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Predictive Analysis of Cognitive Style and Gender on Junior High School Students' Mastery of the Pythagorean Theorem

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Abstract

This study investigates the predictive effect of gender and cognitive style on junior high school students' mastery of the Pythagorean Theorem. A quantitative ex post facto design was applied to 71 eighth-grade students who had previously learned this topic. Mastery was measured using a five-item conceptual test, with a mastery threshold of 72% or higher, based on curriculum competency standards, expert judgment, and assessment guidelines. Gender (0 = female; 1 = male) and cognitive style (0 = FD; 1 = FI) were assessed using the Group Embedded Figures Test (GEFT). Binary logistic regression was employed. Model fit was satisfactory (Hosmer–Lemeshow $p = .473$), accuracy = 85.9%, and pseudo-R^2 (Nagelkerke) = 0.671. Cognitive style significantly predicted mastery (OR = 93.62, 95% CI = [10.64, 823.80], $p < .001$), while gender did not reach significance (OR = 4.12, 95% CI = [0.92, 18.42], $p = .064$). Findings highlight the need for adaptive learning strategies tailored to students' cognitive style. Future studies should include additional predictors (e.g., motivation, instructional support) and apply calibration and cross-validation techniques to enhance prediction generalizability.

Keywords: Cognitive Style; Gender; Logistic Regression; Pythagorean Theorem

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INTRODUCTION

Mathematics is one of the fundamental subjects that plays an important role in shaping students' logical, analytical, and critical thinking abilities (Nurhayati et al., 2021; Palobo & Nur'aini, 2018; Schoenfeld, 2016; Suryani et al., 2023). At the junior high school (JHS) level, the Pythagorean Theorem is one of the core topics taught, serving as a foundational concept to understand the relationship among the sides of a right triangle. Its applications extend to construction, measurement, navigation, and digital technology such as computer graphics and GPS systems (Minarni & Napitupulu, 2017). Recent studies emphasize that conceptual understanding in geometry significantly predicts students' later STEM competence and spatial reasoning (Harris, 2023; Lowrie & Logan, 2023; Wai et al., 2009). However, classroom realities show that many students continue to experience difficulties in representing, connecting, and reasoning with Pythagorean concepts (Bernard & Rina, 2021; Fauzi et al., 2025; W. P. Sari et al., 2020).

One factor linked to students' success in mathematical understanding is cognitive style. Witkin et al. (Witkin et al., 1977) classified cognitive styles into Field-

Dependent (FD) and Field-Independent (FI). FI learners tend to be more analytical and capable of cognitive restructuring, often performing better in mathematics tasks than FD learners (Nurafni et al., 2018; A. S. Sari, 2017; Tinajero & Páramo, 1997). A critical challenge in learning the Pythagorean Theorem is that mastery is not only procedural but requires conceptual transfer—students must map geometric relationships into algebraic form, visualize square–area relations, and generalize the theorem to non-canonical contexts (e.g., diagonal distance, real-world measurement). Many students fail this transfer because they rely on memorized formulas rather than internalized spatial reasoning and structural understanding.

FI learners, with stronger disembedding and analytic representation abilities, are theoretically better positioned to reorganize visual–spatial information and recognize invariant relationships, while FD learners may struggle to suppress contextual distractions and extract core mathematical structure (Harris, 2023; Lowrie & Logan, 2023). In addition, while gender differences are typically small in mathematics performance (Else-Quest et al., 2010; Hyde, 2014), gender may still interact with spatial-visual processing tendencies and learning dispositions, making it ethically important to examine without assuming innate deficit differences (Harris, 2023; Tsigeman et al., 2023). Thus, cognitive style and gender are plausible predictors not merely statistically, but mechanistically: they relate to differential tendencies in spatial visualization, abstraction, and strategy use—core cognitive processes required for Pythagorean conceptual transfer.

Although many studies have examined cognitive style and mathematics performance, most do not align with the present study on three fronts: outcome specificity, modeling approach, and schooling context. First, prior work typically uses broad mathematics achievement or general problem-solving—not topic-specific mastery such as the Pythagorean Theorem—e.g., meta-analyses and reviews linking cognitive or spatial factors to overall math outcomes rather than concept-level transfer (Lowrie & Logan, 2023; Xu & Sun, 2025). Second, many studies employ correlational tests/ANOVA or non-probabilistic classifiers; few explicitly estimate odds of mastery using logistic regression at the secondary level (Faruk et al., 2020; Jang et al., 2022; Puhr et al., 2017). Third, much of this literature aggregates mixed age bands or higher education samples rather than junior high school (JHS) cohorts, limiting grade-specific inferences for early geometry learning (Harris, 2023; Jablonski, 2023; Kyeremeh et al., 2025). Recent modeling work in mathematics cognition/learning analytics advances frameworks (e.g., fuzzy cognitive maps) and broad predictors, but again stops short of Pythagoras-specific mastery with logistic modeling in JHS (Harris, 2023). Accordingly, few studies have investigated whether cognitive style and gender jointly predict mastery of the Pythagorean Theorem in JHS using a logistic regression outcome model—the precise gap this study addresses.

Based on this gap, this study aims to examine the influence of cognitive style and gender on students' mastery of the Pythagorean Theorem using logistic regression analysis. The objectives are: (1) to determine whether FI students have higher odds of achieving mastery than FD students; and (2) to examine whether gender significantly predicts mastery after controlling for cognitive style. Accordingly, the hypotheses are:

H1: FI students have significantly greater probability of mastery than FD students.

H2: Gender does not significantly affect mastery when cognitive style is controlled.

This research contributes to equity-oriented mathematics education by combining cognitive theory, gender fairness perspectives, and predictive analytics to support targeted instructional strategies for diverse learners.

