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The Effect of Student Engagement and Self-Regulated Learning on Algebraic Reasoning

Muhammad Syawahid[1*], Lalu Sucipto[2], Muttaqiah[3], Nasrun[4]
[1,2,3]Universitas Islam Negeri Mataram, [4]Universitas Muhammadiyah Makasar
Email: syawahid@uinmataram.ac.id[1*], ciptobajok@uinmataram.ac.id[2],
200103045.mhs@uinmataram.ac.id[3], nasrun.anthy@unismuh.ac.id[4]

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Abstract:

Few studies have examined the affective factors influencing students' algebraic reasoning. This study aims to investigate the effect of student engagement and self-regulated learning on algebraic reasoning. The research employed a quantitative correlational design. Using a cluster sampling technique, 202 students from Islamic State Junior High Schools in Mataram were selected as participants. Data were collected through tests and questionnaires. The instruments used included an algebraic reasoning test, student engagement questionnaires, and self-regulated learning questionnaires. Data analysis involved both descriptive analysis (categorical and descriptive statistics) and inferential analysis (prerequisite tests and hypothesis testing). The results of this study indicate that student engagement has a significant influence on algebraic reasoning. However, self-regulated learning did not show a significant effect on algebraic reasoning. Additionally, student engagement and self-regulated learning, when considered together, significantly influence algebraic reasoning. The study also found that student engagement and self-regulated learning contribute to algebraic reasoning. These findings suggest that teachers should prioritize fostering student engagement and self-regulated learning in the classroom, emphasizing interactive, collaborative, and contextually relevant algebra instruction.

Abstrak:

Beberapa penelitian telah mengeksplorasi faktor afektif yang memengaruhi penalaran aljabar siswa. Penelitian ini bertujuan untuk mengetahui pengaruh keterlibatan siswa dan pembelajaran yang diatur sendiri terhadap penalaran aljabar. Jenis penelitian yang digunakan adalah kuantitatif korelasional. Dengan teknik sampling klaster, 202 siswa dari Sekolah Menengah Pertama Negeri di Mataram dipilih sebagai sampel penelitian. Data dikumpulkan menggunakan tes dan kuesioner. Instrumen yang digunakan dalam penelitian ini adalah tes penalaran aljabar, kuesioner keterlibatan siswa, dan kuesioner pembelajaran yang diatur sendiri. Analisis data yang digunakan dalam penelitian ini adalah analisis deskriptif (kategori dan statistika deskriptif) dan analisis inferensial (uji prasyarat dan uji hipotesis). Hasil penelitian ini menunjukkan bahwa keterlibatan siswa berpengaruh terhadap penalaran aljabar. Namun, pembelajaran yang diatur sendiri tidak berpengaruh terhadap penalaran aljabar. Selain itu, keterlibatan siswa dan pembelajaran yang diatur sendiri secara bersamaan berpengaruh terhadap penalaran aljabar. Penelitian ini juga menunjukkan bahwa keterlibatan siswa dan pembelajaran yang diatur sendiri memberikan kontribusi terhadap penalaran aljabar. Temuan ini memberikan implikasi bagi guru untuk memprioritaskan keterlibatan siswa dan pembelajaran yang diatur sendiri di dalam kelas, dengan menekankan pembelajaran aljabar yang interaktif, kolaboratif, dan relevan dengan konteks.

Keywords:
Algebraic Reasoning, Engagement, Self-Regulated Learning

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Introduction

Mathematics equips students with a method of reasoning through mental activities that form a continuous flow of thought, leading to the development of an understanding of mathematical concepts. This understanding encompasses facts, concepts, principles, operations, relations, problems, and formal-universal solutions (BSKAP, 2022). One of the primary objectives of mathematics education is to enable students to use reasoning in identifying patterns and properties, performing mathematical operations to make generalizations, compiling evidence, and explaining mathematical ideas and statements (NCTM, 2000; BSKAP, 2024). Students who exhibit strong reasoning skills tend to achieve higher levels of success in mathematics learning (Mukuka, Balimuttajjo, & Mutarutinya, 2023; Öz & Işık, 2024; Supriadi, Jamaluddin, & Suherman, 2024).

