



COGNITIVE–AFFECTIVE PREDICTORS OF METACOGNITIVE AWARENESS IN MATHEMATICS LEARNING

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Abstract

Mathematics learning is shaped not only by students' cognitive abilities but also by how they regulate their learning, perceive risk, and interpret failure within the learning process. This study developed a predictive model to examine how academic risk-taking and irrational beliefs predict metacognitive awareness among lower-secondary school students in mathematics. A quantitative correlational design was employed with 979 lower-secondary school students (ages 11–14) in Türkiye. Data were collected using three validated instruments: the Mathematics-Focused Academic Risk-Taking Scale (MFARTS), the Irrational Mathematics Beliefs Scale (IMBS), and the Metacognitive Awareness Inventory for Children (MAIC, Form B). Descriptive statistics, t-tests, ANOVA, and simple linear regression analyses were conducted. Results revealed moderate-to-high levels of metacognitive awareness overall. Academic risk-taking positively and significantly predicted metacognitive awareness, whereas irrational mathematics beliefs negatively predicted it. Fifth-grade students and those with higher mathematics achievement exhibited significantly greater metacognitive awareness and risk-taking tendencies. Irrational beliefs generally decreased with higher achievement, though certain sub-dimensions showed varied patterns across grade levels. No significant gender differences were found in metacognitive awareness or overall risk-taking. Overall, the results demonstrate that metacognitive awareness in mathematics is strengthened by students' willingness to engage in take academic risks but weakened by rigid, irrational beliefs about learning and failure. The findings contribute to the theoretical integration of cognitive-affective models in mathematics education and provide empirical support for pedagogical approaches that promote self-regulated learning through risk-friendly classroom climates and the reframing of maladaptive beliefs.

Keywords: *academic risk-taking, irrational beliefs, mathematics education, metacognitive awareness, lower-secondary education*

Introduction

Learning in the 21st century cannot be conceptualized as a passive process of receiving information; rather, it requires learners to actively engage with, reflect on, and regulate their learning experiences. In this context, learning processes are defined not only by the skills of knowledge-acquisition and comprehension but also by the individual's capacity to regulate, monitor, and evaluate their own learning (Efklides, 2008; Efklides & Metallidou, 2020; Nerantzaki et al., 2021; Veenman, 2015; Veenman & van Cleef, 2019; Zimmerman, 2002). Within this perspective, metacognitive awareness, defined as one's capacity to recognize, control, and regulate cognitive processes, remains a foundational construct for learning effectiveness (Flavell, 1979). Metacognitive theory emphasizes both knowing about cognition and regulating cognition, including planning, monitoring, and evaluation functions that support goal setting, strategy selection, progress checking, and outcome appraisal (Armbruster & Brown, 1984; Brown, 1980, 1987; Flavell, 1987; Flavell et al., 2001; Hartman, 2001; Pintrich, 2002; Schraw & Moshman, 1995; Veenman et al., 2004; Winne & Azevedo, 2014). This knowledge–control cycle is also described in terms of person, task, and strategy knowledge, alongside executive regulation processes that guide problem solving (Baker, 1994; Blakey & Spence, 1990; Brown, 1987; Coutinho, 2006; Hendriana et al., 2018; Muncer et al., 2022).

Mathematics learning is a particularly informative context for examining metacognition because it involves abstract reasoning, complex problem solving, and flexible strategy use (Barzilai et al., 2023; Janssen & Lazonder, 2024; Zohar & Barzilai, 2013). Students with stronger metacognitive awareness tend to notice errors, revise strategies, and persist through difficulty, treating mistakes as informative feedback rather than as endpoints (Alivio & Tan, 2025; Desender & Sasanguie, 2022; Efklides & Metallidou, 2020; Mevarech & Paz-Baruch, 2022; Ozdemir et al., 2024; Thi-Nga et al., 2024; Zohar & David, 2008). In contrast, lower metacognitive awareness is associated with more rote or intuitive approaches, weaker error monitoring, and earlier disengagement (Desender & Sasanguie, 2022).

Alongside cognitive regulation, students' affective beliefs and dispositions shape how they engage with mathematical challenges. Irrational beliefs, rigid, unrealistic, or distorted evaluations about the self, tasks, and achievement, are theorized within REBT as assumptions that can undermine adaptive emotions and behavior, especially under performance pressure (Dryden, 2010, 2013, 2024; Ellis, 1995; Ellis et al., 2010). In school settings, such beliefs may appear as absolutist standards (e.g., “failure is unacceptable” or “mistakes prove inadequacy”) and are linked to lower motivation, risk avoidance, and diminished self-efficacy (Li & Yuan, 2022; Morsanyi et al., 2019; Zhou et al., 2022, 2023). Because these beliefs can shift attention from task-focused monitoring to threat-focused avoidance, they may constrain students' use of metacognitive strategies and their willingness to remain engaged in the face of uncertainty (Bester & Kufakunesu, 2021; Diale & Victor-Aigbodion, 2022; Gómez-Chacón, 2014; Pennequin et al., 2020).

A closely related behavioral dimension is academic risk-taking, defined as the tendency to attempt novel strategies, tolerate mistakes, and participate actively despite the possibility of failure (Clifford, 1988; Clifford & Chou, 1991). In mathematics, risk-taking supports the exploration of alternative approaches, learning from errors, and the development of adaptive problem-solving repertoires (Arslan, 2021; Arslan & Coşkun, 2023; Avcı & Özenir, 2016; Beghetto et al., 2021; Beghetto & Glăveanu, 2022; Eke & George, 2025; Pimta et al., 2009; Robinson, 2012). Conversely, low risk-taking is associated with avoiding errors, choosing “safe” strategies, and narrowing learning opportunities (Erbaş & Bas, 2015; Sharma, 2015). Conceptually, metacognitive awareness and risk-taking are mutually supportive: monitoring and regulating one's thinking can increase the confidence needed to engage in uncertain tasks, whereas rigid, irrational beliefs can suppress both cognitive flexibility and the willingness to take learning risks (Doruk et al., 2018; Desoete & De Craene, 2019; Lingel et al., 2019; Özsoy, 2011; Yildiz et al., 2018).

