinking problems?
2) What are the conceptual challenges in understanding mathematical thinking problems?

METHODOLOGY

A mixed-method methodology, namely a sequential research design, was used for this study, utilising both quantitative and qualitative approaches. A descriptive design, as Kothari (2004) elucidates where, "it describes, records and interprets phenomena without manipulation of variables that either exist or previously existed" (p.120), was utilised, comprising 640 randomly selected high school leavers who attained an A grade in Mathematics in their national examination. Based on these grades, one could surmise that these students are high math achievers. A paper and pencil test called the Mathematical Thinking Test (MTT) was administered among the students. It provided background information on students' mathematical thinking development after eleven years of learning mathematics in school.

For the qualitative approach, interviews were conducted with nine purposively selected students to paint a mental picture of their progression in their ability to think mathematically. The criteria for student selection were based on how well they did on the test for mathematical thinking. A total of three high achievers, three intermediate achievers, and three low achievers were selected for this purpose. These criteria enabled the researcher to identify the thought processes, stumbling blocks, and difficulties faced by the three different groups of students. Using interviews is a common and significant feature in assessing students' learning in mathematics education. Interviews are pertinent in identifying students' difficulties, challenges, and misconceptions about a learning concept. This is also incongruent with Merrifield and Pearn's (1999) elucidation of it as an effective method in assessing learners' development of mathematical thinking. Thus, the use of interviews for this study provides information on students' thinking processes, their understanding, and difficulties faced, and answers the most critical question, why.

For the quantitative approach, an instrument developed by Parmjit et al. (2016) was adapted for this study to assess the mathematical reasoning proficiency of high school leavers. This test had ten questions from school math that covered the fundamentals of ratio and proportion, algebra, basic permutation and combination, sequence, indices, simultaneous equations, and fundamentals of numbers. All the questions were classified as non-routine, meaning that no formulas were required to be remembered and the employment of calculators was not allowed. Examples of the questions are as follows:

- *Three hoses fill a pool. The first hose fills the pool in 3 hours, the second in 4 hours, and the third in 12 hours. How long will it take to fill the pool with all three hoses open?*
- *There are seven students in the meeting room. Each student shakes hands with each other except for themselves. How many handshakes are made altogether?*
- *Find the last digit of 32007.*
- *A book's pages are numbered with 993 digits by a printer. How many pages does the book have?*
- *What is the digit in the ones position of the total after the first 97 whole numbers are added up? 1 + 2 + 3 + 4 + . . . + 94 + 95 + 96 + 97*

This was not a speed test, and students were given one hour and fifteen minutes to answer the questions. This study aims to examine students' conceptions of mathematics; thus, the working steps and procedures were taken into consideration in assigning the marks based on a pre-set criterion. Each question was assigned three points, yielding a maximum score of 33 on the Mathematical Thinking Test.

Table 1. The Scoring Rubric

Score	Description
0	No effort was made; this was a failed attempt.
1	Some aspects of the problem are identified, but solutions that address those aspects are either insufficient or unsuitable.
2	Determine the majority aspects of the problem and provide at least one viable solution despite certain flaws.
3	Determine all components of the problem; the suitable strategies are presented along with the correct response.

For the qualitative research design, interviews were conducted with the selected students. The primary interview questions were from the Mathematical Thinking test, followed by probing questions aiming to elicit the thought processes used by students in assessing the conceptual difficulties they faced in solving the given problems. In these interview sessions, the researchers got an opportunity to study the causes of each step and which heuristic was employed by the respondents. These complete transcripts were necessary to accurately represent what students had to say and to serve as a source for the long quotes often included in qualitative research reports as part of the interpretation validation process (Shenton, 2004). Verbatim transcripts strengthen a study's "audit trail" (p. 21) by providing more evidence (Sacks, 1984).

RESULTS

The first section presented the study findings from the administration of the paper and pencil test comprising ten questions, item analysis for each question, followed by interviews with students. We assess their non-routine problem-solving skills; the difficulty faced, their content knowledge, and their ability to use it to solve the given problems.

