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Students' Algebraic Proficiency and Attitude towards Learning Algebra

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Learning algebra is a difficult process that necessitates a positive attitude in order to maintain interest and master key concepts. Previous research found that students' attitudes influenced their algebra learning. As a result, more input is required to observe the current influence of attitudes on algebra learning. This study aims to investigate secondary school students' levels of proficiency and attitudes towards learning algebra. A case study was employed to collect data using an algebra test, a questionnaire on attitude, and task-based interviews. The subjects of this study were Form Three and Form Four students who were in the Dual Language Programme (DLP) in a school in Malaysia. A total of 93 students volunteered to participate in this study, and three of them were interviewed for insights into solving algebra problems. This study revealed that (1) there was no significant difference in algebra achievement between the Form Three and Form Four students; (2) there was a negative correlation between the achievement and attitudes; and (3) the students displayed rather low proficiency in answering the test questions, which could be attributed to difficulties with comprehension of problems in algebra and inadequate reasoning when applying problem solving strategies. These findings have implications for developing positive attitudes towards the learning of algebra. It is recommended that educators look into these areas to equip students with the right attitudes and knowledge for advanced learning at university.

Keywords: algebraic proficiency; attitude; learning of algebra

I. INTRODUCTION

Improvement in mathematics proficiency has become a key mission articulated in development plans in education in many countries (Ball, 2003; Blausten *et al.*, 2020; Seah *et al.*, 2021). Much effort has been made to raise proficiency in mathematics, as evident from the increasing body of research conducted among researchers in mathematics education. The research findings, informed by the continuous theoretical and practical developments in mathematics education, have been translated into comprehensive guidelines for classroom teachers to adopt and to develop students' knowledge of key components of mathematics (English & Kirshner, 2015). Algebra falls into a broad area of mathematics but is a critical component for developing mathematical knowledge and problem-solving skills. Research studies in algebra have examined strategies to enable students to achieve proficiency in algebra at an early age. Although these studies have provided significant insights into the development of algebraic learning, there is a need to deepen the understanding of how students integrate their existing knowledge with their attitudes, especially at higher levels of learning, before they pursue tertiary education. These students are expected to be better able to articulate their strategies than students at an early-stage age since they have more linguistic skills. This interest is attracting attention since it enables educators to uncover the thinking processes of students who have had substantial exposure to algebra training and learning. In addition, studies on how to better learn algebra are vital for the classroom because many students still do not fully comprehend fundamental concepts. So far, research has investigated students' attitudes to the learning of algebra and their relations to the changes in the learning environment and social context (Díez-Palomar *et al.*,

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2020), but it is clear that attitudes do not remain static and vary according to the contexts of learning. Students' attitudes may change with time and in different learning environments. Therefore, it is crucial to examine students' attitudes to the learning of algebra and their proficiency, considering that algebraic knowledge is fundamental to problem solving in academic and workplace contexts. Thus, this study aimed to investigate students' attitudes to learning algebra and their proficiency in algebra at the secondary school level, before students enter university for advanced STEM (namely science, technology, engineering, and mathematics) studies.

In helping students to achieve mathematical proficiency at the international level, educators around the world refer to the Trends in International Mathematics and Science Study (TIMSS) as a benchmark. Algebra is emphasised as an essential component of the development of mathematical proficiency since it is listed as a key component in TIMSS. The TIMSS 2019 eighth grade mathematics assessment comprised four main content areas in mathematics: number (30%), algebra (30%), geometry (20%), and data and probability (20%). In this assessment, the educators could obtain insightful feedback from the TIMSS report about students' achievements. Hence, TIMSS provides a valuable guideline for educators to develop mathematics education internationally based on the standard curricular goal among participating countries. Following the TIMSS, the Malaysian mathematics curriculum also lists algebra as an essential component throughout primary, secondary, and tertiary education. It is hoped that proficiency in algebra does not only provides a golden opportunity for students to excel in TIMSS mathematics assessment but also develops students' proficiency in mathematics (Wiberg, 2019). Universities and colleges are also aware of the importance of algebra by emphasising the need to develop students' proficiency in algebra for enhancing problem-solving skills and promoting STEM careers (Powel *et al*., 2019; Anderson, 2021). Black *et al.* (2021) draw attention to the importance of algebra for workers to meet the demands of their careers. The importance of algebra is echoed in actions taken by educators as well as the findings of the research. One of the many initiatives adopted by Malaysian educators involved preparing 8th-grade students (Form Two) for the TIMSS assessment, as in 2019, Malaysia's Form Two students obtained only 461, falling below the standard of 500 (Thomson *et al.*, 2020). Hence, it is crucial for the community especially teachers to take concrete action to equip students with strong fundamental skills in algebra to enable them to cope with the more advanced learning of algebra. Measures would include provision of resources that need to be deployed for teachers to equip the students with skills to meet the benchmark set by the TIMSS. The relatively low scores imply that the Form Two students need much more support to prepare them to reach a higher proficiency in mathematics and meet the international benchmark. Remediation is crucial for those who have performed below expectations in lower secondary school mathematics assessments.