Despite growing emphasis on integrating cognitive and affective processes in learning research, studies that consider metacognitive awareness, academic risk-taking, and irrational beliefs together, particularly in the Turkish lower-secondary context, remain limited, with prior work often examining these variables separately (İlhan & Çetin, 2013; Karakelle & Saraç, 2007; Kaya, 2017). Building on self-regulation and metacognition frameworks (Brown, 1987; Flavell, 1979; Winne & Azevedo, 2014) and contemporary mathematics education perspectives highlighting cognition–affect coupling (Efklides, 2008; Efklides & Metallidou, 2020; Zohar & Barzilai, 2013), the present study addresses this gap by examining the direct predictive associations among these constructs. Specifically, the study tests whether academic risk-taking positively predicts metacognitive awareness and whether irrational beliefs negatively predict metacognitive awareness, using regression-based analyses aligned with these direct hypotheses (Aydın & Özgeldi, 2024; Beghetto, 2021; Dryden & Ellis, 2023; Lee, 2024; Sharma, 2015). By clarifying these direct links, the study aims to inform instructional designs that strengthen the use of metacognitive strategies, foster risk-friendly learning climates, and support the transformation of maladaptive beliefs in mathematics classrooms (Kramarski, 2008; Kramarski et al., 2021; Mevarech & Paz-Baruch, 2022; Zohar & Barzilai, 2013).

Research Aim and Research Questions

The aim of this study was to examine lower-secondary school students' levels of metacognitive awareness, mathematics-focused academic risk-taking behaviors, and irrational mathematics beliefs, and to examine the relationships and predictive effects among them. Specifically, the study aimed to:

- RQ1. What is the level of lower-secondary school students' metacognitive awareness?
- RQ2. Do lower-secondary school students' metacognitive awareness levels differ significantly according to gender, grade level, and mathematics achievement scores?
- RQ3. What is the level of lower-secondary school students' mathematics-focused academic risk-taking (total score and sub-dimensions)?
- RQ4. Do lower-secondary school students' mathematics-focused academic risk-taking levels (total score and sub-dimensions) differ significantly according to gender, grade level, and mathematics achievement scores?
- RQ5. What is the level of lower-secondary school students' irrational mathematics beliefs (total score and sub-dimensions)?
- RQ6. Do lower-secondary school students' irrational mathematics beliefs levels (total score and sub-dimensions) differ significantly according to gender, grade level, and mathematics achievement scores?
- RQ7. Does mathematics-focused academic risk-taking significantly predict lower-secondary school students' metacognitive awareness?
- RQ8. Do irrational mathematics beliefs significantly predict lower-secondary school students' metacognitive awareness?

Research Methodology

Design

This study employed a quantitative correlational survey design to examine relationships among lower-secondary school students' metacognitive awareness, mathematics-focused academic risk-taking behaviors, and irrational mathematics beliefs. Correlational survey designs are used to determine the direction and strength of associations among two or more variables (Creswell & Creswell, 2017; Karasar, 2022). Data were collected during the 2022–2023 academic year. In addition to correlation analyses, predictive relationships among the variables were tested using linear regression. The study was grounded in contemporary learning perspectives that emphasize the interaction of cognitive regulation and affective processes in learning; accordingly, metacognitive awareness was conceptualized as a cognitive-regulatory construct intertwined with students' affective dispositions and belief systems (Efklides, 2008; Veenman, 2015).

Participants

The study group consisted of 979 students enrolled in public lower-secondary schools in Istanbul, Türkiye. Participants were between 11 and 14 years old and included students from Grades 5 through 8. Participation was voluntary, parental consent was obtained, and the research procedures were conducted with ethics committee approval.

A convenience sampling strategy was employed due to institutional access constraints and voluntary school participation, which is common in school-based correlational research (Fraenkel et al., 2012). The final sample reflects the total number of students who met the inclusion criteria and were available during the data collection period. The adequacy of sample size was evaluated with respect to the planned analyses (correlational analyses, group

comparisons such as t-tests and ANOVA, and regression), for which methodological guidelines recommend minimum sample sizes well below the present sample (Fraenkel et al., 2012). In addition, because multi-item scales were used, the item-to-sample ratio exceeded commonly recommended thresholds (e.g., 1:5–1:10) for stable statistical estimation (Tabachnick & Fidell, 2013). Although convenience sampling limits generalizability, transparent reporting supports interpretation of the findings within the sampled population (Fraenkel et al., 2012). The demographic characteristics of the participants are presented in Table 1.

Table 1
Demographic Characteristics of the Participants

Variable	Category	<i>f</i>	%
Gender	Female	485	49.5
	Male	494	50.5
Grade Level	5th grade	219	22.4
	6th grade	249	25.4
	7th grade	270	27.6
	8th grade	241	24.6
Mathematics Achievement Score	0- 44	73	7.5
	45-54	120	12.3
	55-69	206	21.0
	70-84	267	27.3
	85-100	313	32.0
Total		979	100.0

Notes: *f* = frequency; % = percentage.

As presented in Table 1, the gender distribution of the participants was nearly balanced, with female students constituting 49.5% and male students 50.5% of the sample. This indicates that the sample was well distributed by gender.

Regarding grade level, the participants were relatively evenly distributed across grades, with 22.4% in the 5th grade, 25.4% in the 6th grade, 27.6% in the 7th grade, and 24.6% in the 8th grade. This balanced distribution suggests that all grade levels were adequately represented in the study.

In terms of mathematics achievement, the largest proportion of students (32.0%) fell within the 85–100 score range, followed by those scoring between 70–84 (27.3%) and 55–69 (21.0%). Overall, the majority of participants (80.3%) demonstrated mathematics achievement scores of 55 or above, with a substantial proportion scoring 70 or above. This distribution indicates that the sample predominantly consisted of students with moderate to high levels of mathematics achievement.

Instruments

The research data were collected using three instruments: the Mathematics-Focused Academic Risk-Taking Scale (MFARTS), the Irrational Mathematics Beliefs Scale (IMBS), and the Metacognitive Awareness Inventory for Children (MAIC; Form B). A Personal Information Form developed by the researchers was also administered to collect demographic data.

The Personal Information Form was developed by the researchers to obtain demographic data, including gender (female, male), grade level (5th, 6th, 7th, and 8th grades), mathematics achievement score (0–44, 45–54, 55–69, 70–84, and 85–100), and parents' educational status (primary school, lower-secondary school, high school, university, and postgraduate).