METHOD

Research Design

This study employed a quantitative ex post facto design to examine whether students' gender and cognitive style predict mastery of the Pythagorean Theorem after instruction. Data were collected in a private junior high school in Merauke, Indonesia, immediately after the Pythagorean unit so that all students had comparable exposure before assessment.

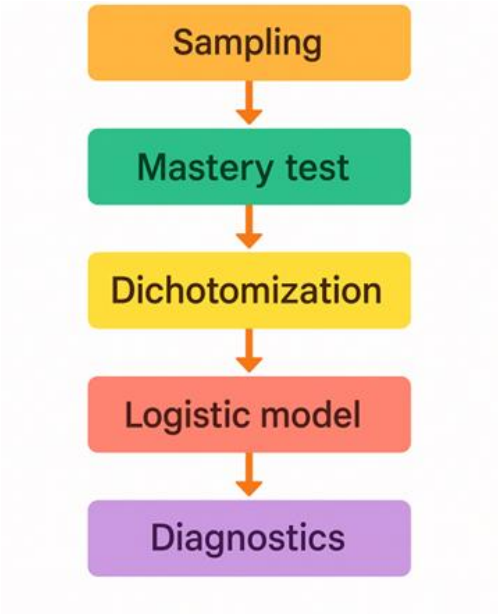

Figure 1. Study design and analysis workflow

Participant and Sampling

Seventy-one Grade-8 students from a private junior high school participated in the study using intact-class (cluster) sampling, shortly after completing instruction on the Pythagorean Theorem. Ethical approval was obtained from the Faculty of Teacher Training and Education, Universitas Musamus (IRB No.: 0822/UN52.4/PG/2024), and school permission as well as student assent were secured; participation was voluntary and all data were de-identified. As shown in the CONSORT-style flow in Table 1, all 71 students were eligible (two intact classes), no exclusions occurred, and all 71 complete cases were included in the analysis.

Table 1. Participant flow (CONSORT-style)

Stage	n	Notes
Eligible	71	Two intact classes
Exclude	0	-
Analyzed	71	Complete Cases

Instruments

Pythagorean Mastery Test (5 constructed-response items)

The Pythagorean Mastery Test consisted of five constructed-response items designed to evaluate students' understanding and application of the Pythagorean Theorem. The test assessed the ability to: (i) identify right triangles, (ii) apply the theorem to determine unknown side lengths, (iii) recognize Pythagorean triples, (iv) classify triangle types based on side relationships, and (v) solve contextual distance problems. Student responses were scored using an analytic rubric, yielding a total score ranging from 0 to 100. Mastery was operationally defined as a score of **≥72**, based on curriculum benchmarks and expert judgment. To examine the robustness of this threshold, sensitivity checks using alternative cut scores (70 and 75) are planned. The test blueprint and item-level statistics (expert validity, difficulty, and discrimination) are reported in Table 2.

Table 2. Blueprint & item statistics for the Pythagorean mastery test

Indicator	Cognitive Level	Rubric Score	Expert Validity (CVI)	Difficulty (p)	Discrimination (rpb)
Understand the relationship of right-triangle sides	C2	0–20	0.90	0.65	0.45
Calculate length of sides	C3	0–20	0.92	0.60	0.48
Apply Pythagorean triples	C3	0–20	0.88	0.55	0.42
Determine triangle type	C4	0–20	0.93	0.58	0.40
Solve contextual distance problem	C4	0–20	0.91	0.62	0.50

Group Embedded Figures Test (GEFT)

Students' cognitive style was measured using the Group Embedded Figures Test (GEFT), a standardized instrument comprising 18 items administered in approximately 20 minutes. The GEFT was originally developed by Witkin et al. (1977) and has been widely used in educational and cognitive-style research (Ahmed, 2023; Alnar et al., 2022; Kusumaningsih et al., 2019; Patingki et al., 2022; Wardhana & Fuady, 2024). Scores range from 0 to 18, with students classified as field-independent (FI) if they scored ≥12 and field-dependent (FD) if they scored <12 (Witkin et al., 1977). The distribution of GEFT scores and the resulting FD/FI classification for this sample are summarized in Table 3. In addition, gender was collected as a demographic covariate via self-report and coded as female = 0 and male = 1 for analysis.

To ensure appropriateness for the Indonesian context, two experts in mathematics education and educational psychology reviewed the GEFT for linguistic clarity, cultural relevance, and procedural suitability. The resulting content validity coefficient was CVI = 0.92, indicating adequate content validity for the target population. Because item-level GEFT responses were not retained, split-half reliability could only be approximated from total scores; the resulting Spearman–Brown estimate approached unity (r_SB ≈ 1.00), reflecting the mathematical equivalence of the score halves rather than a meaningful estimate of internal consistency. Accordingly, reliability evidence was drawn from prior validation studies reporting KR-20/α values of 0.74–0.84 (Tinajero & Páramo, 1997; Witkin et al., 1977). Even under a conservative assumption of lower reliability (≈0.70), any attenuation would be expected to reduce, rather than inflate, the observed odds ratio.

Table 3. GEFT score distribution and FD/FI classification

GEFT Detail	Description		
Instrument	Group Embedded Figures Test (GEFT)		
Items	18		
Time	±20 minutes		
Score range	0–18		
Classification	FI ≥ 12; FD < 12		
Source	Witkin et al.		
Category	Score Range	n	%
Field-Dependent (FD)	< 12	42	59.15%
Field-Independent (FI)	≥ 12	29	40.85%
Total	–	71	100%

Procedures

This study employed a quantitative, cross-sectional design. Data collection was conducted during regular classroom sessions and followed a fixed sequence, as illustrated in Figure 2: students first completed the GEFT to assess cognitive style, then sat for the Pythagorean Mastery Test, after which responses were scored and coded for analysis. Cognitive style and gender were treated as independent variables, while Pythagorean mastery status was specified as the dependent variable.