Malaysian students' poor performance in algebra has been a growing concern (Teoh *et al.*, 2020; Ying *et al.*, 2020), but not unsurprising as research has shown that the learning of algebra is considered challenging among many students in many learning environments, even among students with positive attitudes (Poçan *et al.*, 2023). Students' problems in algebra, such as rational numbers, arithmetic, and word problems need to be resolved as these concepts are fundamental to university mathematics (Powell & Nelson, 2021). Hence, secondary school students' algebra proficiency needs to be carefully monitored and developed (Anderson, 2021) to equip them with mathematical skills for advanced learning at tertiary level, in particular among those planning to pursue STEM careers. Profiling algebraic fundamental knowledge has now become the current trend of mathematics education research (Anderson, 2021; Barbieri *et al.*, 2021). These studies are aimed at developing problem-solving and critical thinking skills and skills of communicating by turning algebraic representation into a reality (Lepak *et al.*, 2018). It is observed that university students' algebraic knowledge has received more attention (Bayat & Meamar, 2016) than other students, but investigating algebraic knowledge of secondary students is important so that problems could be detected earlier and appropriate effective solutions could be delivered (Bush & Karp, 2013).

The investigation into the teaching and learning of algebra has identified challenges. Despite the acknowledgement that algebra has real-life application for students, it is clear that students' proficiency in mathematics, especially, is worrying. For example, in the UK, authorities have expressed great concern about attainment in mathematics, especially algebra (Hodgen *et al.*, 2022). Students find algebra difficult and require much time to learn and master the concepts. To address this issue, research has recommended introducing algebra at an early age (Byrd *et al.*, 2015) and building positive attitudes toward the learning of algebra. It is clear that much of the discussion on the development of algebraic skills is school-based, and the responsibility of developing competency in algebra seems to have been relegated to teachers. However, for mastery of challenging skills, parents need to be involved by providing a supportive environment, for example, teaching them some content if they themselves have algebraic knowledge and making available enrichment or reinforcement activities at home. Besides, they could also inculcate the right attitudes to learning, as research has drawn attention to the importance of positive attitudes to learning mathematics (Mazana *et al.*, 2018; Bakar & Mohd Ayub, 2020). With the right attitude, students will be ready to engage in learning. Their engagement will make it possible for teachers to take them to a higher level of learning (Hiebert, 1988; Hiebert *et al.*, 1996). In the context of learning mathematics, where students need to grapple with abstract concepts, learning requires engagement. Teachers need to ensure that concepts taught are meaningful and the learning environment is free from anxiety (Du *et al.*, 2021). If the right learning environment is created, and if students are imbued with positive attitudes, learning will be facilitated, as teachers will focus on imparting knowledge and ensure that lessons are meaningful. Students' prior knowledge can be properly harnessed and developed. Thus, students' positive attitudes and teachers' efforts and work are necessary to foster learning (Marchis, 2011; Davadas & Lay, 2017; Tambunan, 2018; Deieso & Fraser, 2019). A necessary step, therefore, involves determining learners' attitudes to learning. A review of recent studies done in Malaysia shows that specific examination of secondary students' attitudes to learning algebra is surprisingly limited. This study, therefore, aims to identify Form Three and Form Four students' competencies in algebra, specifically students' proficiency in solving algebra problems.

II. METHOD

A case study using an algebra test and a questionnaire was designed and employed to collect data to answer three research questions, presented as follows:

Research Question One: Is there any difference in algebra achievement as measured in the test between the Form Three and Form Four students?
Research Question Two: Is there a relationship between the algebra achievement and attitude among the students?
Research Question Three: What is the students' algebra proficiency in algebra?