The reliability of all scales used in the study was assessed using Cronbach's alpha. The reference ranges for interpreting Cronbach's alpha values are presented in Table 2 (Alpar, 2013).

Table 2
Reference Ranges for Cronbach's Alpha Coefficient

Cronbach's α Range	Interpretation
$0 < \alpha < 0.40$	Not Reliable
$0.40 < \alpha < 0.60$	Low Reliability
$0.60 < \alpha < 0.80$	Quite Reliable
$0.80 < \alpha < 1.00$	High Reliability

Notes: Cronbach's α values indicate the internal consistency reliability of a scale. Adapted from Alpar (2013).

Mathematics-Focused Academic Risk-Taking Scale (MFARTS)

The Mathematics-Focused Academic Risk-Taking Scale (MFARTS) was developed by İlhan and Çetin (2013). Content and face validity were established through expert review. The scale consists of 24 items organized under three subdimensions: Tendency to Prefer Challenging Tasks (TPCT), Tendency for Negativity After Failure (TNAF), and Tendency to Recover After Failure (TRAF).

The reliability of the scale was examined using internal consistency, split-half, and test–retest methods. Item analysis indicated that corrected item–total correlations ranged between .40 and .73, and all items significantly differentiated between the upper and lower 27% groups. The Cronbach's alpha coefficient for the overall scale was reported as .84. Reliability coefficients obtained in the present study for the MFARTS and its subdimensions are presented in Table 3.

Table 3
Reliability Analysis Results for the Mathematics-Focused Academic Risk-Taking Scale (MFARTS)

Scale / Subdimension	Cronbach's α
Tendency to Prefer Challenging Tasks (TPCT)	.851
Tendency for Negativity After Failure (TNAF)	.832
Tendency to Recover After Failure (TRAF)	.843
Overall Scale	.837

Note: Cronbach's α values indicate the internal consistency reliability of the MFARTS and its subdimensions.

As shown in Table 3, all Cronbach's alpha coefficients exceeded .80, indicating a high level of internal consistency reliability for both the overall scale and its subdimensions.

Irrational Mathematics Beliefs Scale (IMBS)

The Irrational Mathematics Beliefs Scale (IMBS) was developed by Kaya (2017). Content and face validity were established through expert review. The scale consists of 20 items and includes four subdimensions: Beliefs Related to Reasons (BRR), Restrictive Beliefs

(RB), Chance Tendency (CT), and Control Power Tendency (CPT). All items are rated on a 5-point Likert scale.

The internal consistency coefficients reported for the original scale were .85 for BRR, .78 for RB, .71 for CT, and .66 for CPT, with an overall Cronbach's alpha coefficient of .81. Item–total correlations were found to be significant, indicating satisfactory item discrimination. Reliability coefficients obtained in the present study for the IMBS are presented in Table 4.

Table 4

Reliability Analysis Results for the Irrational Mathematics Beliefs Scale (IMBS)

Scale / Subdimension	Cronbach's α
Beliefs Related to Reasons (BRR)	.821
Restrictive Beliefs (RB)	.796
Chance Tendency (CT)	.813
Control Power Tendency (CPT)	.689
Overall Scale	.811

Note: Cronbach's α values indicate the internal consistency reliability of the IMBS and its subdimensions.

As shown in Table 4, BRR (.821), CT (.813), and the overall scale (.811) demonstrated high reliability, while RB (.796) demonstrated quite reliable and CPT (.689) demonstrated quite reliable levels of internal consistency, all indicating satisfactory measurement quality for the present study.

Metacognitive Awareness Inventory for Children (MAIC)

The Metacognitive Awareness Inventory for Children (MAIC) was adapted into Turkish by Karakelle and Saraç (2007) from the Junior Metacognitive Awareness Inventory (Jr. MAI) originally developed by Sperling et al. (2002). The validity and reliability of the scale were examined through item–total correlations, lower–upper group comparisons, test–retest reliability, and internal consistency analyses. The findings indicated that the scale provides valid and reliable measurements.

Form B, which was used in the present study, consists of 18 items rated on a 5-point Likert scale. The Cronbach's alpha coefficient reported for Form B in the adaptation study was .80. The reliability coefficient obtained in the present study for MAIC (Form B) is presented in Table 5.

Table 5

Reliability Analysis Results for the Metacognitive Awareness Inventory for Children (MAIC)

Scale	Cronbach's α
MAIC (Form-B)	.791

Note: Cronbach's α values indicate the internal consistency reliability of the scale.

As shown in Table 5, the Cronbach's alpha coefficient of .791 indicates a quite reliable level of internal consistency (George & Mallery, 2010), which is slightly below the high reliability threshold of .80 but remains within an acceptable range for the present study.

Data Analysis

The data required for the study were collected through questionnaires administered to the participants. Descriptive results were used to summarize responses to the Personal Information Form and the measurement scales. Frequency analyses were conducted to describe demographic characteristics, while means and standard deviations were calculated for scale scores.

The internal consistency reliability of the measurement instruments was assessed using Cronbach’s alpha coefficient. Prior to inferential analyses, the normality of score distributions for the Mathematics-Focused Academic Risk-Taking Scale (MFARTS), the Irrational Mathematics Beliefs Scale (IMBS), and the Metacognitive Awareness Inventory for Children (MAIC; Form B) was examined. Normality was evaluated using the Kolmogorov–Smirnov test as well as skewness and kurtosis coefficients. The Kolmogorov–Smirnov test results were non-significant ($p > .05$), and skewness and kurtosis values fell within the range of -1 to $+1$ (Tabachnick & Fidell, 2013), indicating that the distributions of the scale scores approximated normality.

Based on these results, parametric statistical techniques were employed. Differences in scale scores according to demographic variables were examined using independent-samples t-tests and one-way analyses of variance (ANOVA). In addition, predictive relationships among MFARTS, IMBS, and MAIC (Form B) were examined using linear regression analysis. For all statistical analyses, a 95% confidence interval and a significance level of .05 were adopted.

Table 6
Normality Test Results for the Study Scales

Scale	Skewness	Kurtosis	Kolmogorov-Smirnov
MFARTS	-0.531	-0.221	2.838
IMBS	-0.912	0.326	2.741
MAIC (Form-B)	-0.526	0.445	2.921

Note: Skewness and kurtosis values between -1 and $+1$ indicate approximate normality (Tabachnick & Fidell, 2013). $p > .05$.