The results of the 2023 Programme for International Student Assessment (PISA) revealed that Indonesian students scored an average of 366 in mathematics, which is below the global average for all PISA participants (OECD, 2023a). This score represents the lowest performance since Indonesia's participation in PISA, which began in 2006 (Prinantyo, 2023). One of the key areas evaluated in PISA is reasoning, specifically the ability to apply mathematical concepts, tools, and logic to solve real-life problems and situations (OECD, 2023a, 2023b).

Algebraic reasoning, an essential aspect of mathematical reasoning, refers to the process of generalizing mathematical ideas through argumentation and formal expression (Blanton & Kaput, 2005). It involves the ability to analyze quantities within contexts and express their relationships through tables, graphs, symbols, and mathematical expressions (Carraher & Schliemann, 2007). Students who develop algebraic reasoning can generalize specific situations into broader mathematical concepts (Kaput, 1999), and it serves as a foundation for learning algebra.

Several studies have explored various factors influencing algebraic reasoning. Lannin, Barker, & Townsend (2006) identified several predictors of algebraic reasoning, including input, structured mathematical tasks, strategies, visual representations, and social interactions. Tikkun (2018) proposed five factors influencing algebraic reasoning, including task time, task analysis, efficiency ratings, cognitive load, and working memory. Ünal, Ala, Kartal, Özel, & Geary (2023) found that algebraic reasoning is affected by both visual and symbolic representations. While these studies primarily focus on cognitive factors, fewer studies have examined the affective factors that influence algebraic reasoning. This study explores one such factor—students' engagement. Sunawan, Dwistia, Kurniawan, Hartati, & Sofyan (2017) suggested that student engagement plays a crucial role in mathematics achievement, underscoring its potential influence on algebraic reasoning.

Students' Engagement refers to the active involvement of students in the learning process across cognitive, emotional, and behavioral dimensions (Lerdpornkulrat, Koul, & Poondej, 2018). It encompasses students' participation in classroom activities, including their attention, interest, and effort expended during learning (Wang, Bergin, & Bergin, 2014). Researchers have classified students' engagement into three categories: cognitive, affective, and social/behavioral engagement (Fredricks, Blumenfeld, & Paris, 2004; Rimm-Kaufman, 2010; Lerdpornkulrat, Koul, & Poondej, 2018; Özkal, 2018). Previous studies, such as those conducted by Pakpahan & Simanjorang (2024), have shown that students' engagement significantly affects mathematics achievement. Students' engagement is identified as a key factor influencing students' learning outcomes in mathematics (Singh, Granville, & Dika, 2002; Al Mutawah, Thomas, & Khine, 2017). The three components of engagement—cognitive, emotional, and social—have been found to have distinct and individual relationships with students' mathematics achievement (Francis, Tan, & Chen, 2018).

However, students' engagement is not the sole determinant of mathematics achievement, including algebraic reasoning. Self-regulated learning is another critical factor influencing mathematics performance (Wood, 2022). According to Ong'uti, Aloka, & Nyakinda (2022), enhancing students' self-regulated learning is key to improving their mathematics learning outcomes. Self-regulated learning refers to a self-directed process of planning, monitoring, evaluating, and reflecting on one's learning using relevant strategies and tools (Zahrawati, Maryadi, Idris, Gusti, Asri, & Aras, 2021; Khiat & Vogel, 2022). Zimmerman (2012) describes self-regulated learning as the process by which individuals independently manage their learning through goal-setting, planning, and self-monitoring. Self-regulated learning consists of three phases: the thinking and planning phase, the monitoring phase, and the reflection phase (Zimmerman, 2008).