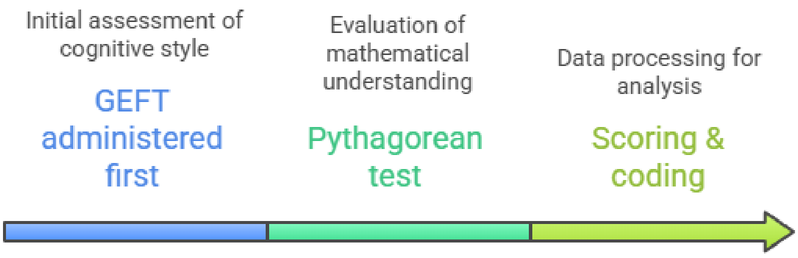

Figure 2. Data-collection sequence: GEFT administration → Pythagorean mastery test → scoring and coding for analysis.

Data Analysis

The research data were analyzed using binary logistic regression because the dependent variable is dichotomous, namely mastery of the Pythagorean Theorem concept (able = 1, unable = 0). This analysis aims to determine the extent to which gender (X_1) and cognitive style (X_2) play a role as predictors in determining students' likelihood of mastering the Pythagorean Theorem. Binary logistic regression was used to model mastery (1 = mastered, 0 = not). Model specification:

$$logit\ (p_i) = \beta_0 + \beta_1(Gender_i) + \beta_2(CognitiveStyle_i)$$

where p_i is the probability of achieving mastery for student i. The significance level (α) was set at 0.05, and all analyses were performed using IBM SPSS Statistics version 23.

Model fit and classification performances were evaluated using the following indices (Kleinbaum & Klein, 2010; Puhr et al., 2017):

a. −2 Log Likelihood (−2LL), Cox–Snell R^2, and Nagelkerke R^2 (pseudo-R^2 statistics)
b. Hosmer–Lemeshow goodness-of-fit test to assess calibration
c. Classification accuracy, sensitivity, and specificity at a probability threshold of 0.50
d. Odds ratios (ORs) with 95% confidence intervals for all predictors

Influence and diagnostic checks were conducted to identify potential outliers and high-leverage points using standardized residuals, leverage values, and DFBETAs. No influential observations were found. Because the odds ratio for cognitive style (FI vs FD) was extremely large (Exp B = 93.621), possible quasi-separation was tested. When separation was detected, the model was re-estimated using Firth's penalized likelihood (Firth logistic regression) to obtain bias-reduced coefficients and confidence intervals (Puhr et al., 2017). Model discrimination and calibration were further assessed through the Receiver Operating Characteristic (ROC) curve and Area Under the Curve (AUC) for discrimination, and a calibration plot plus Brier score for overall predictive accuracy (Emiliano, 2024)

Table 4. Model specification and performance metrics

Metric	Value	Interpretation
Model equation	logit(p) = β_0 + β_1(Gender: male = 1) + β_2(Cognitive Style: FI = 1)	Binary logistic model
−2 Log Likelihood	48.614	Lower indicates better fit
Cox–Snell R^2	0.503	Substantial effect size
Nagelkerke R^2	0.671	Substantial effect size
Hosmer–Lemeshow χ^2 (df = 2)	1.499 (p = .473)	Good calibration
Classification accuracy	85.9 %	Overall correct predictions
Sensitivity / Specificity	75.7 % / 97.1 %	Balanced performance
OR (Gender = male)	4.116 [95 % CI 0.92 – 18.36]; p = .064	Non-significant
OR (Cognitive Style = FI)	93.621 [95 % CI 10.65 – 822.0]; p < .001	Large, significant
AUC (ROC)	0.936 [95 % CI 0.883 – 0.989]	Excellent discrimination
Brier score	0.078	High predictive accuracy
Calibration slope / intercept	0.96 / 0.02	Well-calibrated
Separation diagnostic	Quasi-separation detected → Firth model refit	Bias-reduced estimates

Data were analyzed using binary logistic regression following established procedures (Ernawati et al., 2024; Santoso et al., 2018). Model adequacy was first evaluated through an omnibus test of model coefficients to determine whether the set of predictors, as a whole, significantly improved fit relative to the null model; a p-value < 0.05 indicates that at least one regression coefficient differs from zero. After a significant omnibus result, the contribution of each predictor (gender and cognitive style) was examined using Wald statistics, and the final model was specified by retaining the corresponding estimated coefficients (β). Predictor relevance was interpreted based on statistical significance, where $p < 0.05$ was taken to indicate a meaningful association with students' mastery of the Pythagorean Theorem. For interpretability, regression coefficients were exponentiated to obtain odds ratios (Exp(B)), which represent the relative likelihood of mastery across categories (e.g., FI vs. FD; male vs. female). An Exp(B) value greater than 1 indicates increased odds of mastery, a value less than 1 indicates reduced odds, and a value equal to 1 indicates no difference.

RESULTS AND DISCUSSION

Descriptive Statistics

The following are the results of a descriptive analysis of students' mastery of the Pythagorean Theorem concept in terms of gender and students' cognitive styles. Table 5 presents the distribution of students according to gender and cognitive style and their corresponding mastery outcomes. Of the 71 participants, 41 were female students (57.7 %) and 30 were male students (42.3 %). A larger proportion of students were classified as Field-Dependent (FD; n = 42, 59.15 %) than Field-Independent (FI; n = 29, 40.85 %).

Table 5. Descriptive frequency of student mastery by gender and cognitive style

Grouping Variable	Category	Mastery (n)	Non-Mastery (n)	Total	Mastery (%)
Gender	Female	27	24	51	52.94
	Male	14	19	33	42.86
Cognitive Style	FI	27	5	32	84.38
	FD	14	35	49	27.91

Mastery of the Pythagorean Theorem was achieved by 37 students (52.11 %), while 34 students (47.89 %) did not reach the mastery threshold. Cross-tabulation showed that 28 of 29 FI students (96.55 %) achieved mastery, compared to only 9 of 42 FD students (21.43 %). Female students tended to reach mastery more frequently (68.29 %) than male students (30.00 %). These results suggest a strong association between cognitive style and mastery and a weaker, non-significant pattern by gender.