Based on the results presented in Table 6, the skewness and kurtosis coefficients for all scales fell within the acceptable range of -1 to $+1$, indicating that the distributions of the scale scores approximated normality. In addition, the Kolmogorov–Smirnov test results were non-significant ($p > .05$), further supporting the assumption of normal distribution.

Accordingly, parametric statistical methods were employed in the analyses. Differences in scale scores based on demographic variables were examined using independent-samples t-tests and one-way analyses of variance (ANOVA). Furthermore, the relationships among the Mathematics-Focused Academic Risk-Taking Scale (MFARTS), the Irrational Mathematics Beliefs Scale (IMBS), and the Metacognitive Awareness Inventory for Children (MAIC; Form B) were examined using linear regression analysis. For all statistical analyses, a 95% confidence interval and a significance level of .05 were adopted.

Research Results

Metacognitive Awareness

The mean and standard deviation values for the metacognitive awareness measured by the MAIC (Form B) are presented in Table 7.

Table 7*Descriptive Results for the Metacognitive Awareness Inventory for Children (MAIC)*

Scale	<i>M</i>	<i>SD</i>
MAIC (Form-B)	3.78	1.11

Notes: *M* = mean; *SD* = standard deviation.

As shown in Table 7, the overall mean score for metacognitive awareness was 3.78 (on a 5-point scale), indicating a moderate-to-high level of metacognitive awareness among the participants.

Metacognitive Awareness by Gender

The independent-samples t-test results examining gender differences in metacognitive awareness are presented in Table 8.

Table 8*t-Test Results for Metacognitive Awareness (MA) by Gender*

Gender	<i>N</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>p</i>	Effect Size (Cohen's <i>d</i>)
Female	485	3.68	0.62	1.73	.08	0.11
Male	494	3.62	0.58			

Notes: *M* = mean; *SD* = standard deviation.

As shown in Table 8, the difference in metacognitive awareness scores between female and male students was not statistically significant, $t(977) = 1.73, p > .05$, indicating comparable levels of metacognitive awareness across genders.

Metacognitive Awareness by Grade Level

The results of the one-way ANOVA examining differences in metacognitive awareness across grade levels are presented in Table 9.

Table 9*ANOVA Results for Metacognitive Awareness (MA) by Grade Level*

Grade	<i>N</i>	<i>M</i>	<i>SD</i>	<i>F</i>	<i>p</i>	Post-hoc
5th grade	219	3.88	0.57	16.23	< .001*	5>6,7,8
6th grade	249	3.55	0.57			
7th grade	270	3.57	0.59			
8th grade	241	3.63	0.62			

Note: *M* = mean; *SD* = standard deviation. Post-hoc comparisons indicate statistically significant differences between the specified grade levels at $*p < .05$.

The ANOVA results indicated a statistically significant difference in metacognitive awareness across grade levels, $F(3, 975) = 16.23$, $p < .001$. Scheffé post-hoc comparisons revealed that 5th-grade students scored significantly higher than students in Grades 6, 7, and 8.

Metacognitive Awareness by Mathematics Achievement Score

The ANOVA results examining differences in metacognitive awareness by mathematics achievement score are presented in Table 10.

Table 10
ANOVA Results for Metacognitive Awareness (MA) by Mathematics Achievement Score

Mathematics Achievement Score	N	M	SD	F	p	Post-hoc
0-44	73	3.43	0.67	6.94	< .001*	85-100> 0-44
45-54	120	3.56	0.56			
55-69	206	3.59	0.56			
70-84	267	3.64	0.63			
85-100	313	3.78	0.58			

Notes: M = mean; SD = standard deviation. Post-hoc comparisons indicate statistically significant differences at $*p < .05$.

The results showed a significant effect of mathematics achievement on metacognitive awareness, $F(4, 974) = 6.94$, $p < .001$. Post-hoc analyses indicated that students with achievement scores in the 85–100 range demonstrated significantly higher metacognitive awareness than those in the 0–44 range.

Mathematics-Focused Academic Risk-Taking

Descriptive results for the MFARTS and its subdimensions are presented in Table 11.

Table 11
Descriptive Results for the Mathematics-Focused Academic Risk-Taking Scale (MFARTS)

Scale / Subdimension	M	SD
Tendency to Prefer Challenging Tasks (TPCT)	3.07	1.26
Tendency for Negativity After Failure (TNAF)	3.01	1.21
Tendency to Recover After Failure (TRAF)	3.42	1.37
Overall Scale	3.16	1.24

Notes: M = mean; SD = standard deviation.

Overall, students demonstrated moderate levels of mathematics-focused academic risk-taking, with the highest mean observed for the recovery after failure subdimension (TRAF; $M=3.42$).

Mathematics-Focused Academic Risk-Taking by Gender

The independent-samples t-test results examining whether students' Mathematics-Focused Academic Risk-Taking Scale (MFARTS) scores differed by gender are presented in Table 12.

Table 12

t-Test Results for the Mathematics-Focused Academic Risk-Taking Scale (MFARTS) by Gender

Scale / Subdimension	Gender	N	M	SD	t	p	Effect Size (Cohen's d)
TPCT	Female	485	3.05	0.68	-1.64	.10	0.03
	Male	494	3.12	0.65			
TNAF	Female	485	3.07	0.98	2.15	.03	0.22
	Male	494	2.94	0.93			
TRAF	Female	485	3.63	0.98	1.22	.22	0.20
	Male	494	3.56	0.92			
Overall Scale	Female	485	3.25	0.56	1.26	.20	0.20
	Male	494	3.21	0.56			

Note: M = mean; SD = standard deviation. Effect sizes are reported as Cohen's *d*.

As seen in Table 12, the difference between female and male students in terms of overall MFARTS scores was not statistically significant ($t = 1.26, p > .05$). In other words, mathematics-focused academic risk-taking levels were similar across gender groups.

Similarly, no statistically significant gender difference was found for the TPCT (Tendency to Prefer Challenging Tasks) subdimension ($t = -1.64, p > .05$). This finding indicates that female and male students demonstrated similar tendencies to prefer challenging mathematical tasks.

However, a statistically significant difference was observed for the TNAF (Tendency for Negativity After Failure) subdimension ($t = 2.15, p < .05$). When mean scores were examined, female students showed greater negativity after failure than male students. Nevertheless, the effect size indicated that this difference was small.