Several studies have established a relationship between self-regulated learning and mathematics achievement. Ong'uti, Aloka, & Nyakinda (2022) found that self-regulated learning positively impacts mathematics performance. Alyani & Ramadhina (2022) emphasized that there is a positive correlation between self-regulated learning and mathematics problem-solving. Handican, Darwata, Ananda, Azwar, & Mukhaiyar (2022) reported that self-regulated learning accounts for 32.49% of the variance in mathematics learning outcomes. Additionally, two studies confirmed that self-regulated learning positively influences mathematical reasoning (Hertzog, Smith, & Ariel, 2018; Cann, García-Valcarcel, & Morales-Morgado, 2022). Students who exhibit self-regulated learning and actively engage in cognitive, affective, and social learning processes are more likely to achieve better learning outcomes. Higher levels of self-regulated learning and engagement are correlated with higher mathematics achievement (Salma & Alsa, 2023). Specifically, self-regulated learning and student engagement are linked to enhanced mathematical reasoning (de Blume & Montoya, 2023; Huang, Li, Wang, Pan, & Lajoie, 2023). Despite the crucial role of algebraic reasoning as a foundation for advanced mathematical thinking and its impact on mathematical achievement, Indonesian students continue to face challenges in this area (BSKAP, 2024; NCTM, 2000). The most recent PISA 2023 results highlight a significant decline in mathematics performance, with Indonesian students scoring well below the international average (OECD, 2023a, 2023b). This underperformance emphasizes the need to strengthen reasoning skills, particularly in algebraic reasoning, which is essential for understanding mathematical relationships and solving real-world problems.

Although prior research has focused on cognitive factors influencing algebraic reasoning, such as task structure and working memory (Tikkun, 2018; Ünal, Ala, Kartal, Özel, & Geary, 2023), limited attention has been given to the affective factors contributing to students' reasoning abilities. Students' engagement and self-regulated learning have been identified as key predictors of mathematics achievement (Wood, 2022), but their combined effect on algebraic reasoning remains underexplored. Engagement, which includes cognitive, emotional, and behavioral dimensions, has been shown to influence mathematical outcomes (Francis, Tan, & Chen, 2018; Fredricks, Blumenfeld, & Paris, 2004). Likewise, self-regulated learning, characterized by goal-setting, monitoring, and reflection, is strongly associated with mathematics problem-solving and reasoning (Alyani & Ramadhina, 2022; Zimmerman, 2008). However, there is limited research investigating the simultaneous effect of these affective factors on algebraic reasoning. This study aims to fill this gap by exploring the individual and combined effects of students' engagement and self-regulated learning on algebraic reasoning. The research hypothesizes that both factors, individually and together, influence algebraic reasoning, thereby providing a framework for understanding how affective factors contribute to the development of mathematical reasoning. This investigation is crucial for addressing the challenges faced by Indonesian students and improving overall mathematics learning outcomes.

Research Method

The research adopted a quantitative correlational approach, aiming to examine the relationships between variables and assess the strength of these relationships (Creswell, 2012). The population comprised 713 eighth-grade students from three Islamic junior high schools in Mataram. These schools were selected due to their status as public institutions under the Ministry of Religious Affairs in the Mataram area, making them suitable for exploring student engagement and self-regulated learning in the context of algebraic reasoning. Additionally, prior studies had been conducted in these schools, which identified challenges related to functional thinking, a key aspect of algebraic reasoning. Using the Krejcie and Morgan table, 249 students were chosen as a sample through cluster sampling. However, 47 students were identified as outliers and excluded from the analysis, resulting in a final sample of 202 students. This sample comprised 51.5% girls and 48.5% boys, with an average age of 14 years.

Data collection involved the use of tests and questionnaires. The test was administered to gather students' algebraic reasoning data, while the questionnaire was used to collect information on students' engagement and self-regulated learning. The algebraic reasoning test consisted of 20 multiple-choice items, which were divided into three sections: 8 items on general arithmetic, 8 items on functional thinking, and 4 items on generalization and justification. This test was adapted from Blanton & Kaput (2005). Prior to distributing the test, the researchers conducted expert validity assessments involving two mathematics education experts, a construct validity test on 75 students using Pearson Product Moment Correlation, and a reliability test using Cronbach's Alpha. The expert validity test resulted in scores of 82.2 and 84.4, both of which met the valid criteria. The construct validity test yielded 20 items with an r-value greater than the r-table value of 0.227. In terms of reliability, the Cronbach Alpha coefficient was 0.727, indicating acceptable reliability.

The questionnaires included a student engagement questionnaire and a self-regulated learning questionnaire. The student engagement questionnaire, adopted from Rimm-Kaufman (2010), consisted of 16 items divided into three dimensions: emotional engagement (5 items), social engagement (4 items), and cognitive engagement (4 items). Participants rated their responses on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Construct validity was assessed using confirmatory factor analysis (CFA), which included convergent validity (loading factor > 0.5) and discriminant validity (square root of AVE > 0.7) (Junianto et al., 2020). The reliability of the instrument was evaluated using Cronbach's Alpha and composite reliability, which yielded good results (Cronbach Alpha = 0.753, composite reliability = 0.835).