Due to the Covid-19 pandemic, the test and questionnaire were distributed through WhatsApp and email to the participants. A total of 93 participants volunteered to participate in this study, and three participants were interviewed to provide insights into their problem-solving strategies used to answer three selected questions in the test. The purposive sampling method was appropriate for this study as it allowed the researcher to select participants based on specific criteria that were relevant to the research questions. The inclusion criteria of the population were Form Three and Form Four students who have learned functions, equations, and equalities. They were in the Dual Language Programme (DLP) that used English in the Teaching of Science and Mathematics. The exclusion criterion was students who did not give consent to this study. The participants submitted the completed test and questionnaire through the same platform within the time given. Three participants volunteered to be interviewed to provide insights into their problem-solving strategies used to answer three selected questions in the test. The quantitative data were collected using a 15-question algebra test (8 multiple-choice questions with 7 subjective questions) and a questionnaire to uncover the attitudes of the participants. The test was adapted from an unpublished thesis (Li, 2006). All the items except item 14 were included in the instrument and were validated to establish face and content validity by two experts in mathematics. The questionnaire on attitude was adopted from Students Questionnaire Advanced Mathematics developed by TIMSS Advanced 2015 (TIMSS Advanced, 2015). This instrument was used to measure students' attitudes among secondary school students. The dimensions encompassed confidence, engagement, and importance. Each item was rated using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The Cronbach's Alpha coefficient for confidence towards mathematics, the importance of mathematics, and engagement in mathematics were 0.93, 0.87, and 0.91, respectively. Semi-structured interviews were conducted to collect qualitative data in this study. The qualitative data were used to determine misconceptions because they could provide in-depth information about students' understanding (Deringöl, 2019). The interview provided input for the development of students' proficiency in algebra and as a guide and benchmark of pre-university-level algebraic knowledge as well as STEM career development. A descriptive analysis was conducted to identify the respondents' achievements in the test as well as their attitudes. Additionally, a correlation analysis was conducted to determine if there was any significant relationship between achievement in algebra and attitude. The interview data were employed as a baseline for triangulation. Hence, the triangulation involved examining the data from the respondents' performance in the test and their interviews.

III. FINDINGS

The following findings are presented to address the research questions listed in the preceding section.

A. Finding 1: Achievement as measured in the algebra test

Finding 1 attempts to answer the first research question. Table 1 shows the mean scores of the algebra test of Form Three and Form Four students. Form Four students (mean=80.58, Std deviation=15.01) showed a slightly higher mean score than Form Three students (mean=76.22, Std deviation=12.86) descriptively. Nevertheless, the independent samples t-test showed there was no significant difference in the achievement between Form Three and Form Four students at $t=-1.369$, $p>0.05$.

Table 1. Descriptive statistics and the independent samples t-test.

	Level	N	Mean	Std. Deviation	t	df	Sig.
Algebraic test	Form Three	30	76.22	12.86	-1.369	91	0.974
	Form Four	63	80.58	15.01			
Overall		93	79.17	14.43			

B. Finding 2: Relationship between the algebra achievement and attitude among the students

Table 2 presents the results on students' attitudes to the learning of algebra. The students rated themselves comparatively higher on the perceived importance of learning algebra (mean = 4.17, std deviation = 0.88) than the perceived engagement (mean = 3.90, Std deviation = 0.97) and perceived confidence (mean = 3.71, std deviation = 0.97). The students were aware of the importance of learning algebra and were moderately engaged in the learning but had less confidence in the learning of this topic. Even though the students demonstrated good achievement (Table 1), seen from the overall mean score of 79.17 (std deviation = 14.43), a lower rating score was seen in their confidence level (mean = 3.71, std deviation = 0.97).

Table 2. Overall attitude to learning algebra.

	Category	Mean	Std. Deviation
1	Confidence in mathematics	3.71	0.97
2	Importance of mathematics	4.17	0.88
3	Engagement in Mathematics	3.90	0.97
	Overall Attitude	3.93	0.94

Table 3 shows the correlation between attitude to learning and achievement. Table 3 shows there was a low negative correlation ($r = -0.229$, $p < 0.05$). The negative correlation indicated that even though they managed to do reasonably well in algebra, their attitude showed that they might not have much confidence in their learning. Thus, with regard to the second research question, this finding suggested that the achievement does not reflect the level of confidence in the learning of algebra. It indicated that the students' frequent action or decision in solving algebra questions is not aligned with achievement.

Table 3. Correlation between students' attitude and algebra achievement.