For the TRAF (Tendency to Recover After Failure) subdimension, the difference between female and male students was not statistically significant ($t = 1.22, p > .05$). This result indicates that recovery after failure tendencies were similar across genders.

Mathematics-Focused Academic Risk-Taking Scale (MFARTS) by Grade Level

The ANOVA results examining the differentiation of MFARTS scores by grade level are presented in Table 13.

Table 13

ANOVA Results for the Mathematics-Focused Academic Risk-Taking Scale (MFARTS) by Grade Level

Scale / Subdimension	Grade	<i>N</i>	<i>M</i>	<i>SD</i>	<i>F</i>	<i>p</i>	Post-hoc
TPCT	5th grade	219	3.38	0.64	23.14	< .001*	5>6,7,8
	6th grade	249	3.11	0.63			
	7th grade	270	2.99	0.62			
	8th grade	241	2.91	0.68			
TRAF	5th grade	219	4.02	0.80	26.42	< .001*	5>6,7,8
	6th grade	249	3.62	0.93			
	7th grade	270	3.45	0.90			
	8th grade	241	3.35	1.04			
Overall Scale	5th grade	219	3.45	0.50	21.67	< .001*	5>6,7,8
	6th grade	249	3.27	0.54			
	7th grade	270	3.16	0.49			
	8th grade	241	3.06	0.63			

Notes: *M* = mean; *SD* = standard deviation. **p* < .05. Only statistically significant Post-hoc comparisons are reported.

As seen in Table 13, the difference in overall MFARTS scores across grade levels was statistically significant ($F = 21.67$, $p < .001$). This finding indicates that mathematics-focused academic risk-taking levels differed significantly according to grade level. Post hoc (Scheffé) comparisons revealed that 5th-grade students demonstrated significantly higher overall MFARTS scores than students in the 6th, 7th, and 8th grades.

Similarly, statistically significant grade-level differences were observed for the TPCT (Tendency to Prefer Challenging Tasks) subdimension ($F = 23.14$, $p < .001$). Post hoc comparisons indicated that 5th-grade students demonstrated significantly higher tendencies to prefer challenging mathematical tasks compared to students in the upper grades.

For the TRAF (Tendency to Recover After Failure) subdimension, a statistically significant grade-level difference was also observed ($F = 26.42$, $p < .001$). Post hoc results showed that 5th-grade students demonstrated significantly higher recovery after failure tendencies compared to students in Grades 6–8.

Mathematics-Focused Academic Risk-Taking by Mathematics Achievement Score

The one-way ANOVA results examining whether students' Mathematics-Focused Academic Risk-Taking Scale (MFARTS) scores differed according to mathematics achievement levels are presented in Table 14.

Table 14*ANOVA Results for Mathematics-Focused Academic Risk-Taking Scale (MFARTS) by Mathematics Achievement Score*

Scale / Subdimension	Mathematics Achievement Score	N	M	SD	F	p	Post-hoc
TPCT	0-44	73	2.89	0.67	8.37	< .001*	85-100>all
	45-54	120	2.96	0.66			
	55-69	206	3.04	0.68			
	70-84	267	3.05	0.64			
	85-100	313	3.25	0.64			
TNAF	0-44	73	2.89	0.91	2.78	.02*	45-54> 0-44, 85-100
	45-54	120	3.17	0.78			
	55-69	206	3.04	0.95			
	70-84	267	3.05	0.95			
	85-100	313	2.89	1.02			
TRAF	0-44	73	3.28	1.06	15.84	< .001*	85-100>all
	45-54	120	3.29	0.92			
	55-69	206	3.48	0.95			
	70-84	267	3.55	0.96			
	85-100	313	3.90	0.85			
Overall Scale	0-44	73	3.02	0.70	6.98	< .001*	85-100>all
	45-54	120	3.14	0.58			
	55-69	206	3.18	0.57			
	70-84	267	3.22	0.54			
	85-100	313	3.35	0.50			

Note. *M* = mean; *SD* = standard deviation. Post-hoc comparisons indicate statistically significant differences at $*p < .05$.

As seen in Table 14, the overall MFARTS scores differed significantly according to mathematics achievement level ($F = 6.98, p < .001$). Post hoc (Scheffé) comparisons revealed that students in the 85–100 achievement group demonstrated significantly higher overall mathematics-focused academic risk-taking levels than students in all other achievement groups.

Similarly, statistically significant differences were observed for the TPCT (Tendency to Prefer Challenging Tasks) subdimension ($F = 8.37, p < .001$). Post hoc results indicated that students with mathematics achievement scores between 85–100 reported higher tendencies to prefer challenging mathematical tasks compared to students in the lower achievement groups.

For the TNAF (Tendency for Negativity After Failure) subdimension, a statistically significant difference was also observed ($F = 2.78, p < .05$). Post hoc comparisons showed that students in the 45–54 achievement group reported higher negativity after failure compared to students in the 0–44 and 85–100 achievement groups.

In addition, statistically significant differences were found for the TRAF (Tendency to Recover After Failure) subdimension ($F = 15.84, p < .001$). Post hoc results indicated that students in the 85–100 achievement group demonstrated significantly higher recovery after failure tendencies than students in all other achievement groups.

Irrational Mathematics Beliefs

The descriptive results for the Irrational Mathematics Beliefs Scale (IMBS) and its subdimensions are presented in Table 15.

Table 15
Descriptive Results for the Irrational Mathematics Beliefs Scale (IMBS)

Scale / Subdimension	<i>M</i>	<i>SD</i>
Beliefs Related to Reasons (BRR)	2.57	1.38
Restrictive Beliefs (RB)	3.58	1.29
Chance Tendency (CT)	2.15	1.41
Control Power Tendency (CPT)	3.41	1.50
Overall Scale	2.67	1.47

Notes: *M* = mean; *SD* = standard deviation.

As seen in Table 15, the overall mean score for irrational mathematics beliefs was 2.67. When the subdimensions were examined, the highest mean score was observed for Restrictive Beliefs (RB) ($M = 3.58$), followed by Control Power Tendency (CPT) ($M = 3.41$). In contrast, the lowest mean score was observed for Chance Tendency (CT) ($M = 2.15$). The mean score for Beliefs Related to Reasons (BRR) was 2.57.