Ability to Solving Non-Routine problems

Research Question

What is the extent of the students' cognitive disposition ability in solving mathematical thinking problems?

Table 2. Mathematical Thinking Test Scores

	N	Mean	Std. Deviation
Math Thinking Test Scores	640	9.15	3.84

Max Score:33

The data in Table 2 reveals that the scores achieved by 640 students engaged in the research are a low 9.15 (SD=3.84). In other words, these students attained a low score of 27.7% $\left(\frac{9.15}{33}\times 100\right)$ in the Mathematical Thinking Test.

Item Analysis of Mathematical Thinking Test

This section analyses each of the ten questions in phase one of the Mathematical Thinking Test. Table 3 indicates the challenges students had on the test, which gives background information on high school graduates' conceptual comprehension and stumbling blocks of basic math concepts.

Table 3. Item analysis of MTT

Question	Correct %	Incorrect %
1	53.3	47.7
2	26.6	73.4
3	24.8	75.2
4	28.4	71.6
5	13.3	86.7
6	45.5	55.5
7	15.9	84.1
8	19.3	80.7
9	27.7	72.3
10	34.2	65.8

The table shows that the questions students faced difficulty with based on the incorrect responses of 50% or more were all the questions except question 1. The findings depict the notion that students faced great difficulty solving problems requiring higher-order thinking skills. These non-routine problems elicit students' mathematical thinking skills. However, these students were considered high achievers in mathematics based on their national examination results, and they still lack the cognitive repertoire one expects to have. This outcome is consistent with previous findings from both local and international contexts over the last decade (Parmjit et al., 2018; Intan, 2016; Aida, 2015; Borsuk, 2016; Adams, 2014). The findings suggest that, despite graduating from high school, most students lack the cognitive skills and growth required to meet the academic requirements of college. Parmjit et al. (2018) viewed this downfall due to the common proverb "practice makes perfect". This might be true for mastery skills for arithmetic operations but not for developing mathematical thinking. Students "practice" these skills to get the right answer. In other words, they neglect context, structure, and conditions, and students do not produce the "richly interconnected spaces" Cooper (1988) identifies as necessary for building mathematical thinking. They end up with islands of superficial knowledge without a boat to travel from one end to the other.

The following section's findings from the interviews detail the difficulties encountered in cognizing the mathematical thinking problems that greatly hindered students' mathematical thinking development.

Difficulties Faced by Students

This section discussed samples of students' incorrect responses to the Mathematical Thinking Test. These incorrect responses were then probed to investigate the root of these difficulties faced via interviews. Due to space constraints, six interview participants were depicted in this paper to determine their mistakes and difficulties in solving the problems.

Coding for the interviews was used in identifying the respondents according to respondent number and achievement. The coding was as follows:

- Students Number: 1 to 6;
- Achievement: L: Low, I: Intermediate, and H: High

Notification for each participant:

- Student 1, Low achiever as S_{1L}
- Students 2, Low achiever as S_{2L}
- Student 3, Intermediate Achiever as S_{3I}
- Student 4, Intermediate Achiever as S_{4I}
- Student 5, High Achiever as S_{5H}
- Student 6, Male, High Achiever as S_{6H}

Did students lack factual knowledge or access it poorly?

All 640 students participated in this study were High Math Achievers based on national exam results. The test's non-routine problems were fundamental questions within their zone of potential development. No questions required any high-level formulaic structures or complicated computations to solve them. Instead, the carefully selected items require some fundamental knowledge and skills upon which all higher tertiary level mathematics courses are built upon. Three experienced high school teachers teaching mathematics in their respective schools also validated this item selection.

From the interviews, all the respondents did not face problems in understanding the problems that, to an extent, asserted the math knowledge required for each question was within their zone of proximal development.

