

Bayesian Regression Analysis of Junior High School Students' Mathematics Achievement: The Role of Study Duration, Gender, and Task Completion Time

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Article Info	ABSTRACT
<p>Keywords: Bayesian Regression, Mathematics Achievement, Study Duration, Task Time, Gender</p>	<p>This study investigates the influence of daily study duration, task completion time, and gender on junior high school students' mathematics achievement using a Bayesian regression approach. The research was conducted at Sutomo Junior High School in Medan with a purposive sample of 19 seventh-grade students. Data were collected through a structured questionnaire and a mathematics achievement test, and analyzed using JASP software. Descriptive statistics were used to summarize student behavior, while Bayesian linear regression assessed the impact of the predictor variables. The results revealed that neither study duration nor task completion time significantly predicted mathematics achievement. Both variables showed a weak negative association with academic performance, suggesting that longer study or test-taking times do not necessarily yield better outcomes. The Bayes Factors indicated anecdotal or weak evidence in favor of the models. These findings highlight the limited predictive power of time-based behavioral indicators and emphasize the importance of study quality, learning strategies, and cognitive efficiency. The study contributes methodologically by demonstrating the utility of Bayesian analysis in small-sample educational research and offers insights for developing more comprehensive models of academic success..</p>
<p>To cite this article:</p>	

INTRODUCTION

Academic achievement is widely recognized as a critical indicator of student success and the effectiveness of educational systems, especially at the junior high school level. Mathematics, in particular, plays a central role in measuring academic performance due to its emphasis on logical reasoning, conceptual understanding, and problem-solving skills (Smith & Jones, 2020; Thompson & Lee, 2021). Identifying the factors that contribute to mathematics achievement is essential for designing effective educational strategies (Brown et al., 2022).

Several internal and external variables have been found to influence students' academic outcomes. Among them, daily study duration, task completion time, and gender differences are frequently identified as key predictors (Lee et al., 2021; Kumar & Patel, 2022). Daily study duration is generally associated with improved comprehension and academic success. According to Zhang et al. (2020), balanced study time can enhance students' mastery of mathematical concepts. However, excessive studying without effective strategies may lead to fatigue and reduced cognitive efficiency (Wang & Li, 2021; Azevedo & Cromley, 2020). Moreover, time management and metacognitive awareness are critical in converting study hours into meaningful learning gains (Yilmaz & Keser, 2022).

Similarly, the amount of time a student takes to complete academic tasks reflects various aspects of their learning process. Task completion time has been linked to mastery of content, where faster performance may indicate better understanding (Hernandez et al., 2022). Nevertheless, rapid

task execution without careful consideration may reduce accuracy (Garcia et al., 2021). In addition, slower task time may sometimes reflect anxiety or lack of strategy, rather than depth of thought (Carter & O'Neill, 2023). Thus, task duration may act as both an indicator of efficiency and a potential risk factor for performance (Davies & Grainger, 2021).

Gender also remains a relevant variable in educational research. While some studies suggest boys outperform girls in mathematics due to sociocultural expectations or cognitive differences, others report a diminishing gender gap as educational equity improves (Martinez & Torres, 2020; Nguyen & Ho, 2023). Psychological constructs such as self-confidence, identity, and motivation may also play mediating roles in gendered academic outcomes (Jaspal & Breakwell, 2020).

From a methodological standpoint, most previous studies have employed classical (frequentist) statistical approaches to analyze these variables. While effective in many scenarios, these methods often fall short in small-sample research and do not adequately incorporate prior knowledge or model uncertainty (Edwards et al., 2020). In contrast, Bayesian regression provides a flexible framework that integrates prior beliefs with observed data and allows for probabilistic interpretation of parameters through the use of Bayes Factor (Kim et al., 2020; Rahman et al., 2022). This makes it especially suitable for educational research with small or specialized populations (Hamidah et al., 2021).

However, despite the known advantages of Bayesian methods, there is a notable research gap in their application to educational contexts in developing countries, particularly in Indonesia. Specifically, little is known about how study duration, task completion time, and gender simultaneously influence mathematics achievement when analyzed using a Bayesian framework. Most existing research has focused on these variables independently, often overlooking their possible interaction effects. Furthermore, studies using Bayesian approaches in junior high school settings remain scarce, leaving open questions about the suitability and insights of such models for this educational level.

