




The impact of academic pressure on mathematical academic achievement in middle school students: A perspective based on mediation effects

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ABSTRACT

Objective: This study explores how academic pressure affects middle school students' mathematical academic achievement, focusing on the mediating roles of academic self-concept and academic engagement.

Results: A survey of 454 students from two schools in Yunnan province collected data on academic pressure, self-concept, engagement, and achievement. Mediation analysis was performed using Model 6 in the SPSS PROCESS macro. Results showed a significant negative correlation between academic pressure and mathematical academic achievement. Academic self-concept partially mediated this relationship, while a chain mediation effect involving both academic self-concept and engagement was also found. These findings suggest that reducing academic pressure, while strengthening students' academic self-concept and engagement, can improve mathematical academic achievement.

Conclusions: The study provides empirical support for educational strategies aimed at enhancing students' academic performance in mathematics.

1. Introduction

Mathematics, as a scientific tool, uses abstract symbols and formulas to precisely express and analyze objective phenomena (Skansi et al., 2023). It serves as a vital means for humans to understand the world and solve problems. In middle school education, the importance of mathematics cannot be overlooked. It not only forms the foundation for developing students' logical thinking and problem-solving skills but also serves as a prerequisite for further studies in natural sciences such as physics and chemistry (Alivio et al., 2024). Achievement emotions refer to the emotional responses of students related to their learning outcomes, such as pride in success or frustration in failure (Wang, Wu, & Wang, 2024). These emotions have a profound impact on students' self-efficacy and academic performance (Wang, Wang, et al., 2024). Therefore, positive mathematics learning experiences not only enhance students' confidence and self-efficacy but are also crucial in fostering a positive learning attitude (Khasawneh et al., 2021). Mathematical academic achievement (MAA) is typically measured through mathematics test scores, problem-solving abilities, and the level of understanding of mathematical concepts. It reflects students' proficiency in mathematical knowledge and skills (Balsamo et al., 2019). MAA not only indicates

students' proficiency in mathematical knowledge and skills but also significantly influences their personal growth, future educational opportunities, and career prospects. Students with higher MAA often gain access to a broader range of educational choices, particularly in science, technology, engineering, and mathematics (STEM) fields. The demand for talent in these areas continues to grow with the advancement of society (Leyva et al., 2022). Students with a strong foundation in mathematics are more likely to secure desirable employment opportunities. Conversely, poor MAA not only negatively impacts their current learning but may also lead to a series of adverse long-term consequences. For example, prolonged low achievement in mathematics may result in psychological issues, including anxiety and depression (Gedda-Muñoz et al., 2023), and significantly reduce students' confidence (Çiftçi & Yıldız, 2019). This decline in confidence can, in turn, contribute to a broader decrease in overall academic performance (Chue, 2020). In conclusion, MAA plays a crucial role in middle school students' personal development, mental health, social adaptability, and future educational and career opportunities. Therefore, it is essential to gain a deeper understanding of the key factors and potential mechanisms influencing MAA. This study, for the first time, explores the chain-mediating effects of academic self-concept and academic engagement in the relationship

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between academic pressure and MAA. These insights not only help educators design more effective teaching strategies to improve students' academic performance but also provide a solid foundation for supporting their mental health and overall development.

2. Literature review

2.1. Academic pressure and mathematical academic achievement

Academic pressure (AP) refers to the psychological and physiological stress responses that students experience during the learning process due to factors such as academic workload, examination demands, competitive pressure, and expectations from parents and teachers (Wijaya et al., 2022). In the context of Chinese culture, AP is particularly prominent. Influenced by Confucian traditions, there is a widespread societal emphasis on educational achievement, and the high expectations of parents and teachers cause students to endure significant pressure from the early stages of their education (Ye et al., 2019). The study by Chyu and Chen (2022b) on the correlational factors of AP among Chinese middle school students indicates that sociocultural pressures not only increase students' AP but also potentially lead them to focus excessively on external evaluations, neglecting their intrinsic academic interests and emotional needs. This, in turn, affects their MAA. AP also contributes to emotional fluctuations, anxiety, and physical health problems, all of which can impact academic performance (Gao, 2023). For example, Han et al. (2024) in their research on AP, learning anxiety, and burnout among Chinese middle school students demonstrate that AP can trigger negative emotions such as anxiety, tension, and depression, leading to a sense of burnout in learning. This directly impacts students' learning efficiency and academic performance. Particularly in mathematics, a subject requiring high concentration and deep thinking, emotional fluctuations may result in issues such as lack of focus, memory decline, and blocked problem-solving strategies (Lin & Yin, 2024). Additionally, AP may also influence MAA through physiological pathways (Cho & Kim, 2024; Park et al., 2025). For example, Cho and Kim (2024) in their study on the negative impact of cortisol on AP in Korean students indicates that AP increases cortisol levels, a stress-related hormone, which inhibits cognitive function and reduces learning efficiency. However, existing research predominantly focuses on overall student achievement or achievement in other subjects, while studies specifically examining MAA remain relatively scarce. Moreover, within the Chinese cultural context, research on how AP specifically affects MAA remains a gap. Therefore, it is crucial to explore this relationship and its potential mechanisms.