S_{1L} : *I understand the questions quite easily, but I don't know what concept to use…how to answer the question."*

S_{2L} : *This question seems easy but challenging because …I am not sure which math formula or concept to use*

S_{3I} : *I am not sure how to make a connection… which concept and formula to use*

S_{4I} : *The problems given are interesting……. I like it……. seems easy but difficult to solve.*

S_{5H} : *These problems seem easy……but definitely challenging when I try to solve them because quite often I am not sure what fact to look for….in fact, I got so confused about how to solve the problem...*

These statements above elucidate the fundamental descriptors of non-routine problems, such as Kantowski (1977), "an individual is faced with a problem when he encounters a question he cannot answer or a situation he is unable to resolve using the knowledge immediately available to him (p. 163). Similarly, Woodward et al. (2012) highlighted these non-routine problems that cannot be addressed with a known approach or memorised formulae that demand analysis and synthesis with the aid of critical thinking.

Factor 1: Lack of a habitual mind in checking their answers

The first item is a ratio and proportion item, which is widely used in the literature. This item aims to assess students' ability to use proportionality in solving problems. The quantitative analysis revealed that 47.7% (n = 306) of the 640 students attained an incorrect solution to this problem. A further probe indicates that 92.7% (n = 284) of these students obtained an incorrect response of four (4) instead of nine (9) as the correct solution to this problem.

Two factors embedded in this problem inhibited students from finding the solution. The first factor relates to not looking back to check their attained solution, and the second relates to the rote application of the formulaic cross multiplication method. The following is the verbatim that took place between the researcher and the participating student:

Question 1: If it takes six men 21 days to paint a house, how many men will be needed to do the same job in 14 days?

R : *Do you understand the question and related to which topic?*
S_{1L} : *Yes, it is related to proportion.*
R : *Please solve this item*
S_{1L} : After about 2 minutes, he responded
Four
R : *Four what?*
S_{1L} : (Hesitated for a while) ….*err…four days*……. (hesitated again) …*no…four men. Yes, four men*
R : *How did you solve it?*
Showing me his procedures (refer to Figure 1)

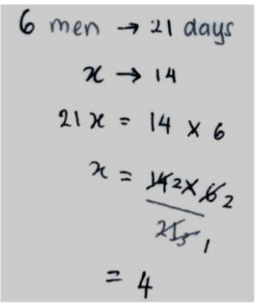

Figure 1. S_{1L} incorrect response for Item 1

R : *Can you please explain?*
S_{1L} : *Six men takes twenty-one days, so x men will take (pointing at his steps) fourteen…..So cross multiply … twenty-one x equals fourteen times six … x is four!*
R : *So, the answer is four?*
S_{1L} : *Yes (with a very confident tone)*

S_{1L} utilised a mechanical procedure called cross multiplication, commonly used in schools, to solve the problem. This cross multiplication refers to a process where the numerator of the first fraction is multiplied by the second fraction's denominator and vice versa, setting the products equal.

During the interviews, all the respondents produce "4 men" as the answer. Scaffolding was introduced to provide guidance to probe students' thinking.

R : *Please look at the question, if one needs six men to paint a house in twenty-one days. Will you require more or lesser men to paint it in a lesser time of fourteen days?*

S_{3I} began to ponder and was perturbed based on his facial expression.

S_{3I} : *Something is not right because......you definitely need more men!*

R : *Why?*

S_{3I} : *Because if six men can paint in twenty-one days, then definitely more men are needed for fewer days err…fourteen days*

R : *So, where is your mistake?*

S_{3I} : *This should be an inverse proportion*

R : *What do you mean by inverse Proportion?*

S_{3I} : *More men fewer days or fewer men more days*

R : *So, what is the answer? Can you do it mentally?*

S_{3I} : *The answer will be twenty-one per (over) fourteen times six .....three over two times six and.....nine men…Let me check my answer.*

The following were the procedure used:

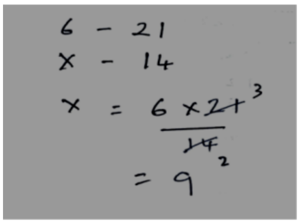

Figure 2. S_{3I} correct response for Item 1

R : *You were very sure of your answer as four men earlier. Why was that?*

S_{3I} : *This was a direct question we always do.... I should have checked my answer if it makes sense!*

Most of the students (based on the paper and pencil test script) utilised this cross multiply method to attain an incorrect solution of 4. The findings indicate poor algorithm operations of $\frac{14}{21}\times 6$, indicating students' superficial comprehension of proportion and ratio. Students' failing to double-check their answers to see if they make sense is a massive cause for concern.

According to the data, most students answered "four guys" since they did not comprehend that the question was about inverse proportions. Figure 3 illustrates samples of the incorrect solution obtained in the paper and pencil test among the students involved in the study.

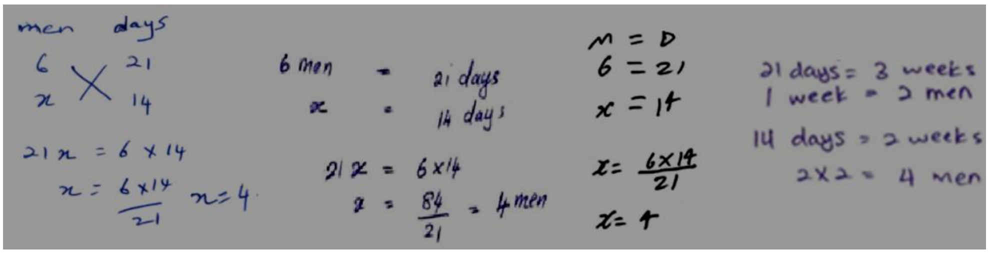

Figure 3. Samples of incorrect responses for Item 1 from the paper and pencil test

Polya (1971) asserted that "looking back" when the problem has been solved maximises learning opportunities. By re-examining the result and the route that led to it, students may solidify their information and improve their problem-solving skills. We believe that instilling the habit of looking back extends beyond confirming answers and the procedures used to achieve answers, as it maximises problem-solving learning opportunities.

Factors 2 and 3: Inability to Relate With Formulaic Structure Learned in School and Lack of a Heuristics Repertoire in Solving Problems

The second and third factor that students faced difficulty were their inability to relate and apply the various formulas learned in school and a lack of heuristics repertoire to solve the non-routine problems. The following problem exacerbated this factor.

Question 8: There are seven students in the meeting room. Each student shakes hands with each other except for themselves. How many handshakes are made altogether?

One would expect the following procedures commonly learned in school (the topic of combination and permutations) to be utilised to solve the problem:

$$^{7}C_{2} = \frac{7\times 6}{3} = 21$$

The paper and pencil test findings revealed that 80.7% of the 640 samples involved in the study responded incorrectly to this problem. Within these responses, approximately 82% (n = 423) left a blank space without attempting to solve it. None of the 640 samples involved in the study could use this learned combination formula to solve the problem. Further analysis from the paper and pencil test suggests that 9.1% (n = 58) of the 640 sampled students attempted to use heuristics to attain the solution. Examples of the heuristics used are shown in Figure 4.