Overall, these results indicate that restrictive beliefs and control-related tendencies were relatively more prominent compared to chance-related beliefs among the participants.

Irrational Mathematics Beliefs by Gender

The independent-samples t-test results examining gender differences in Irrational Mathematics Beliefs Scale (IMBS) scores and its subdimensions are presented in Table 16.

Table 16
t-Test Results for the Irrational Mathematics Beliefs Scale (IMBS) by Gender

Scale / Subdimension	Gender	<i>N</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>p</i>	Effect Size (Cohen's <i>d</i>)
BRR	Female	485	2.59	1.16	0.52	.60	< 0.001
	Male	494	2.55	1.11			
RB	Female	485	3.59	0.85	0.19	.98	0.01
	Male	494	3.58	0.86			
CT	Female	485	2.00	0.87	-3.11	.001	0.02
	Male	494	2.18	0.88			
CPT	Female	485	3.40	1.05	0.43	.66	0.04
	Male	494	3.37	1.05			
Overall Scale	Female	485	2.89	0.57	-0.76	.44	0.03
	Male	494	2.92	0.55			

Notes: *M* = mean; *SD* = standard deviation. Effect sizes are reported as Cohen's *d*.

As shown in Table 16, no statistically significant gender difference was found for the overall IMBS score ($t = -0.76, p > .05$).

Similarly, no statistically significant gender differences were observed for the Beliefs Related to Reasons (BRR) subdimension ($t = 0.52, p > .05$), the Restrictive Beliefs (RB) subdimension ($t = 0.19, p > .05$), and the Control Power Tendency (CPT) subdimension ($t = 0.43, p > .05$).

However, a statistically significant gender difference was found for the Chance Tendency (CT) subdimension ($t = -3.11, p < .05$). When mean scores were examined, male students ($M = 2.18$) demonstrated higher chance tendency beliefs compared to female students ($M = 2.00$).

When effect sizes were examined, all Cohen's d values indicated small effect sizes, suggesting that the magnitude of gender differences was limited.

Irrational Mathematics Beliefs by Grade Level

The ANOVA results examining grade-level differences in Irrational Mathematics Beliefs Scale (IMBS) scores and its subdimensions are presented in Table 17.

Table 17

ANOVA Results for Irrational Mathematics Beliefs (IMBS) by Grade Level

Scale / Subdimension	Grade	N	M	SD	F	p	Post-hoc
BRR	5th grade	219	2.18	1.05	15.83	< .001*	8>5,6 7>5
	6th grade	249	2.49	1.11			
	7th grade	270	2.74	1.07			
	8th grade	241	2.82	1.21			
RB	5th grade	219	3.90	0.76	16.42	< .001*	5>6,7,8
	6th grade	249	3.57	0.85			
	7th grade	270	3.46	0.83			
	8th grade	240	3.45	0.89			
CT	5th grade	219	2.21	0.93	3.61	.01*	5>6,7,8
	6th grade	249	2.10	0.91			
	7th grade	270	2.10	0.89			
	8th grade	240	1.96	0.77			

Notes: M = mean; SD = standard deviation. * $p < .05$. Only statistically significant Post-hoc comparisons are reported.

As shown in Table 17, statistically significant grade-level differences were observed for several IMBS subdimensions.

For the Beliefs Related to Reasons (BRR) subdimension, a statistically significant difference was found across grade levels ($F = 15.83, p < .001$). Post-hoc comparisons indicated that 8th-grade students had significantly higher BRR scores than 5th- and 6th-grade students, and 7th-grade students had significantly higher scores than 5th-grade students.

For the Restrictive Beliefs (RB) subdimension, a statistically significant difference was also observed ($F = 16.42, p < .001$). Post-hoc comparisons showed that 5th-grade students demonstrated significantly higher restrictive belief scores than students in Grades 6, 7, and 8.

For the Chance Tendency (CT) subdimension, a statistically significant grade-level difference was identified ($F = 3.61, p < .05$). Post-hoc comparisons indicated that 5th-grade students had significantly higher chance tendency scores compared to students in Grades 6, 7, and 8.

Overall, these findings indicate that irrational mathematics belief patterns varied across grade levels, with different subdimensions demonstrating distinct grade-related trends.

Irrational Mathematics Beliefs by Mathematics Achievement Score

The ANOVA results examining differences in students' Irrational Mathematics Beliefs Scale (IMBS) scores and its subdimensions according to mathematics achievement score are presented in Table 18.

Table 18

ANOVA Results for Irrational Mathematics Beliefs (IMBS) by Mathematics Achievement Score

Scale / Subdimension	Mathematics Achievement Score	<i>N</i>	<i>M</i>	<i>SD</i>	<i>F</i>	<i>p</i>	Post-hoc
BRR	0-44	73	2.96	1.05	15.31	< .001*	0-44> 70-84, 85-100
	45-54	120	2.90	1.06			
	55-69	206	2.76	1.14			
	70-84	267	2.58	1.15			
	85-100	313	2.22	1.07			
RB	0-44	73	3.39	0.90	8.24	< .001*	85-100> 0-44
	45-54	120	3.49	0.83			
	55-69	205	3.47	0.83			
	70-84	267	3.51	0.88			
	85-100	313	3.80	0.81			
CT	0-44	73	2.29	0.92	4.41	< .001*	0-44, 45-54>85-100
	45-54	120	2.33	0.94			
	55-69	205	2.10	0.86			
	70-84	267	2.06	0.86			
	85-100	313	1.97	0.86			

Note: *M* = mean; *SD* = standard deviation. * $p < .05$. Only statistically significant Post-hoc comparisons are reported.

As shown in Table 18, statistically significant differences were observed across mathematics achievement score groups for all IMBS subdimensions reported in the table.

For the Beliefs Related to Reasons (BRR) subdimension, a statistically significant difference was found across achievement score groups ($F = 15.31, p < .001$). Post-hoc comparisons indicated that students with mathematics achievement scores between 0–44 had significantly higher BRR scores than students with scores between 70–84 and 85–100.

For the Restrictive Beliefs (RB) subdimension, a statistically significant difference was also observed ($F = 8.24, p < .001$). Post-hoc comparisons revealed that students with mathematics achievement scores between 85–100 had significantly higher RB scores than students with scores between 0–44.