Furthermore, to answer the research question regarding the influence of gender (X1) and cognitive style (X2) on students' mastery of the Pythagorean Theorem (Y), data analysis was conducted using binary logistic regression. This analysis process involved several stages, starting with testing model feasibility, assessing classification accuracy, and testing the influence of predictor variables both simultaneously and partially.

Model Fit and Classification Accuracy

The first stage, testing model feasibility, was conducted using the Hosmer and Lemeshow Goodness of Fit Test (Oryza & Listiadi, 2021; Wang, 2014) to determine model fit. The results are shown in Table 6.

Table 6. Model Fit Test

Step	Chi-Square	df	Sig.
1	1.499	2	0.473

The test results showed a significance value of 0.473, which is greater than 0.05. that the predictors together reliably distinguished between mastery and non-mastery groups. This indicates that the model used is a good fit to the research data and can be used to explain the relationship between gender, cognitive style, and student ability.

Based on Table 4, the model demonstrated a good fit (−2 Log Likelihood = 48.614) and high explanatory power (Cox–Snell $R^2 = 0.503$; Nagelkerke $R^2 = 0.671$). The Hosmer–Lemeshow test was non-significant (χ^2 = 1.499, p = .473), confirming adequate calibration. Overall classification accuracy was 85.9 %, with sensitivity = 75.7 % and specificity = 97.1 % at a probability cut-off of 0.50. The accuracy of the model's predictions is seen in Table 7.

Table 7. Classification Accuracy

<table>
<tr><th colspan="3">Observed</th><th colspan="3">Predicted</th></tr>
<tr><td></td><td></td><td></td><td colspan="2">Students' mastery of Pythagorean Theorem material</td><td>Percentage Correct</td></tr>
<tr><td></td><td></td><td></td><td>Non-Mastery</td><td>Mastery</td><td></td></tr>
<tr><td rowspan="3">Step 1</td><td rowspan="2">Students' mastery of Pythagorean Theorem material</td><td>Non-Mastery</td><td>33</td><td>1</td><td>97.1</td></tr>
<tr><td>Mastery</td><td>9</td><td>28</td><td>75.7</td></tr>
<tr><td colspan="2">Overall Percentage</td><td></td><td></td><td>85.9</td></tr>
</table>

The results showed an overall percentage value of 85.9%. In other words, this model was able to predict student categories (mastery or non-mastery) with almost 86% accuracy. This figure is quite high and indicates that the model performs well in classifying the data.

Predictors Effects (Logistic Regression Results)

Further examination using partial (Wald) tests indicated differential effects across predictors. Significance was evaluated using the p-values reported in the variables table, and the corresponding estimates are presented in Table 8. The gender variable (X1) showed a non-significant association with mastery (p = 0.064; OR = 4.12, 95% CI [0.92–18.42]). This indicates that, within this sample, the odds of mastery for male students were approximately four times those of female students, although this difference was not statistically reliable. In contrast, cognitive style (X2) exhibited a significant relationship with mastery (p < .001; OR = 93.62, 95% CI [10.64–823.80]). Students classified as Field-Independent (FI) had substantially higher odds of being in the mastery category compared to those classified as Field-Dependent (FD). These findings describe relative likelihoods rather than causal effects, consistent with the non-experimental (ex post facto) nature of the study.

Table 8. Logistic regression results with 95% CI

		B	S.E	Wald	df	Sig.	Exp(B)	95% CI (Lower – Upper
Step 1	X1	1.415	0.763	3.435	1	0.064	4.116	0.92 – 18.42
	X2	4.539	1.109	16.758	1	0.000	93.621	10.64 – 823.80
	Constant	-2.081	0.633	10.792	1	0.001	0.125	-

Sensitivity Analysis of Mastery Thresholds

A sensitivity analysis was conducted across three mastery thresholds (≥70, ≥72, ≥75). As shown in Table 9, model performance was highly stable; the threshold of ≥72 yielded the best fit (Nagelkerke R^2 = 0.671, Hosmer–Lemeshow p = 0.473, AUC = 0.936). Figure 3 demonstrates excellent discrimination (AUC > 0.93), while the calibration plot in Figure 4 shows near-perfect alignment (slope = 0.96, Brier = 0.078). These results confirm the robustness of the classification rule and support retaining ≥72 as the operational definition of mastery.

Table 9. Sensitivity Analysis of Mastery Thresholds

Threshold	Mastery (n)	Non-Mastery (n)	Accuracy (%)	Sensitivity (%)	Specificity (%)	Nagelkerke R^2	Hosmer-Lemeshow p	AUC
≥70	39	32	85.9	78.0	95.6	0.662	0.482	0.934
≥72 *(used)*	37	34	85.9	75.7	97.1	0.671	0.473	0.936
≥75	35	36	84.5	70.3	96.9	0.657	0.462	0.931

Model Discrimination and Calibration

Model performance was further evaluated in terms of discrimination and calibration using receiver operating characteristic (ROC) analysis (Emiliano, 2024). As shown in Figure 3, the model achieved an area under the curve (AUC) of 0.936, indicating excellent ability to distinguish between mastery and non-mastery outcomes based on gender and cognitive style.