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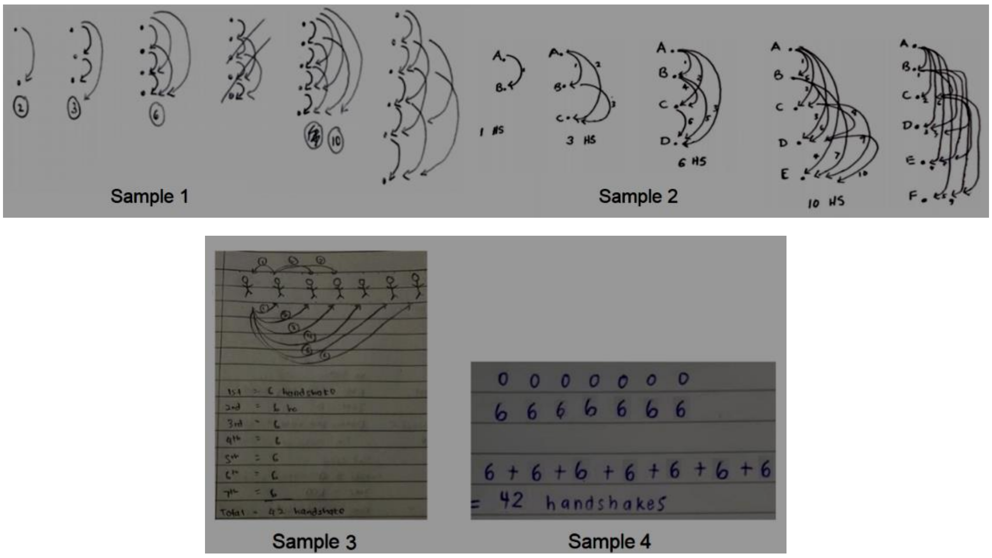

Figure 4. Samples of respondent's usage of heuristics in the Paper and Pencil Test

The interviews suggest that with scaffolding, students were able to be guided to solve the problem. S_{4I} was unable to solve the problem; however, it reaps the benefits with scaffolding.

R : *Can you solve the problem?*
S_{4I} : *No, difficult to solve.*
R : *Have you learned or solved this type of problem in school?*
S_{4I} : *No, I don't think so*
R : *Let me give you a hint. Say you have two students, A and B. With two students, how many handshakes?*
S_{4I} : *Two students….one handshake.*
R : *Three students?* (mumbled two get one, three get ….)
S_{4I} : *Three handshakes.*
R : *What about four students?*
S_{4I} : I think I know how to solve the problem…
S_{4I} started working on the sheet of paper. After working for about 4 minutes,
S_{4I} : *Twenty-one handshake is the answer for (pointing to his heuristic as shown in Figure 6) for seven students.*
R : *This is for five students; question is for seven students.*
S_{4I} : *You see there is a pattern one, three six, ten, then will be (heard saying five) fifteen and then (heard saying six) twenty-one.*
R : *Tell me more of this pattern.*
S_{4I} : *You see from one to three, you add two, then three to six add three, add four, five and then six*

With scaffolding, S_{4I} s solve the problem by using the drawing heuristics and then recognise a pattern to provide the solution of twenty-one handshakes.

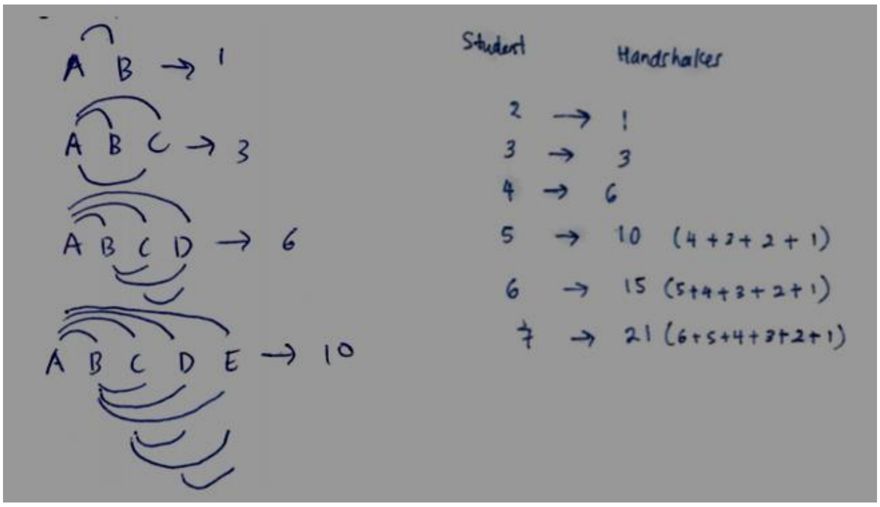

Figure 5. Heuristics for Question 8 by S_{4I}

S_{5H} was also successful in solving the problem using a pattern recognition heuristic.