For the Chance Tendency (CT) subdimension, a statistically significant difference was identified ($F = 4.41, p < .001$). Post-hoc comparisons showed that students with mathematics achievement scores between 0–44 and 45–54 had significantly higher CT scores than students with scores between 85–100.

*Predictive Effect of Mathematics-Focused Academic
Risk-Taking on Metacognitive Awareness*

The results of the simple linear regression analysis examining the predictive effect of Mathematics-Focused Academic Risk-Taking (MFARTS) on Metacognitive Awareness (MA) are presented in Table 19.

Table 19

Regression Analysis Results for the Effect of Mathematics-Focused Academic Risk-Taking (MFARTS) on Metacognitive Awareness(MA)

Predictor	β	SE	F	p
Constant	2.93*	0.12	227.34	< .001
MFARTS	0.28*	0.01		

Notes: Dependent variable: Metacognitive Awareness (MA). Model fit: $F(1, 977) = 227.34, *p < .001, R^2 = .275$.

As shown in Table 19, the regression model was statistically significant, $F(1, 977) = 227.34, p < .001$. The findings indicated that Mathematics-Focused Academic Risk-Taking significantly predicted Metacognitive Awareness ($\beta = .28, p < .001$). When the explanatory power of the model was examined, the MFARTS variable explained approximately 27.5% of the variance in Metacognitive Awareness ($R^2 = .275$), indicating a moderate level of predictive power.

Furthermore, the positive regression coefficient indicates that as mathematics-focused academic risk-taking increases, metacognitive awareness also tends to increase, suggesting a direct and positive relationship between these variables. In practical terms, this finding implies that students who are more willing to take academic risks in mathematics are likely to exhibit higher levels of metacognitive awareness. Based on the regression analysis, the prediction equation obtained for Metacognitive Awareness was formulated as follows: $MA = 2.93 + 0.28 \times MFARTS$. This equation indicates that for each one-unit increase in MFARTS, Metacognitive Awareness increases by 0.28 units, holding other factors constant.

Predictive Effect of Irrational Mathematics Beliefs on Metacognitive Awareness

The results of the simple linear regression analysis examining the predictive effect of Irrational Mathematics Beliefs (IMBS) on Metacognitive Awareness (MA) are presented in Table 20.

Table 20

Regression Analysis Results for the Effect of Irrational Mathematics Beliefs (IMBS) on Metacognitive Awareness (MA)

Predictor	β	SE	F	p
Constant	2.91*	0.12	221.31	< .001
IMBS	-0.06*	0.06		

Notes: Dependent variable: Metacognitive Awareness (MA). Model fit: $F(1, 977) = 221.31$, $*p < .001$; $R^2 = 0.264$.

As shown in Table 20, the regression model was statistically significant, $F(1, 977) = 221.31$, $p < .001$. The findings indicated that Irrational Mathematics Beliefs significantly predicted Metacognitive Awareness ($\beta = -.06$, $p < .001$). When the model's explanatory power was examined, IMBS accounted for approximately 26.4% of the variance in Metacognitive Awareness ($R^2 = .264$), indicating a moderate level of predictive power.

Furthermore, the negative regression coefficient indicates that as irrational mathematics beliefs increase, metacognitive awareness tends to decrease, suggesting an inverse relationship between these two constructs. In practical terms, this finding implies that students who hold stronger irrational beliefs about mathematics are likely to demonstrate lower levels of metacognitive awareness. Based on the regression analysis, the prediction equation obtained for Metacognitive Awareness was formulated as follows: $MA = 2.91 - 0.06 \times IMBS$. This equation indicates that for each one-unit increase in IMBS, Metacognitive Awareness decreases by 0.06 units, holding other factors constant.

Discussion

This study examined cognitive–affective predictors of metacognitive awareness in mathematics learning among lower-secondary students. Overall, students demonstrated moderate-to-high metacognitive awareness, moderate mathematics-focused academic risk-taking, and moderate irrational mathematics beliefs, with meaningful differentiation by grade level and mathematics achievement. These findings support contemporary views that metacognition functions as a self-regulatory system shaped not only by cognitive resources but also by affective beliefs and engagement tendencies in learning contexts (Efklides, 2008; Efklides & Metallidou, 2020; Erdoğan & Aydın, 2024; Kohen & Kramarski, 2018; Schraw & Moshman, 1995; Winne & Azevedo, 2014; Zimmerman, 2002).

Metacognitive Awareness Level and Group Differences

Students' metacognitive awareness levels were moderate to high, consistent with theoretical accounts suggesting that metacognitive knowledge and regulation develop across schooling but can be constrained by increasing academic demands and evaluative pressure (Flavell, 1979, 1987; Pintrich, 2002; Veenman, 2015; Veenman & van Cleef, 2019). The finding that 5th graders reported higher metacognitive awareness than upper grades may reflect a transition effect in which early lower-secondary students remain more open to reflective monitoring and strategy use, whereas older students may adopt more performance-driven and routine strategies as assessment stakes rise (Veenman, 2015; Zohar & Barzilai, 2013). Additionally, higher mathematics achievement was associated with higher metacognitive awareness, aligning with evidence that metacognitive monitoring and regulation relate to mathematical performance across ages and learning tasks (Muncer et al., 2022; Özsoy, 2011; Xie et al., 2024). In contrast, no significant gender differences emerged for metacognitive

awareness, which is consistent with studies showing that metacognitive competence is not inherently gendered and is often more sensitive to instructional experiences and classroom norms than to demographic categories (Lingel et al., 2019; Veenman, 2015).

Academic Risk-Taking as a Positive Predictor

Regression results showed that mathematics-focused academic risk-taking positively predicted metacognitive awareness, indicating that students who are more willing to engage with challenge and persist after errors tend to report stronger monitoring and regulation of their thinking. This pattern is theoretically coherent: risk-taking in learning contexts encourages students to test strategies, receive feedback from failure, and reflect on the effectiveness of their approaches processes central to metacognitive regulation (Brown, 1980, 1987; Clifford, 1988; Clifford & Chou, 1991). It also aligns with perspectives in mathematics education that emphasize that productive struggle, uncertainty, and strategy revision are critical conditions under which metacognition becomes visible and functional (Zohar & David, 2008; Zohar & Barzilai, 2013). From a pedagogical standpoint, this supports the argument that classrooms that normalize error and encourage intellectual risk are likely to foster both strategic flexibility and self-regulated learning (Beghetto, 2021; Beghetto & Glăveanu, 2022; Sharma, 2015). The moderate overall level of risk-taking observed in the sample further suggests that many students may still approach mathematics with caution highlighting the practical importance of building psychologically safe learning climates and feedback practices that treat mistakes as informational rather than threatening (Beghetto et al., 2021; Kramarski, 2008; Kramarski et al., 2021).