		Attitude to learning algebra
Algebra achievement (test)	Pearson Correlation	-0.229*
	Sig. (2-tailed)	0.027
	N	93

The findings revealed that when students proceeded to a higher level, their achievement showed a higher score. Nevertheless, their confidence level could still be low. More analyses on exploring on how they solved the algebraic question were conducted. The focus was limited to three aspects, namely function, equation, and forming an equation.

C. Finding 3: Students' proficiency in algebra

The students' proficiency was analysed based on the strategies and the steps they used to find answers to the questions. It was found that the students were not confident in solving the questions. Two conditions were uncovered. Firstly, they failed to solve the questions. Secondly, they could answer the questions but failed to interpret confidently. Hence, the qualitative analysis focused on these two aspects in the three domains (function, equation, and forming an equation).

1. Function

Students showed their understanding by dealing with patterns but did not show the acquisition in presenting the meaning of function in the interviews. A respondent (P2) shared her understanding of 'Question 6'. She used 'parallel' instead of 'linear' to interpret the relationship of a function. Question 6 is displayed below.

6. Which of the following statements is NOT TRUE about the equation $y = 2t$ if t is a positive number?

   A. It shows how y changes for different values of t.
   B. It shows a linear relationship between y and t.
   C. It shows that the value of y is independent of the value of t.
   D. It shows that as t increases, y also increases.

Question 6 contains important terminology, namely 'linear relationship' (a key word in 'B') and 'independent' (a key answer in 'C'). Even though the correct answer for question 6 was 'C', not all students provided the right answer. This question tested the participants' conceptual understanding of key terminology. It was found that there were possibilities for students to generate the right answer, but they failed to show their understanding of mathematical language. This confusion was shown in the interpretation of the two key concepts in an interview. Firstly, in using the terminology of 'linear relationship', a respondent (P2) showed that 'linear relationship' and 'parallel' carried the same meaning, as conveyed in the following excerpt.

P2 : From what I understand, linear means parallel. So, y is parallel to t.

I : What do you mean by parallel?

P2 : What I mean is…when the value of y increases, the value of t also increases. Same like at the graph; if value on y-axis is increasing, the value on x-axis also increasing.

The respondent also failed to make the connection between 'linear' and the concept of 'increasing' and 'decreasing'. She misinterpreted the degree of increase and decrease. The linear relationship showed consistent changes (either increasing or decreasing constantly). For this question, it is acceptable to explain that "y = 2t" has a linear relationship and the increase of the t value results in the increase of the y value. Nevertheless, the independent variable (here, it means 't') should be treated as a moderated variable (means someone can control the changes of value), which will cause the changes of values in y. She had to be clear before getting the right explanation for the increase and decrease of the variables. For this concept, P2 also explained that she was unclear about certain concepts, as can be concluded from the following extract:

P2 : Yes. like some of the words such as 'independent' make me cannot really understand what it means.

Upon probing, it was found that she had problems understanding the questions in English too. Nevertheless, the literature shows that it is far more important for students to fully understand and conceptualise mathematical language than linguistic knowledge, for example, understanding the words 'parallel' and 'linear' mathematically completely, before attempting to solve a problem.

2. *Equations and equality*

This study found that students applied procedural knowledge in solving an equation without understanding the steps, clearly depicted in their work on question 15 (Figure 1).

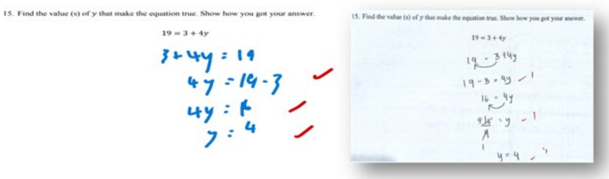

Figure 1. P1's answer (left) and P2's answer (right).

Respondents P1 and P2 presented their solutions to question 15 by finding the value of y in an equation. They used the word 'moving' to explain how they obtained the answer. When they were asked to explain an alternative strategy, they could only say that moving the number to the other side of '=' comes together with changing the operators, as described in the following excerpts.

P1 : First, I bring the number to another side, and minus 19 by 3.
I got answer 16. after that, I bring 4 to another side and divide 16 by 4.
finally, I got the answer that y is equal to 4.

P2 : At first, I identified the variable was on right side, y its unknown. Then, I moved '3' to left side. so, it becomes minus because that number used to be positive. So, when I move it…it become negative. Therefore, 19 minus 3 is 16. For '4y', 4 is multiplied by y… so when we want to move. it must be divided to that number. 16 divides by 4, so the solution of y is 4.