R : *How many handshakes are made altogether with seven students?*
S_{5H} : *Twenty-One*
R : *Please explain.*
S_{5H} : *There is a pattern here (pointing to his systematic list-refer Figure 7) two students, one handshake, three students three, four students six and so on…seven students you get twenty-one*

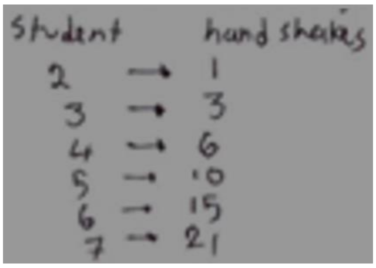

Figure 6. Heuristics for Question 8 by S_{5H}

R : *What about ten students? How many handshakes?*
S_{5H} : *Nine plus eight plus seven plus six plus five plus four plus three plus two plus one…… will be the answer!*

S_{5H} made a systematic list and discovered a pattern in deriving the solution.

The analysis from the paper and pencil test elucidated the inability of students to relate to the formulaic structure learned in school math to solve the given problem. Instead, the successful students used heuristics by looking at a pattern in their attempt to solve the problem. As Parmjit et al. (2016) explain, although mathematics learning has progressed over the decades (from elementary to secondary school), students lack cognitive strategies, thinking skills, and mathematical aptitude. He further stressed that the inability of students to solve non-routine problems is an area of concern that might inhibit their cognitive entry requirements demand for tertiary-level mathematics learning.

Problem-solving is a fundamental element in cognitive ability development, and heuristics play an essential role in enhancing this ability. Heuristics act as a key in the process of solving a problem, thereby showing a clear pathway to find the solution. One can conclude that generally, the students in this study seemed to lack the repertoire to use heuristics in solving non-routine problems posed in the study, as only a low 9.1% of the respondents attempted to use heuristics towards deriving the solution. The majority of students involved in this study rarely exhibited systematic usage heuristics when they could not solve fundamental problems. Researchers (Devlin, 2013; Liu & Niess, 2006) have argued that one solution towards overcoming this deficiency among students is for mathematics to be taught as a thinking activity through heuristics strategies. This mode of teaching activities via heuristics will equip students with the necessary tools to solve problems to accommodate changing needs (Treffinger, Selby, & Isaksen, 2008). Based on researchers' views, using heuristic strategies as a problem-solving tool in solving non-routine tasks can enhance students' mathematical thinking.

DISCUSSION AND CONCLUSION

High school leavers carry a wealth of "learned" mathematical subject knowledge with them as they prepare for college-level education. However, the study findings, to a large extent, postulated that the low cognitive capacity of high school leavers does not match the expected level of cognitive demand at the tertiary level. These findings are in congruence with previous findings (Aida, 2015; Parmjit et al., 2016; Parmjit & White, 2006), where students' mathematical performance on the national exam grades does not relate to their ability to develop mathematical thinking.

The findings showed that these students lack the ability to effectively use the previously learned factual knowledge to solve mathematical thinking problems. This, to a large extent, conceptualises the image of school mathematics as a rigid, procedural-orientated subject, which indirectly implies a negative connotation. To a large extent, this implication might impede meaningful mathematical learning in higher education. This impediment might lead to avoidance behaviours, meaning less engagement in the classroom (Ashcraft et al., 2007), completing fewer mathematical credits, and critically skipping attending advanced mathematics courses that are vital in obtaining full economic opportunity (Moses & Cobb, 2001). This is further compounded by its importance in STEM education, where it is an essential subject for the development of students' mathematical thinking.

Although the thrust of the new curriculum (KPM, 2016) was the embedment of a balanced set of knowledge and skills in creative thinking, critical thinking, and problem-solving for the development of students as philosophised, it is yet to be materialised. The answer to the question posed in the introduction section, "Does the new curriculum adequately prepare students for college readiness by offering a rigorous math curriculum?" is No!