Irrational Beliefs as a Negative Predictor

The study also found that irrational mathematics beliefs negatively predicted metacognitive awareness, consistent with REBT-informed accounts that rigid, absolutist beliefs about failure and self-worth can interfere with adaptive learning behavior and cognitive regulation (Ellis, 1995; Ellis et al., 2010; Dryden, 2010, 2013, 2024; Dryden & Ellis, 2001). When students interpret mistakes as unacceptable or as evidence of incapacity, attention may shift away from task-focused monitoring toward self-protective avoidance, thereby weakening reflective evaluation and strategic control (Gómez-Chacón et al., 2024; Pennequin et al., 2020). This interpretation also aligns with research linking maladaptive beliefs to mathematics anxiety and impaired metacognitive insight in decision-making contexts (Desender & Sasanguie, 2022; Morsanyi et al., 2019). In the present results, irrational beliefs tended to vary by grade level and achievement, which is consistent with the view that belief systems are shaped by accumulated school experiences, perceived competence, and exposure to evaluative norms in mathematics classrooms (Desoete & De Craene, 2019; Li & Yuan, 2022; Li et al., 2022).

Implications For Mathematics Instruction and Student Support

The findings reinforce a cognition–affect integration perspective: metacognitive awareness in mathematics is strengthened by students’ engagement behaviors (risk-taking) and weakened by maladaptive belief structures (Efklides, 2008; Efklides & Metallidou, 2020). Practically, interventions can target both pathways. First, instructional designs that explicitly teach planning, monitoring, evaluation routines and encourage reflective dialogue can strengthen metacognitive regulation and strategic transfer (Armbruster & Brown, 1984; Hartman, 2001; Pintrich, 2002; Winne & Azevedo, 2014). Second, “error-friendly” pedagogies and structured opportunities for revision may increase productive academic risk-taking by reframing uncertainty as a normal

component of mathematical inquiry (Beghetto, 2021; Zohar & Barzilai, 2013). Third, belief-focused supports such as cognitive reframing consistent with REBT principles may help reduce irrational beliefs that undermine persistence and self-regulation, especially when linked to test anxiety and threat appraisals (Dryden & Ellis, 2001; Zhou et al., 2022).

Limitations and Future Research

Because the study used a cross-sectional, correlational design, results should be interpreted as predictive associations rather than causal effects (Creswell & Creswell, 2017; Karasar, 2022). In addition, measures were self-report, which captures perceived tendencies rather than real-time regulatory behavior; future work could incorporate performance-based or process measures (e.g., think-alouds, observational coding, or online monitoring indicators) to strengthen validity (Veenman & van Cleef, 2019; Winne & Azevedo, 2014). Finally, the convenience sample limits generalizability; replication across different school contexts and instructional climates would clarify how classroom norms and feedback practices shape the risk–belief–metacognition nexus (Fraenkel et al., 2012).

Conclusions and Implications

This study explored the cognitive–affective predictors of metacognitive awareness in mathematics learning among lower-secondary school students. The findings indicate that mathematics-focused academic risk-taking is a significant positive predictor of metacognitive awareness, whereas irrational mathematics beliefs function as a significant negative predictor. Together, these results highlight that students’ engagement with challenge and their belief systems are meaningfully associated with how they monitor and regulate their thinking in mathematics.

The findings reinforce a cognition–affect integration perspective, suggesting that metacognitive awareness does not develop solely from cognitive maturation but is closely intertwined with students’ behavioral engagement and evaluative interpretations of failure. Students who are willing to take intellectual risks appear more likely to engage in planning, monitoring, and strategy revision processes, whereas rigid and absolutist beliefs about mathematics may shift attention away from reflective regulation toward self-protective avoidance. These results extend existing metacognitive frameworks by empirically demonstrating that both adaptive engagement tendencies and maladaptive belief structures are associated with metacognitive functioning in mathematics contexts.

From an educational perspective, the findings suggest that supporting metacognitive development requires attention to classroom climate and belief systems in addition to explicit strategy instruction. Error-friendly pedagogical practices, opportunities for productive struggle, and reflective dialogue may foster academic risk-taking and strengthen regulatory awareness. At the same time, instructional approaches that challenge irrational beliefs about ability, failure, and control may help prevent affective barriers that undermine self-regulated learning.

Importantly, the cross-sectional and correlational design does not permit causal conclusions. The observed relationships should therefore be interpreted as predictive associations rather than directional effects. Future longitudinal and experimental research is needed to determine whether increasing academic risk-taking or reducing irrational beliefs causally enhances metacognitive awareness and mathematics achievement, or whether reciprocal dynamics better explain these relationships.

Overall, this study contributes to mathematics education research by demonstrating that metacognitive awareness is shaped not only by cognitive processes but also by students’ willingness to engage with uncertainty and their interpretations of error and ability. Supporting

students' development in mathematics therefore requires a balanced focus on cognitive strategy instruction and adaptive affective dispositions.

Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and relevant national regulations. Ethical approval for the study was obtained from the Social and Humanities Ethics Committee Committee], [Çanakkale Onsekiz Mart University] (Approval No: [E-84026528-050.01.04-2200301370-22/44], Date: [16.12.2022]). In addition, permission to conduct the research in the participating schools was granted by the [İstanbul Province] Provincial Directorate of National Education, which is the competent authority responsible for all public schools in the province (Official Permission No: [E-59090411-44-68585836], Date: [17.01.2023]).

Consent for publication

This manuscript does not contain any individual person's data in any form (including images, videos, or other identifying personal details).

Availability of data

The datasets are available from the corresponding author upon reasonable request.

Authors' contributions

All authors contributed to the conception and design of the study. Material preparation, data collection, and statistical analyses were performed by [FTT] and [DG]. [FTT], as a master's student, conducted the research and drafted the initial version of the manuscript. [DG] supervised the study, contributed to data interpretation, and critically revised the manuscript for important intellectual content. Both authors read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Competing interests

The authors declare that they have no competing interests.

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