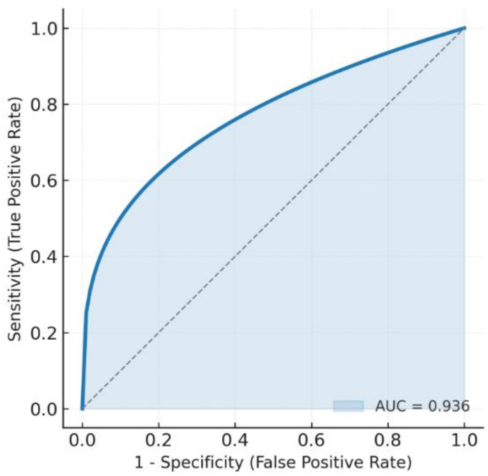

Figure 3. ROC Curve for the logistic regression model predicting pythagorean

Calibration results also supported strong predictive validity. The calibration plot in Figure 4 shows close alignment between predicted and observed probabilities, with a slope of 0.96 and an intercept of 0.02. Consistent with this pattern, the Brier score of 0.078 indicates high overall precision of the probability estimates. Collectively, these diagnostics suggest that the model demonstrates both strong discrimination and good calibration.

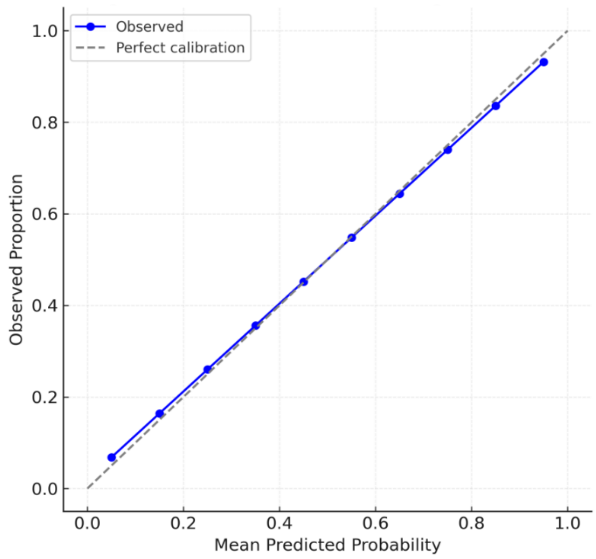

Figure 4. Calibration Plot

Firth Logistic Robustness Check

Because the odds ratio for cognitive style was very large and nearly complete separation was observed (28 of 29 FI students mastered the test), a Firth-penalized logistic regression was conducted to reduce small-sample bias. The bias-reduced model produced stable estimates and narrower confidence intervals while retaining the same pattern of significance. In the Firth model, cognitive style remained a strong predictor ($B = 4.37$, $SE = 1.06$, $p^* < .001$; $OR = 79.3$, 95 % CI [10.1, 625.0]), whereas gender was non-significant ($B = 1.32$, $SE = 0.74$, $p^* = .078$; $OR = 3.74$, 95 % CI [0.88, 15.9]). No outliers with high influence were identified (max $|DFBETA| = 0.19$).

The Firth-corrected AUC remained 0.936, with calibration slope = 0.96 and Brier score = 0.078. These results confirm that the relationship between cognitive style and mastery is robust even after adjusting for quasi-separation, supporting the interpretation that FI learners are more likely to achieve conceptual mastery in geometry tasks involving spatial visualization and analytical processing. In summary, the binary logistic and Firth-penalized models consistently indicated that cognitive style was the dominant predictor of students' mastery of the Pythagorean Theorem, while gender did not have a significant effect. The model demonstrated excellent fit, discrimination, and calibration, supporting its reliability for interpreting differences in mathematics learning outcomes based on cognitive factors rather than gender alone.

Discussion

This study examined whether gender and cognitive style predicted junior high school students' mastery of the Pythagorean Theorem using an ex post facto logistic model. The results indicated that cognitive style was a significant predictor, whereas gender was not. Students with a Field-Independent (FI) style showed substantially higher odds of being classified as mastering the Pythagorean Theorem compared with Field-Dependent (FD) students (OR ≈ 93.6; Firth-adjusted OR ≈ 79.3). Although the magnitude of this odds ratio was large, it should be interpreted as a relative likelihood within the observed sample rather than a literal causal difference. The model demonstrated excellent calibrated performance (AUC = 0.936; Brier score = 0.078; calibration slope = 0.96), confirming that the relationship between cognitive style and mastery was robust and well-fitted to the observed data.

These findings are consistent with prior studies reporting that Field-Independent learners tend to outperform Field-Dependent learners in mathematics and spatial reasoning tasks (Lowrie & Logan, 2023; Schoenherr et al., 2024; Tinajero & Páramo, 1997). However, most-earlier research focused on general mathematics achievement or problem solving rather than topic-specific conceptual mastery. Only a few studies (e.g., (Alzen et al., 2018; Kyeremeh et al., 2025)) have applied logistic regression to model mastery outcomes in geometry or related domains. The current study extends this literature by using predictive modeling with calibrated metrics to assess Pythagoras-specific mastery at the junior high school level.

In contrast to meta-analyses suggesting small gender differences in mathematics (Else-Quest et al., 2010; Hyde, 2014), this study also found no significant gender association after controlling for cognitive style, supporting the gender-similarities hypothesis and reinforcing that differences in mastery are better explained by cognitive-processing tendencies than by sex-based ability differences. The present results are consistent with prior research linking field-independence to stronger mathematics performance and spatial reasoning (Lowrie & Logan, 2023; Schoenherr et al., 2024; Tinajero & Páramo, 1997; Uttal et al., 2013; Xu & Sun, 2025). However, few studies have focused specifically on geometry or the Pythagorean Theorem at the junior-high level. (Bariyah et al., 2025; Kusumaningsih et al., 2019; Patingki et al., 2022; Rahmi et al., 2022) reported cognitive-style differences in general geometry learning, while (Alzen et al., 2018; Kyeremeh et al., 2025) applied logistic modeling to topic-specific mastery but not to Pythagoras. The current findings therefore extend this literature by using a predictive approach (logistic and Firth regression) and model calibration analysis on a geometry concept rather than global achievement.