The self-regulated learning questionnaire, adopted from Nambiar, Alex, & Pothiyil (2022), comprised 36 items, which were divided into three phases: forethought (10 items), performance control (19 items), and self-reflection (7 items). Both the student engagement and self-regulated learning questionnaires used a 5-point Likert scale, with response options ranging from strongly agree to strongly disagree. The validity of the instruments was assessed through construct validity using confirmatory factor analysis (CFA), which included tests for convergent validity (loading factor > 0.5) and discriminant validity (square root of AVE > 0.7). Reliability was evaluated using Cronbach's Alpha and composite reliability, yielding satisfactory results (Cronbach Alpha = 0.905, composite reliability = 0.868).

Data collection took place at three Islamic state junior high schools in Mataram, following approval from the school authorities. The researchers, in collaboration with mathematics teachers, administered tests and distributed questionnaires in an offline setting during mathematics lessons. The schools granted permission to use class time for administering the algebraic reasoning tests and distributing the questionnaires. Prior to the students beginning the tests, the researchers provided clear directions and instructions for completing the algebraic reasoning tests. During the tests, the researchers accompanied the students, offering assistance and clarifying any questions that were not understood.

For the questionnaire distribution, the researchers explained the instructions and guided the students in filling out the questionnaires. The students were instructed to select answers based on their personal experiences. The researchers reminded the students to complete the identity sections of both the tests and questionnaires. Data analysis involved both descriptive and inferential statistics. Descriptive analysis included categorizing students' algebraic reasoning, engagement, and self-regulated learning data, as well as calculating measures such as mean, median, minimum, maximum, standard deviation, and variance. The categorized data for students' algebraic reasoning was presented in Table 1, and the categorized data for students' engagement and self-regulated learning was presented in Tables 2 and 3.

Table 1. Students' Algebraic Reasoning Category (Azwar, 2011)

Range Criteria	Category
$81 - 100$	Very high
$61 - 80$	High
$41 - 60$	Medium High
$21 - 40$	Low
$0 - 20$	Very low

Table 2. Students' Engagement Category (Azwar, 2022)

Range Criteria	Range Result	Category
$x \geq M + 1{,}5\ SD$	$x \geq 52$	Very high
$M + 0{,}5\ SD \leq x < M + 1{,}5\ SD$	$43{,}33 \leq x < 52$	High
$M - 0{,}5\ SD \leq x < M + 0{,}5\ SD$	$1 \leq x < 43{,}33$	Medium High
$M - 1{,}5\ SD \leq x < M - 0{,}5\ SD$	$98 \leq x < 111$	Low
$M - 1{,}5\ SD \geq x$	$98 \geq x$	Very low

Table 3. Students' Self-regulated Learning Category (Azwar, 2022)

Range Criteria	Range Result	Category
$x \geq M + 1{,}5\ SD$	$x \geq 146$	Very high
$M + 0{,}5\ SD \leq x < M + 1{,}5\ SD$	$130 \leq x < 146$	High
$M - 0{,}5\ SD \leq x < M + 0{,}5\ SD$	$114 \leq x < 130$	Medium High
$M - 1{,}5\ SD \leq x < M - 0{,}5\ SD$	$98 \leq x < 114$	Low
$M - 1{,}5\ SD \geq x$	$98 \geq x$	Very low

Inferential analysis in this study consisted of prerequisite tests and hypothesis tests. The prerequisite tests included a normality test (Kolmogorov-Smirnov test), a linearity test (significance of deviation from linearity), a multicollinearity test (variance inflation factor, VIF), and a heteroscedasticity test (Glejser coefficients). For hypothesis testing, multiple linear regression was used, including both partial hypothesis testing (t-test significance) and simultaneous hypothesis testing (F-test significance) as outlined by Cohen, Manion, & Keith (2007).

Results and Discussion

Result

The statistical description of the algebraic reasoning, student engagement, and self-regulated learning data included the range, minimum, maximum, mean, standard deviation, and variance. These statistics are presented in Table 4.