The steps were not properly explained. With inadequate understanding, students were unable to focus on the concept of eliminating the terms in operation as presented by P3. Figure 2 shows that P3 demonstrated the solution without fully understanding the performance of the operation; hence, he failed to derive the answer. Thus, performing the operation without fully comprehending the purpose may cause the failure to understand the meaning of the equation in terms of the relationship.

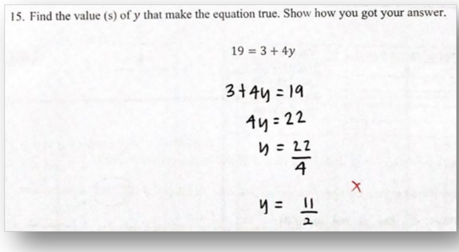

Figure 2. P3's answer.

3. *Forming an Equation*

In this study, students were examined on their skills in writing equations or inequalities from a word problem. The observation was done for the question, "Alex is exactly one year older than Bella. Let A stand for Alex's age and B for Bella's age, write an equation to compare Alex's age and Bella's age". This problem required students to write an equation to represent the relationship between Alex's age and Bill's age. The correct answer is "A = 1+ B" or" A-B=1". Nevertheless, nearly half of the sample in this study (48.5%) provided the wrong equation. Among their answers were: "B – A =1", "A+1 = B", "A+ 1 >B", "A > B". Figure 3 presents P1's work. She explained that she used '>' to show 'older than'. Her description is presented as below.

I : *Why did you write greater?*

P1 : *Because Alex's age is older than Bella's age.*

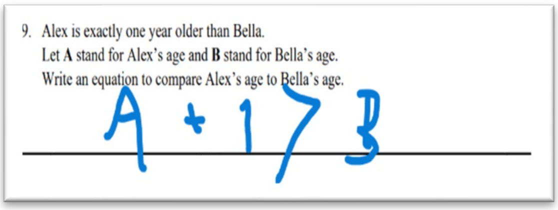

Figure 3. P1's work for Question 9.

Similarly, P3 also used inequalities to present the solution (Figure 4).

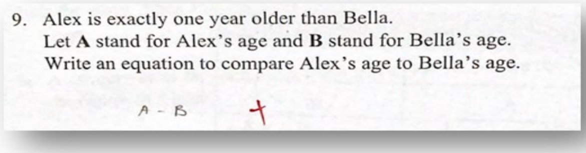

Figure 4. P3's answer.