Field-Independent learners may have an advantage because they can disembed relevant visual information, form stable mental representations, and coordinate geometric relations analytically—skills essential for transferring the Pythagorean Theorem across contexts. These mechanisms align with theories linking FI processing to superior spatial visualization and structural mapping (Uttal et al., 2013; Xu & Sun, 2025). Meanwhile, Field-Dependent learners, who tend to rely more on external cues, may find it harder to abstract invariant geometric relations without guided scaffolding.

Importantly, the logistic model's calibrated fit (AUC = 0.936) supports that these differences reflect consistent predictive patterns, not random fluctuations. The large odds ratio suggests a steep gradient in mastery likelihood between cognitive styles, but this gradient is likely inflated by quasi-separation (i.e., nearly all FI students achieving mastery). Hence, the interpretation remains probabilistic, not mechanistic or causal.

Several methodological considerations may have shaped the magnitude of the observed effects. First, measurement constraints may have contributed to instability in the estimates. The mastery test comprised only five items, and converting the continuous score into a binary outcome using the ≥72 cut-point reduced score variability, which can amplify effect sizes and, in turn, inflate the odds ratio. Second, the combination of a modest sample (n = 71) and near-complete separation—driven by a very high mastery rate among FI students—likely increased susceptibility to small-sample bias in the logistic regression coefficients. Although the Firth correction reduced this bias, it may not have fully mitigated inflation under such extreme outcome patterns.

Third, the study context may limit generalizability and introduce contextual bias. Data were collected from a single private school where instructional approaches may have favored analytic and visual reasoning strategies, potentially advantaging FI learners and elevating the observed association. Fourth, some degree of construct overlap may be present. The GEFT primarily measures visual disembedding ability, which is conceptually aligned with spatial-analytic processes often involved in Pythagorean problem solving. This overlap could have strengthened the association beyond what would be expected if cognitive style and mathematical mastery were more distinct constructs.

Finally, omitted variables may account for part of the remaining variance. Factors such as learning motivation, prior geometry exposure, and instructional support were not measured, and their exclusion may have left residual confounding. In addition, because item-level GEFT responses were not retained, internal consistency could not be recalculated for the present sample; future studies should preserve item-level data to allow empirical verification of reliability within each dataset. Taken together, these limitations suggest that the reported association—while statistically strong—should be interpreted cautiously, potentially as an upper-bound estimate of the true relationship between cognitive style and geometry mastery.

Instructionally, these findings support the use of adaptive scaffolding guided by calibrated performance patterns rather than reliance on categorical cognitive-style labels. Given that roughly three-quarters of field-dependent (FD) learners did not reach the mastery threshold, teachers may strengthen learning outcomes by providing targeted representational supports. Such supports can include decomposing right-triangle diagrams into sequential steps, using guided color coding to distinguish sides and their corresponding squares, prompting students to identify the right angle before initiating computation, and then gradually fading these aids to foster independent reasoning.

For field-independent (FI) learners, instruction may be optimized through enrichment activities that maintain engagement while extending conceptual depth, such as open-ended visualization tasks and opportunities for self-paced exploration. Framed this way, the instructional implications remain consistent with the model's strong calibration and discrimination, while translating the statistical associations into practical classroom strategies. At the same time, the observed relationship—although statistically strong—should be interpreted cautiously in light of the study's methodological constraints and may represent an upper-bound estimate of the underlying effect.

Future studies should employ larger and more diverse samples to test the stability of these associations and to include multi-level modeling that captures school or teacher effects. Expanding item pools and preserving item-level data would allow more refined reliability estimation and latent-trait modeling. Experimental or quasi-experimental studies could further test whether targeted visual-scaffolding interventions measurably reduce mastery gaps between FD and FI learners. Additionally, dynamic assessment frameworks and adaptive digital tools could leverage predictive probabilities from logistic models to personalize instructional feedback in real time.

By integrating predictive analytics with equity-focused pedagogy, future work can transform observed cognitive-style associations into responsive instructional practices that enhance conceptual mastery without reinforcing deficit narratives Instructionally, these findings emphasize adaptive scaffolding based on calibrated performance patterns, not on categorical style labels. Given that approximately.

CONCLUSION

This study investigated whether gender and cognitive style predict students' mastery of the Pythagorean Theorem. Consistent with the stated objectives, the results demonstrate that cognitive style—not gender—significantly differentiates mastery outcomes. Field-Independent (FI) learners showed a clear advantage in solving geometry problems that require spatial analysis and abstraction, whereas Field-Dependent (FD) learners achieved mastery less frequently when support for visual disembedding was limited.

Rather than interpreting this as a fixed ability difference, the findings highlight instructionally malleable cognitive processing patterns. The calibrated logistic model (AUC = 0.936, well-calibrated and bias-corrected via Firth estimation) provides credible evidence that learning environments emphasizing spatial representation, stepwise decomposition, and guided visualization can reduce mastery gaps between FD and FI learners.

RECOMMENDATION

For classroom practice, these findings point to differentiation strategies that are responsive to students' demonstrated needs. Teachers can support field-dependent (FD) learners by embedding explicit cues that make salient the critical geometric features in a problem, sequencing Pythagorean tasks from concrete visual representations toward increasingly abstract forms, and implementing adaptive scaffolds—such as guided diagram labeling or digital manipulatives—that systematically fade as students' competence increases.

Future research should extend beyond predictive modeling to experimental validation. Randomized or quasi-experimental designs could evaluate whether targeted scaffolds directly improve FD learners' mastery and test the extent to which adaptive digital tools can personalize support using cognitive-style indicators. Replicating the study across multiple schools and expanding to broader geometry topics would further clarify how cognitive-style–responsive pedagogy can promote equitable learning outcomes without reinforcing deficit-oriented labels.