Table 4. Statistical Descriptive

	Range	Minimun	Maximun	Mean	Std. Deviation	Variance
Algebraic Reasoning	75.00	25.00	100.00	59.4059	17.28150	298.650
Student engagement	66.15	30.77	96.92	73.6705	11.53118	132.968
Self-Regulated Learning	58.34	39.44	97.78	75.6495	9.41731	88.686

The categorical description of algebraic reasoning, student engagement, and self-regulated learning was divided into five categories: very high, high, medium, low, and very low. This categorization is presented in Figure 1.

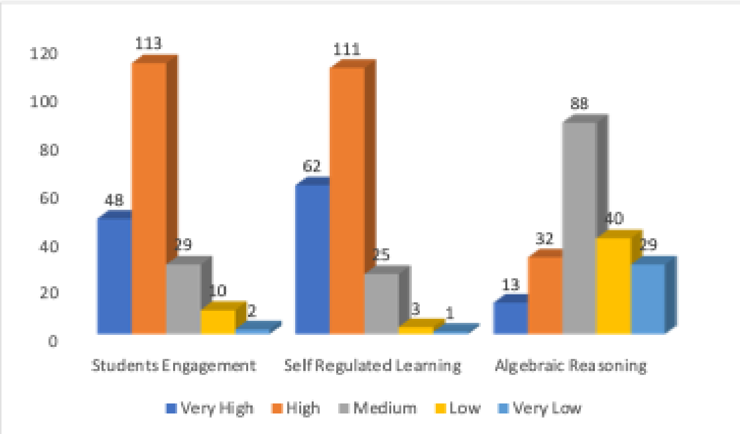

Figure 1. Category Descriptive Data

The normality of the data was assessed using the Kolmogorov-Smirnov test, applied to the residuals. The results of this normality test are presented in Table 5.

Table 5. Normality Test

N	Kolmogorov-Smirnov Z	Asymp. Sign (2-tailed)	Prerequisites for normality test	Conclusion
202	1,052	0,219	0,219 > 0,05	Normal Distribution

A linearity test was conducted to assess the relationship between students' engagement, self-regulated learning, and algebraic reasoning. The test employed the F-test for deviation from linearity with a significance level of 0.05. The results are presented in Table 6.

Table 6. Linearity Test

A Grouping Data	F	Deviation from linearity sig	Prerequisites for linearity test	Conclusion
Student Engagement to Algebraic Reasoning	0,794	0,784	0,784 > 0,05	Linear Pattern
Self-Regulated Learning to Algebraic Reasoning	0,807	0,835	0,835 > 0,05	Linear Pattern

The multicollinearity test in this study was conducted using the Variance Inflation Factor (VIF) to examine the relationships between student engagement, self-regulated learning, and algebraic reasoning. The results are presented in Table 7.

Table 7. Multicollinearity Test

A Grouping Data	Tolerance	VIP	Prerequisites for the Multicollinearity Test	Conclusion
Student Engagement to Algebraic Reasoning	0,832	1,203	0,832 > 0,01 or 1,203 < 10	No multicollinearity symptom detected
Self-Regulated Learning to Algebraic Reasoning	0,832	1,203	0,832 > 0,01 or 1,203 < 10	No multicollinearity symptom detected

The heteroscedasticity test was performed to assess whether there was any bias in the regression analysis model. This test was conducted using the Glejser technique, and the results are displayed in Table 8.

Table 8. Heteroscedasticity Test

A Grouping Data	t	Sig	Prerequisites for Heteroscedasticity test	Conclusion
Student Engagement to Absolute Residual	1,090	0,277	0,277 > 0,05	No heteroscedasticity symptom detected
Self-Regulated Learning to Absolute Residual	0,207	0,837	0,837 > 0,05	No heteroscedasticity symptom detected

Hypothesis testing in this study included both partial and simultaneous tests. Partial hypothesis testing was conducted to determine the individual effect of student engagement and self-regulated learning on algebraic reasoning using a t-test. The results are shown in Table 9. Simultaneous hypothesis testing was performed to evaluate the joint effect of student engagement and self-regulated learning on algebraic reasoning using an F-test. These results are presented in Table 10.