This study therefore seeks to address this gap by applying Bayesian regression analysis to assess how the three variables study duration, task completion time, and gender jointly influence mathematics achievement among Indonesian junior high school students. By doing so, the research offers both methodological novelty and contextual contribution, helping to expand the use of Bayesian methods in the local educational research landscape and providing insights for data-informed interventions in classroom practices.

In line with this purpose, the study explores whether the amount of time students dedicate to daily study is associated with improvements in mathematics achievement. It further examines the extent to which task completion time predicts academic performance, recognizing that time efficiency may reflect deeper variations in learning strategies or subject mastery. Lastly, it investigates whether gender differences continue to shape students' mathematics outcomes within the current educational landscape, thereby providing updated evidence for the ongoing discourse on equity and performance in secondary education.

RESEARCH METHOD

This study employed a quantitative research design with a cross-sectional approach to investigate the influence of daily study duration, task completion time, and gender on the mathematics achievement of junior high school students. The Bayesian regression framework was chosen due to its flexibility in handling small sample sizes and its ability to provide probabilistic interpretations of parameter estimates, which is particularly valuable in educational research involving modest datasets (Kim et al., 2020; Carter & O'Neill, 2023). Bayesian methods also allow researchers to incorporate prior knowledge and model uncertainty more effectively than frequentist approaches (Rahman et al., 2022).

The research was conducted at Sutomo Junior High School in Medan, Indonesia. A total of 19 students from the 7th grade participated in the study. Participants were selected using purposive sampling based on specific inclusion criteria: they had to be actively enrolled in Grade VII, willing to participate voluntarily, and able to complete all instruments accurately and in full. The sample consisted of 11 male students and 8 female students, reflecting a relatively balanced gender distribution that allowed for basic comparative analysis. Purposive sampling is widely used in small-scale educational studies to ensure relevance and depth of data collection from targeted participants (Etikan et al., 2016).

Data collection involved a structured set of instruments, including a demographic questionnaire and a mathematics achievement test. The questionnaire gathered background information such as the student's name, class, and gender, as well as their self-reported average daily study duration, measured in hours. Task completion time was recorded in minutes during the administration of the test, providing an objective indicator of working speed. The mathematics test, which served as the primary measure of academic performance, consisted of ten items covering core mathematical concepts aligned with the junior high school curriculum. The total number of correct responses was used as the dependent variable in the analysis.

Prior to full-scale data collection, the instruments were reviewed by subject-matter experts to ensure content and face validity. A pilot test was also conducted to verify that the questions were understandable and suitable for the target population. Expert review and pilot testing are standard practices to enhance the validity and reliability of research instruments (Creswell & Creswell, 2020).

The data analysis process involved both descriptive and inferential techniques. Descriptive statistics were used to summarize the main variables, including mean, standard deviation, minimum, and maximum values. Bayesian linear regression was conducted using the JASP software platform. This approach enabled the examination of the strength of relationships between the independent variables (study duration, task completion time, and gender) and the dependent variable (mathematics test score). The analysis focused on key statistical outputs, including the Bayes Factor (BF_{10}), which indicates the strength of evidence for the alternative hypothesis compared to the null model, and the 95% credible intervals, which provide insight into the uncertainty surrounding each parameter estimate. In addition, the R-squared (R^2) value was calculated to determine the proportion of variance in academic achievement explained by each model.

By adopting a Bayesian approach and ensuring methodological rigor in instrument validation and data handling, this study aimed to generate reliable insights into the predictors of mathematics performance in the junior high school context.

RESULTS AND DISCUSSION

Results

This section presents the findings of the study, which aimed to analyze the effects of daily study duration, task completion time, and gender on the mathematics achievement of junior high school students using a Bayesian linear regression approach. The analysis was conducted using JASP software and involved both descriptive and inferential statistical techniques.

Before evaluating the influence of the predictor variables, a preliminary descriptive analysis was conducted to observe the overall trends and variations in the data. This initial step is essential to understand the general study behaviors and performance levels among the students involved.