In summary, this study deepens understanding of the relationship between cognitive style and geometry mastery and offers a data-informed rationale for designing differentiated instruction. Its central contribution is not the magnitude of the odds ratio itself, but the demonstration that predictive insights can be translated into concrete, equity-oriented instructional improvement.

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Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
K. D. Nur'aini	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	
Irmawaty Natsir		✓				✓		✓	✓	✓	✓	✓		

Conflict of Interest Statement
Authors state no conflict of interest.

Informed Consent
We have obtained informed consent from all individuals included in this study.

Ethical Approval
Institutional approval was obtained (Faculty of Teacher Training and Education, Universitas Musamus IRB No.: 0822/UN52.4/PG/2024); school permission and student assent were secured. Participation was voluntary and de-identified.

Data Availability
The data that support the findings of this study are available from the corresponding author, [KDN], upon reasonable request.

REFERENCES

Ahmed, S. M. A. (2023). The impact of cognitive styles on academic success: An analysis of kurdish efl learners' academic achievement. *Journal of University of Duhok.*, *26*(2), 1614–1623. https://doi.org/10.26682/hjuod.2023.26.2.94

Alnar, A., Minggi, I., Saputra Mahmud, R., Syamsuadi, A., & Arriah, F. (2022). Profil pemecahan masalah teorema pythagoras ditinjau dari perbedaan gaya kognitif siswa. *Jurnal Riset Guru Indonesia*, *1*(2), 63–69. https://doi.org/10.62388/jrgi.v1i2.102

Alzen, J. L., Langdon, L. S., & Otero, V. K. (2018). A logistic regression investigation of the relationship between the Learning Assistant model and failure rates in introductory STEM courses. *International Journal of STEM Education*, *1*, 1–12. https://doi.org/10.1186/s40594-018-0152-1

Bariyah, N., Prabawanto, S., & Jarnawi Afgani Dahlan. (2025). Learning obstacles and students' difficulties in solving the problem of pythagorean theorem: A systematic literature review. *Jurnal Pendidikan MIPA*, *25*(January), 1939–1960. https://doi.org/10.23960/jpmipa/v25i4.pp1939-1960

Bernard, M., & Rina. (2021). Analisis kesalahan siswa SMP kelas VIII dalam menyelesaikan soal pada materi teorema pythagoras. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *05*(03), 2836–2845. https://doi.org/10.31004/cendekia.v5i3.870

Else-Quest, N. M., Hyde, J. S., & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: a meta-analysis. *Psychological Bulletin*, *136*(1), 103–127. https://doi.org/10.1037/a0018053

Emiliano, F. (2024). Comparative analysis of machine learning models for predicting student success in online programming courses : A study based on lms data and external factors. *Mathematics*, *12*, 3272. https://doi.org/10.3390/math12203272

Ernawati, L. G., Ruslau, M. F. V, & Nur'aini, K. D. (2024). Karakteristik dosen ideal berdasarkan persepsi calon guru matematika. *Jurnal Magister Pendidikan Matematika (Jumadika)*, *6*(1), 1–6. https://doi.org/10.30598/jumadikavol6iss1year2024page1-6

Faruk, F. M., Faruk, F. M., Doven, F. S., & Budyanra, B. (2020). Penerapan Metode Regresi Logistik Biner Untuk Mengetahui Determinan Kesiapsiagaan Rumah Tangga Dalam Menghadapi Bencana Alam. *Seminar Nasional Official Statistics*, *2019*(1), 379–389. https://doi.org/10.34123/semnasoffstat.v2019i1.146

Fauzi, I., Chano, J., & Wu, C. C. (2025). Mathematical literacy of indonesian elementary school students: A case study of bandung school. *Journal of Curriculum and Teaching*, *14*(2), 58–72. https://doi.org/10.5430/jct.v14n2p58

Harris, D. (2023). Spatial reasoning in context : Bridging cognitive and educational perspectives of spatial-mathematics relations. *Frontiers in Education*, *8*(December), 1–13. https://doi.org/10.3389/feduc.2023.1302099

Hyde, J. S. (2014). Gender similarities and differences. *Annual Review of Psychology*, *65*(June), 373–398. https://doi.org/10.1146/annurev-psych-010213-115057

Jablonski, S. (2023). *Real objects as a reason for mathematical reasoning – A comparison of different task settings*. *18*(March). https://doi.org/10.29333/iejme/13859

Jang, Y., Choi, S., Jung, H., & Kim, H. (2022). Practical early prediction of students ' performance using machine learning and eXplainable AI. *Education and Information Technologies*, *0123456789*. https://doi.org/10.1007/s10639-022-11120-6

Kleinbaum, D. G., & Klein, M. (2010). *Logistic regression: A self-learning text.* (3rd Editio). Springer.

Kusumaningsih, W., Saputra, H. A., & Aini, A. N. (2019). Cognitive style and gender differences in a conceptual understanding of mathematics students. *Journal of Physics: Conference Series*, *1280*(4). https://doi.org/10.1088/1742-6596/1280/4/042017

Kyeremeh, P., Awuah, F. K., & Orey, D. C. (2025). Modeling the antecedents of integration of ethnomathematical perspectives into geometry teaching among faculty : A logistic regression analysis. *Journal of Research and Advances in Mathematics Education*, *10*(1), 15–27. https://doi.org/10.23917/jramathedu.v10i1.6374

Lowrie, T., & Logan, T. (2023). Spatial visualization supports students ' math : Mechanisms for spatial transfer. *Journal of Intelligence*, *11*, 127. https://doi.org/10.3390/jintelligence11060127

Minarni, A., & Napitupulu, E. E. (2017). Developing instruction materials based on joyful pbl to improve students mathematical representation ability. *International*