Thus, action is warranted to curb these concerns, especially in the growth of students' cognitive ability to think mathematically. Firstly, we firmly believe that mathematics teaching in schools should be re-engineered so that the focus of doing mathematics should be synonymous with "teaching students to think." Although the new curriculum has philosophised this intention, it is not taking place. This is because the prevalent misperception is that "doing mathematics" is the same as being interested in "mathematical thinking." This misperception arises from the pedantic mathematics education in our school systems that still emphasises the mastery of mathematics by rote memorising of formulaic patterns. This rote learning procedure might be a yesteryear experience based on the Malaysian Education examination in abolishing exams for lower levels namely Primary and Lower Secondary (The Star, 2 June 2022). This might encourage teachers to focus more on developing students' thinking skills instead of 'covering the syllabus' for exam purposes.

Second, to facilitate the growth of students' mathematical thinking, we proposed using a problem-solving technique based on heuristics. This refers to learner-centered teaching, which can be implemented by introducing non-routine math problems in students' daily homework, followed by heuristic application to solve those problems. Polya (2004) suggested that to fuel growth in students' higher-order thinking skills, non-routine problems should be used. "Non-routine problems" are problems that are very likely to be unfamiliar to students. They make cognitive demands over and above those needed for solving routine problems, even when the knowledge and the skills required for their solution have been learned "(Mullis et al., 2003, p. 32). In order to bring about progress in students' thought processes, they must be challenged to the very core through the problems posed. It must also be intellectually stimulating yet within the range of its potential construction. It implies that solving these problems calls for the application of critical thinking beyond the limited scope of what is taught in the classroom alone and extends the bounds of mere procedure.

The heuristics application is seen as a tool that offers some general strategies and suggestions that assist a learner in either improving their understanding of a problem or making progress toward a solution to that problem. When applied to mathematical circumstances, these repertoires of heuristics as tools might seem to have no intrinsic worth, yet they may be highly potent (Polya, 1973). The utilisation of various heuristics such as searching for a pattern, building a list, working backward, and guessing and checking are active learning strategies that allow students to comprehend concepts and improve procedural skills in a meaningful way. As suggested (Devlin, 2013; Treffinger et al., 2008; Liu & Niess, 2006), using heuristic strategies as a problem-solving tool in solving non-routine tasks can enhance students' development of mathematical thinking. However, more research needs to be done to examine the effective implementation of these heuristics in developing the mathematical thinking growth of students.

Based on its success in TIMSS and PISA over the decades, one major success story for the Singapore Education System in mathematics has been its emphasis on problem-solving in its curriculum since 1992. Although one could argue that the curriculum in other parts of the world, including the Malaysian curriculum, similarly emphasises problem-solving, Singaporean students continue to outperform their peers in mathematics performance. Clark (2009), from his perspective, opined on five primary explanations for this disparity in performance:

> *Problem-solving is embedded in Singapore texts, not as a separate activity but as central to every skill and concept discussion. 2. The problems that Singapore students work on are much more complex than those in standard American texts. Two- and three-step problems are the norm. 3. Non-routine and routine problems are included in every grade level. (p. 2)*

He further elucidated that Singapore's curriculum heavily emphasises problems that are non-routine and beyond computation specification. Learners will often need to use several different heuristics to solve these kinds of problems.

The ability to solve problems does not fully explain the gaps in academic achievement between students in Singapore and those in other parts of the world. Efforts to develop a positive attitude, improve classroom learning materials, and most importantly, teachers' preparedness towards problem-solving is a crucial focus that encourages all students to feel better about mathematics learning. This teachers' preparedness is vital for successful and meaningful curriculum implementation. The final level of curriculum development involves teachers as the primary implementers. More effort needs to be undertaken by the education ministry to actualise the philosophy of the new curriculum.

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