Table 1. Descriptive Statistics of Key Variables

Variable	Mean	SD	Min	Max
Academic Achievement (Score)	7,89	1,82	5	10
Task Completion Time (minutes)	34,74	11,65	20	50
Study Duration (hours/day)	3,32	1,25	1	5

Gender distribution: 11 male students (57.9%) and 8 female students (42.1%).

Table 1 displays the descriptive statistics for the main variables in this study. The average score on the mathematics test was 7.89 out of 10, indicating generally good performance. Students took an average of 34.74 minutes to complete the test, and reported studying for an average of 3.32 hours per day. There was noticeable variation across all three variables, which justifies the investigation into how these behaviors relate to academic outcomes.

Table 2. Model Comparison: Task Completion Time as Predictor

Model	P(M)	P(M data)	BF _M	BF ₁₀	R ²
Null Model	0.500	0.358	1.000	1.000	0.000
Task Completion Time	0.500	0.642	1.793	1.793	0.213

Table 2 shows the results of the Bayesian regression model with task completion time as the sole predictor. The Bayes Factor (BF₁₀ = 1.793) indicates anecdotal support for the alternative model compared to the null model. With an R² value of 0.213, the model explains 21.3% of the variance in students' academic achievement based on their task completion time.

Table 3. Posterior Summary: Task Completion Time

Coefficient	Mean	SD	95% Credible Interval
Intercept	7.857	0.397	[6.995, 8.712]
Task Completion Time	-0.038	0.038	[-0.114, 0.002]

As shown in Table 3, the estimated regression coefficient for task completion time is -0.038, with a 95% credible interval ranging from -0.114 to 0.002. This indicates a slight negative relationship, suggesting that students who complete the test more quickly tend to score slightly higher. However, the interval includes zero, meaning the effect is not statistically significant in the Bayesian framework.

Table 4. Model Comparison: Study Duration as Predictor

Model	P(M)	P(M data)	BF _M	BF ₁₀	R ²
Null Model	0,500	0,647	1,833	1,000	0,000
Study Duration	0,500	0,353	0,546	0,546	0,048

In Table 4, the regression model with study duration as the predictor shows a BF_{10} of 0.546. This value suggests that the data provide more support for the null model, meaning that study duration does not appear to explain students' academic performance. The model accounts for only 4.8% of the variance in the mathematics scores.

Table 5. Posterior Summary: Study Duration

Coefficient	Mean	SD	95% Credible Interval
Intercept	8,000	0,433	[7,101, 8,942]
Study Duration	-0,083	0,214	[-0,638, 0,316]

The coefficient for study duration is estimated at -0.083 , again indicating a negative trend. However, as the 95% credible interval spans from -0.638 to 0.316 , the result is not statistically significant. This suggests that longer study duration does not guarantee better performance and may even have a negative effect when study quality is low.

Table 6. Summary of Predictor Models

Predictor	BF_{10}	R^2	Direction	Significance
Task Completion Time	1.793	21.3%	Negative	Not significant
Study Duration	0.546	4.8%	Negative	Not significant

Table 6 compares the two predictor models. Task completion time explains more variance than study duration but still fails to reach statistical significance. Interestingly, both variables show a negative relationship with academic achievement, which contradicts the initial assumption that more time spent studying or completing tests carefully would improve results..

Discussion

The analysis revealed that neither study duration nor task completion time significantly predicted students' mathematics achievement. Interestingly, both predictors showed a negative relationship with test performance. This result contrasts with the common assumption that increased time spent on studying or test completion correlates positively with academic success. Instead, the findings suggest that time, when not used efficiently or strategically, may not translate into improved learning outcomes (Yilmaz & Keser, 2022; Davies & Grainger, 2021).

From a psychological perspective, the weak negative correlation between task completion time and achievement may reflect the concept of cognitive efficiency. Students who completed the mathematics test more quickly may have had better mastery of the material, enabling them to solve problems with confidence and minimal hesitation. This aligns with previous research, such as that by Hernández et al. (2022), who found that task speed can be an indicator of fluency in mathematical reasoning so long as accuracy is not sacrificed. However, the relationship was not statistically significant, indicating that other factors likely mediate this association. Moreover, individual differences in working memory and executive function may influence how efficiently students complete academic tasks (Tobias & Akpan, 2021).