Table 9. Partial Hypothesis Test

A Grouping Data	t	sig	Prerequisites for Partial Hypotesys test	Conclusion
Student Engagement to Algebraic Reasoning	2,418	0,017	0,017 < 0,05	A significant effect is observed
Self-Regulated Learning to Algebraic Reasoning	-0,425	0,671	0,671 > 0,05	No significant effect detected

Table 10. Simultaneous Hypothesis Test

A Grouping Data	F	sig	Prerequisites for Simultaneous Hypothesis Test	Conclusion
Student engagement and Self-regulated Learning to algebraic reasoning	3,117	0,046	0,046 < 0,05	A significant effect is observed

The results also indicated that the R-squared value of the model was 0.030, with the regression equation represented as $Y = 43{,}491 + 0{,}277CX_1 - 0{,}060X_2$. This suggests that student engagement and self-regulated learning together account for 3% of the variance in algebraic reasoning.

Discussion

Based on the descriptive data, the mean score for algebraic reasoning among students at the 202 Islamic State Junior High School in Mataram was 59.4, with most students falling into the medium category. This score is higher than the algebraic reasoning mean score of 52.83 reported for 60 students in Turkey (Ünal, Ala, Kartal, Özel, & Geary, 2023) but lower than the mean score of 65.3 observed for 34 students at the Islamic Sunan Gunung Jati Junior High School. Regarding student engagement, the mean score for the students at the 202 Islamic State Junior High School was 73.6, with the majority of students categorized as having high engagement. This finding aligns with the results of a study by Sunawan, Dwistia, Kurniawan, Hartati, & Sofyan (2017), which reported a mean score of 78.13 for student engagement in junior high schools in Indonesia. However, it contrasts with the findings of Kristiana, Prihatsanti, Simanjuntak, & Widayanti (2023), who found that 94.45% of students in their study had low engagement, with a mean score of 69.7.

According to the first hypothesis, students' engagement significantly influences algebraic reasoning, as supported by the t-test result of 2.418, with a p-value of 0.017 (< 0.05). This finding is consistent with studies by Singh, Granville, & Dika (2002) and Sunawan, Dwistia, Kurniawan, Hartati, & Sofyan (2017), both of which found that student engagement positively impacts mathematics achievement. Additionally, this result is reinforced by Francis, Tan, & Chen (2018), who demonstrated that the three components of student engagement—cognitive, emotional, and social engagement—are individually related to students' mathematics achievement. Further support for this relationship comes from Zhang, Russell, & Kelly (2022), whose study, based on TIMSS and PISA data, confirmed the association between engagement and mathematics achievement.

Additionally, the findings of Bostwick, Collie, Martin, & Durksen (2020) highlighted a positive link between engagement and mathematics achievement through multilevel patch analysis. Similarly, Putwain, Symes, Nicholson, & Becker (2018) confirmed that behavioral engagement, in particular, is a predictor of mathematics achievement.

Based on the second hypothesis, students' self-regulated learning does not significantly impact algebraic reasoning, as supported by the t-test score of 0.425, with a p-value of 0.671 (> 0.05). This finding contrasts with previous studies that revealed self-regulated learning positively influences mathematics achievement (Ong'uti, Aloka, & Nyakinda, 2022; Wood, 2022; Nufus, Muhandaz, Hasanuddin, Nurdin, Ariawan, Fineldi, Hayati, & Situmorang, 2024) and specifically mathematics reasoning (de Blume & Montoya, 2023; Huang, Li, Wang, Pan, & Lajoie, 2023). However, this result aligns with Gunawan, Prawoto, & Sumarmo (2019), which indicated that students' reasoning was primarily influenced by cognitive level, with no significant effect from self-regulated learning. Additionally, Rosyada, Sari, Sukmaningthias, & Nuraeni (2024) suggested that while self-regulated learning is important, its impact on reasoning might vary based on individual cognitive levels. Losenno, Muis, Munzar, Denton, & Perry (2020) found that high-achieving students exhibited two key trends in employing self-regulated learning: (1) they engaged in task definition, planning, and goal setting before moving to enactment, followed by monitoring and evaluation, and (2) they tended to interrupt self-regulated learning when they encountered task ambiguities. These findings suggest that other factors, such as task clarity or cognitive strategies, might mediate the relationship between self-regulated learning and academic performance. Moreover, studies such as Guo, Lau, & Wei (2019) suggest that the level of academic achievement in a school may also play a role, with students in higher-achieving schools using more self-regulated learning strategies and showing greater motivation in mathematics than their peers in lower-achieving schools.