IV. DISCUSSION

The findings in this study are indeed insightful. With reference to the first research question, it was shown that there was no significant difference in algebraic proficiency between the two different levels of secondary school students – the Form 3 and Form 4 students. It indicated that the students' algebraic knowledge did not show improvement when they entered a higher level, from Form 3 to Form 4. This finding was somewhat surprising, considering that students in Form 4 had already been taught Form 3 algebra. This finding has also drawn attention to the need to conduct further research into reasons why there was no significant difference in students' proficiency in algebra and that the average score of the achievement in the algebra test was at a moderate level. These revelations were of great concern, in view of the fact that secondary education prepares students for tertiary studies. The mastery of foundational concepts of algebra before enrolling in university is crucial; hence, the teaching and learning of algebra in schools need to be scrutinised to determine reasons for students' inability to fully comprehend and use mathematical language correctly. This study has shown that since students had not mastered some important concepts even though they managed to get good grades in algebra tests in the early stage of learning (Liang *et al.*, 2012). At secondary school level, however, it is clear that students' proficiency in algebra still leaves much to be desired. Apart from reports on low proficiency, there are concerns about low proficiency. There are calls to equip elementary and secondary school students with algebraic knowledge to prepare them to meet college requirements, especially for STEM education and careers which require high proficiency in solving mathematical problems using algebraic knowledge. Studies including that conducted by Powell *et al.* (2019), concluded that students across all levels, from primary to tertiary levels still do not have the required competence in algebra. Hence, more efforts need to be made to provide effective instruction to strengthen algebraic foundational knowledge. Referring to the second research question, the findings also showed that there was a small relationship between algebraic achievement and attitude. Measuring attitude strength provides information related to actions taken in solving mathematical problems (Fazio *et al.* 983; Howe & Krosnick, 2017). Getting a positive attitude or a high level of attitude strength indicates the students' quick action to fully engage in working on mathematical problems. This study found that the students' achievement was negatively related to attitude. The students failed to show a strong understanding of algebraic concepts. Although they rated their engagement as moderately high when working on algebraic problems, they showed less confidence. In this regard, Ferguson *et al.* (2005) explained that the strength of attitude provides a guide for monitoring students' understanding. More support is needed to increase students' confidence and cultivate positive attitudes to strengthen their cognition (Seeley, 2004). It means the detection of negative attitudes among the students should be accompanied by effective instructions to improve students' proficiency. Finally, with reference to the final research question, this study revealed that the students displayed rather low proficiency in answering the test questions. They demonstrated low text comprehension of algebraic problems and inadequate reasoning when applying some strategies. Furthermore, this showed that they lacked complete understanding of mathematical language, which affected their ability to solve the test questions. Research has also shown that apart from understanding the concepts, high linguistic proficiency is important (Sandilos *et al.*, 2020). However, Suhr *et al.* (2021) pointed out that high proficiency in the English language may not help students to acquire mathematical knowledge. Getting the meaning right in their reading and transforming their comprehension into mathematical language or algebraic equations correctly will develop students' proficiency in mathematics (Capraro & Joffrion, 2006). This relationship between language and mathematical understanding was further clarified by Salminen *et al.* (2021). It was observed that proficiency in mathematics depends greatly on numerical and reading comprehension. It involves mathematics communication through representation or mathematical processes. Hence, the teachers need to focus on getting students to become familiar with mathematical words and phrases, and help them translate the language into appropriate mathematical expressions (Webb, 1997; Jupri & Drijvers, 2016). However, this process can be demanding for students. The ability to make connections and relate ideas is a basic ability before a higher level of cognitive thinking can take place (Webb, 1997). Hence, getting students to understand fully key concepts, such as the meaning of parallel and linear relationship, and use them correctly is crucial at the early stage of learning algebra. It is unclear if teachers were aware of the students' challenges. In this study, when the students were interviewed and observed on their skills in constructing equations and interpreting word problems using equal signs for connecting the association of two expressions, they showed that there were obstacles in the transition of arithmetic to algebraic thinking. Teachers therefore need to closely monitor students' understanding of key concepts and their ways of tackling algebraic problems. Students' proficiency in algebra can be observed from the aspect of applying algebraic expressions in concrete problem settings (Leitzel, 2018). It has also been emphasised that text comprehension, as well as arithmetic skills, is an important domain to build problem-solving skills (Kintsch, 1998; Pongsakdi *et al.*, 2020). Students need to thoroughly understand the meaning of equations by flexibly using a few strategies. In this study, even though P1 and P2 successfully performed inverse operations to undo the operation in the equations while applying the strategy of 'changing side and sign', they were not able to describe the reason for doing so. The students' challenges were also emphasised by previous researchers in other contexts. Baroody and Ginsburg (1983) recommended that teachers focus on getting students' attention in making the connection of the meaning of "=" with the idea of "the same as" or "equals". It is suggested that exposing students to the additive property and multiplicative property to determine the solution of an equation might make the learning lively and meaningful (Carraher, 2001).

V. CONCLUSION

This study has revealed that developing knowledge of solving algebraic equations should focus on integrating the prior knowledge of arithmetic properties. However, students should be guided on algebraic thinking step by step and not just by manipulating a set of rules. In solving an equation, the focus should be on representing relationships and not performing operations within and among the terms. Since algebraic thinking involves a process, teachers should also build a positive attitude among the students to foster engagement and develop confidence. While this study has shown that there are still gaps in Malaysian secondary students' knowledge of basic concepts, demonstrated through their inadequate reasoning skills, it is hoped that insights from this study could help teachers in secondary school raise students' proficiency in algebra and cultivate positive attitudes to the learning of fundamental conceptual knowledge. These findings demonstrated that it is essential to have a positive attitude toward learning algebra, particularly in the context of STEM education. This is especially true. If students lack self-assurance and interest in learning algebra, it may be difficult for them to achieve success in fields related to science, technology, engineering, and mathematics (STEM), which heavily rely on mathematical skills. Therefore, teachers should place their primary emphasis on boosting students' levels of self-confidence, encouraging students' active participation in the algebra learning process through the use of interactive instructional strategies, and drawing attention to the importance of algebra in the fields of science, technology, engineering, and mathematics. Educators can do a better job of preparing students for success in fields that involve STEM subjects if the students' attitudes toward learning algebra are improved.

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