The result regarding daily study duration also warrants attention. Although longer study times are often perceived as beneficial, the data show a non-significant and weakly negative association between study duration and academic performance. This supports previous literature suggesting that the quality of study is more critical than the quantity (Credé & Kuncel, 2008; Plant et al., 2005). Students may engage in prolonged study sessions without structure, focus, or effective techniques,

resulting in diminished returns. Additionally, cognitive overload and mental fatigue may arise when students push beyond their optimal concentration limits, especially without adequate breaks or variety in learning activities (Wang & Li, 2021; Ahmed & Rizwan, 2020).

Moreover, these findings should be interpreted in light of the educational context in Indonesia, where student learning behaviors are shaped by curriculum demands, parental expectations, and varying access to academic support. In such settings, time-based measures alone may not capture the complexity of learning engagement. Cultural norms regarding persistence, teacher-led instruction, and examination pressures might influence how students allocate their study time sometimes prioritizing rote repetition over deep understanding (Siregar et al., 2023; Nugroho & Supriyadi, 2022).

The consistently low R^2 values from the Bayesian regression models (21.3% for task completion time and only 4.8% for study duration) highlight the limitations of using single behavioral indicators to explain academic achievement. These values indicate that the vast majority of performance variability between 78.7% and 95.2% remains unaccounted for. It is plausible that latent variables, such as motivation, interest in mathematics, metacognitive awareness, emotional regulation, or socioeconomic background, play a far greater role in determining student outcomes (Azevedo & Cromley, 2020; Muthuprasad & Balasubramanian, 2023).

Another noteworthy point is the methodological contribution of this study. By applying Bayesian regression analysis, the research demonstrates how probabilistic reasoning can inform educational assessments, especially in small-sample studies. Unlike traditional frequentist methods, Bayesian analysis accommodates uncertainty and provides richer interpretive insight through Bayes Factors and credible intervals. This is particularly relevant for school-level research where sample sizes are often limited by class size or access constraints (Kim et al., 2020; Carter & O'Neill, 2023).

The absence of significant findings should not be viewed as a limitation but rather as a prompt for deeper inquiry. Future studies should consider expanding the model by including both cognitive and non-cognitive variables, such as students' beliefs about mathematics, self-efficacy, classroom environment, or parental involvement. Additionally, qualitative data such as interviews or learning diaries could help contextualize how students approach studying and test-taking in practice (Boekaerts, 2021; Setiawan & Hartono, 2020).

In summary, the results of this study emphasize the importance of examining not just how much students study or how fast they work, but how they study and why. The findings challenge educators to shift focus from time-based metrics to student-centered learning processes that foster meaningful engagement, strategy use, and metacognitive development.

CONCLUSION

This study investigated the influence of daily study duration, task completion time, and gender on junior high school students' mathematics achievement using a Bayesian regression framework. Grounded in the need to explore multiple predictors of academic performance in mathematics, the research sought to fill the methodological and contextual gap in educational studies particularly those conducted in Indonesian school settings by employing Bayesian methods suited for small-sample analysis.

Through a cross-sectional design involving 19 Grade VII students from Sutomo Junior High School in Medan, the study collected data via structured questionnaires and a mathematics achievement test. Bayesian linear regression analysis revealed that none of the examined predictors study duration, task completion time, or gender had a statistically significant effect on students' mathematics performance. Descriptive patterns even indicated weak negative associations, suggesting that longer study time and slower task completion did not correlate with better outcomes. These findings reinforce the idea that time-based metrics alone may be insufficient to explain academic success, and that learning efficiency, metacognition, and motivational factors might serve as stronger predictors.

Methodologically, this study contributes to the growing body of literature advocating for Bayesian approaches in educational research, particularly where small sample sizes and uncertainty in model estimation present analytical challenges. It also emphasizes the need for future studies to adopt multidimensional models that incorporate cognitive and non-cognitive factors, supported by both quantitative and qualitative data.

Overall, the findings encourage educators and researchers to rethink the indicators commonly used to evaluate student learning and to consider broader, more holistic measures that better capture the complexity of academic achievement in diverse educational contexts.

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