According to the third hypothesis, students' engagement and self-regulated learning together have a significant impact on algebraic reasoning, as supported by the F-test score of 3.117, with a p-value of 0.046 (< 0.05). This finding is consistent with previous studies indicating that both student engagement and self-regulated learning are positively correlated with mathematics achievement (Al Mutawah, Thomas, & Khine, 2017; Salma & Alsa, 2023). Furthermore, the study confirmed that these two factors together account for a 3% contribution to students' algebraic reasoning. This contribution is notably smaller than the 37.16% reported by Salma & Alsa (2023) for mathematics achievement. Despite this, the finding underscores the importance of both engagement and self-regulated learning in promoting academic success in algebraic reasoning.

Based on the findings of this study, it is evident that students' algebraic reasoning can be enhanced by fostering greater engagement and self-regulated learning. Positive student engagement provides a meaningful and motivating experience in mathematics learning. Teachers should consider using diverse teaching strategies to encourage active participation and engagement in the classroom. Additionally, incorporating discussion-based activities and assignments related to algebra can further promote both student engagement and self-regulated learning, ultimately improving students' mathematical reasoning skills.

As a recommendation, schools should prioritize enhancing students’ engagement and self-regulated learning, as these factors have been shown to positively influence algebraic reasoning and overall mathematics achievement. Mathematics teachers should implement learning strategies that engage students cognitively, affectively, and socially. Additionally, teachers should recognize and support students' self-regulated learning as a key factor in improving their academic performance. By fostering both engagement and self-regulation, educators can help students develop more robust mathematical reasoning skills.

Despite providing evidence of the effects of student engagement and self-regulated learning on algebraic reasoning, this study has several limitations. First, the participants were drawn from 8th-grade students in junior high school, which limits the generalizability of the findings to other grade levels or populations. Future studies should include participants from various educational levels—elementary, junior high, and senior high schools—to enhance the representativeness of the results. Second, although engagement was identified as a positive predictor, the study does not establish causal relationships. Future research should employ experimental or longitudinal designs to confirm causality between engagement, self-regulated learning, and algebraic reasoning. Lastly, the study did not account for students' initial abilities, which may have influenced the results. Future studies should consider including students' baseline abilities as a mediating variable in examining the factors that contribute to algebraic reasoning. This would provide a more comprehensive understanding of the relationships among these variables.

Conclusion

In the current study, both students' engagement and self-regulated learning were found to simultaneously play significant roles in students' algebraic reasoning. When considered separately, student engagement was identified as a positive predictor of algebraic reasoning. The positive regression coefficient for student engagement indicates that higher levels of engagement are associated with improved algebraic reasoning. Specifically, as students' engagement increases, their algebraic reasoning abilities tend to improve, suggesting a direct and beneficial relationship between the two.

In contrast, self-regulated learning showed a negative relationship with algebraic reasoning, suggesting that self-regulated learning did not have a significant positive impact on algebraic reasoning in this study. The negative regression coefficient for self-regulated learning implies that higher levels of self-regulated learning were associated with lower levels of algebraic reasoning. This counterintuitive result suggests that, in this context, self-regulated learning may not necessarily enhance students' algebraic reasoning. It is important to note that while lower levels of self-regulated learning were associated with higher levels of algebraic reasoning, this relationship warrants further investigation, as it may be influenced by other underlying factors or variables not accounted for in the current study.

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Ethical Statement

This research was conducted in accordance with ethical principles and guidelines to ensure the protection of participants' rights, safety, and welfare. All necessary permits and approvals were obtained prior to the commencement of the study. The ethical standards adhered to in this research align with both institutional and international ethical guidelines, ensuring the integrity and transparency of the research process.

CRediT Authorship Contribution Statement

- **Author 1:** Conceptualization, Methodology, Investigation, Writing
- **Author 2:** Formal Analysis, Data Curation, Visualization, Writing
- **Author 3:** Resources, Project administration
- **Author 4:** Review, editing, translating

Conflict of Interest

The authors declare that there are no competing financial interests or personal relationships that could have influenced the work reported in this article.

Data Availability

The datasets generated and analyzed during the current study are available upon reasonable request.

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