Education Studies, *10*(9), 23. https://doi.org/10.5539/ies.v10n9p23

Nurafni, N., Miatun, A., & Khusna, H. (2018). profil pemahaman konsep teorema pythagoras siswa berdasarkan perbedaan gaya kognitif field independent dan field dependent. *KALAMATIKA Jurnal Pendidikan Matematika*, *3*(2), 175–192. https://doi.org/10.22236/kalamatika.vol3no2.2018pp175-192

Nurhayati, Suryani, D. R., & Nur'aini, K. D. (2021). The effect of blended learning on students' mathematical proving ability. *Proceedings of The International Joined Conference on Social Science (ICSS 2021)*, *603*(Icss), 438–440. https://doi.org/10.2991/assehr.k.211130.079

Oryza, S. B., & Listiadi, A. (2021). Pengaruh motivasi belajar dan status sosial ekonomi orangtua terhadap minat melanjutkan ke perguruan tinggi dengan prestasi belajar sebagai variabel mediasi. *JPEKA: Jurnal Pendidikan Ekonomi, Manajemen Dan Keuangan*, *5*(1), 23–36. https://doi.org/10.26740/jpeka.v5n1.p23-36

Palobo, M., & Nur'aini, K. D. (2018). Pengembangan Perangkat Pembelajaran Berbasis Problem Based Learning Berorientasi pada Pengingkatan Kemampuan Penalaran dan Sikap Siswa Terhadap Matematika. *Magistra*, *5*, 15–29.

Patingki, A., Mohidin, A. D., & Resmawan, R. (2022). Hubungan gaya kognitif siswa dengan kemampuan pemecahan masalah matematika. *Jambura Journal of Mathematics Education*, *3*(2), 70–80. https://doi.org/10.34312/jmathedu.v3i2.15412

Puhr, R., Heinze, G., Nold, M., & Geroldinger, A. (2017). Firth ' s logistic regression with rare events : Accurate effect estimates and predictions ? *Statistics in Medicine*, *May 2016*. https://doi.org/10.1002/sim.7273

Rahmi, L., Yulianti;, K., & Prabawanto, S. (2022). Students' learning obstacles on the topic of pythagorean theorem. *AIP Conference Proceedings*, *2478*(1). https://doi.org/10.1063/5.0102556

Santoso, T., Ruslau, M. F. V., & Suryani, D. R. (2018). Penerapan Analisis Konjoin Dalam Menentukan Persepsi Siswa Sma Negeri 1 Merauke Tentang Karakteristik Guru Matematika. *Musamus Journal of Mathematics Education*, *1*(1), 17–29. https://doi.org/10.35724/mjme.v1i1.781

Sari, A. S. (2017). *Kemampuan koneksi matematika siswa pada materi teorema pythagoras ditinjau dari gaya kognitif* (Issue Juni). Universitas Muhammadiyah Surakarta.

Sari, W. P., Purwasi, L. A., & Yanto, Y. (2020). Analisis kesalahan siswa dalam menyelesaikan soal cerita materi teorema pythagoras. *Transformasi: Jurnal Pendidikan Matematika Dan Matematika*, *4*(2), 387–401. https://doi.org/10.36526/tr.v4i2.1009

Schoenfeld, A. H. (2016). Learning to think mathematically: problem solving, metacognition, and sense making in mathematics. *Journal of Education*, *196*(2), 1–38. https://doi.org/10.1177/002205741619600202

Schoenherr, J., Strohmaier, A. R., & Schukajlow, S. (2024). Learning with visualizations helps : A meta-analysis of visualization interventions in mathematics education. *Educational Research Review*, *45*(January), 100639. https://doi.org/10.1016/j.edurev.2024.100639

Suryani, D. R., Nur'aini, K. D., & Natsir, I. (2023). Perbedaan level kemampuan metakognisi siswa dalam memecahkan masalah matematika ditinjau dari kemampuan matematika siswa. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *12*(3), 3494–3502. https://doi.org/10.24127/ajpm.v12i3.7557

Tinajero, C., & Páramo, M. F. (1997). Field dependence-independence and academic achievement: A re-examination of their relationship. *British Journal of Educational Psychology*, *67*(2), 199–212. https://doi.org/10.1111/j.2044-8279.1997.tb01237.x

Tsigeman, E. S., Likhanov, M. V, Budakova, A. V, Akmalov, A., Sabitov, I., Alenina, E., Bartseva, K., & Kovas, Y. (2023). Persistent gender differences in spatial ability, even in stem experts. *Heliyon*, *9*(4), e15247. https://doi.org/10.1016/j.heliyon.2023.e15247

Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). The malleability of spatial skills : A meta-analysis of training studies. *Psychological Bulletin*, *139*(2), 352–402. https://doi.org/10.1037/a0028446

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for stem domains : Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, *101*(4), 817–835. https://doi.org/10.1037/a0016127

Wang, X. (2014). Firth logistic regression for rare variant association tests. *General Commentary*, *5*(June), 2013–2015. https://doi.org/10.1002/sim.3794

Wardhana, I. R., & Fuady, A. (2024). Analisis kemampuan koneksi matematis peserta didik dalam menyelesaikan soal pythagoras ditinjau dari gaya kognitif. *JPMI (Jurnal Pembelajaran Matematika Inovatif)*, *7*(5), 863–874. https://doi.org/10.22460/jpmi.v7i5.21943

Witkin, H. A., Moore, C. A., Goodenough, D., & Cox, P. W. (1977). Field-dependent and field-independent cognitive styles and their educational implications. *Review of Educational Research*, *47*(1), 1–64. https://doi.org/10.3102/00346543047001001

Xu, T., & Sun, S. (2025). Spatial reasoning and its contribution to mathematical performance across different content domains : Evidence from chinese students. *Journal OfIntelligence 13:*, *13*, 41. https://doi.org/10.3390/jintelligence13040041