2.2. The potential mediating role of academic self-concept

Academic self-concept (ASC) describes students' perceptions of their own abilities and behaviors in academic domains, reflecting their views on academic experiences and progress (Supervía et al., 2020). Studies have shown that students with a positive ASC tend to perform better in academic achievement compared to those with a negative ASC (Das et al., 2024; García-Martínez et al., 2021; Liu et al., 2022). Mathematics is a subject that requires high concentration and long-term commitment. Liu et al. (2022) conducted a study on the relationship between ASC and Chinese middle school students' enjoyment of math learning. Their findings indicate that in the process of learning mathematics, a positive ASC can stimulate students' interest in math, leading to higher levels of focus and enthusiasm. This, in turn, enhances their motivation to learn and Academic engagement, ultimately improving their MAA. Stable emotions are particularly important for mathematics, a subject that demands high logical thinking and abstract reasoning abilities. A positive ASC is often associated with better emotional regulation skills (Yang & Park, 2023). For example, Zhang et al. (2023) conducted a study on Chinese middle school students' ASC, anxiety, and Mathematical achievement. Their results show that students with a positive ASC are

able to stay calm and avoid emotional fluctuations that might negatively affect their math learning process when facing academic challenges. In contrast, students with a negative ASC are more likely to experience excessive anxiety due to a lack of self-confidence, which can, in turn, negatively impact their MAA.

AP, as one of the main sources of stress for middle school students, can influence their ASC through various pathways (Xu et al., 2024). When students face excessive AP, they often begin to doubt their academic abilities. Specifically, high levels of AP lead students to attribute academic failure to a lack of personal ability, while ignoring external factors or inappropriate learning strategies. This attribution style negatively impacts their ASC, which in turn affects their motivation to learn and emotional state (García-Martínez et al., 2023). AP also leads students to experience negative emotions such as anxiety and depression, which further weaken their ASC and make them feel unable to cope with academic challenges. For instance, a longitudinal study by Hwang and Kim (2021) on the relationship between ASC and AP among elementary to middle school students shows that AP increases over time, which not only weakens students' confidence but also lowers their ASC. Moreover, according to the Control-Value Theory, students' sense of control over academic tasks and their value evaluation directly affects their emotional experiences and academic performance. Students with a positive ASC typically have a higher sense of control over their abilities and assign positive value to academic tasks, enabling them to manage AP and anxiety more effectively, which is crucial for AP (Lee, 2022). Therefore, this study suggests that ASC has the potential to mitigate the negative impact of AP on MAA.

2.3. The potential mediating role of academic engagement

Academic engagement (AE) refers to the proactive attitudes and participation demonstrated by students during the learning process. It typically encompasses three dimensions: behavioral, emotional, and cognitive. These aspects are reflected in students' attendance, completion of assignments, classroom participation, interest in learning, positive emotions, and deep thinking and understanding of academic content (Chen et al., 2023). Prior research has revealed a strong positive relationship between AE and academic achievement (Putwain & Wood, 2023; Shao et al., 2024; Zeng et al., 2023). For instance, Putwain and Wood (2023) found in their research on mathematics learning that students who actively participated in class discussions, collaborated with peers, and even completed additional exercises exhibited better mastery of mathematical knowledge and skills, ultimately enhancing their MAA. Additionally, Widlund et al. (2021) focusing on middle and high school students, investigated the association between AE and academic burnout and its influence on students' mathematics performance. Their results revealed that students interested in mathematics were generally more actively engaged in learning, which, in turn, further promoted their MAA. Among middle school students, AE is also evident in their in-depth analysis of mathematical problems, the selection of problem-solving strategies, and reflection on outcomes. Maamin et al. (2022) linked middle school students' AE with their mathematics performance, finding that students who actively engaged in learning tended to employ higher-order thinking skills in problem-solving processes. This deep learning approach contributed significantly to improved mathematics performance.

Previous research has demonstrated a negative relationship between AP and AE (Alkharj et al., 2024; Sinval et al., 2025; Vargas et al., 2024). According to self-determination theory, fulfilling the three basic psychological needs of competence, autonomy, and relatedness is crucial for sustaining intrinsic motivation, which in turn effectively promotes AE (Chyu & Chen, 2022a). However, research by Zhao et al. (2021) suggests that when students face excessive AP, they may feel that these academic needs are not being met, leading to feelings of incompetence and a lack of confidence in their academic success. At the same time, due to psychological distress, they may struggle to establish normal social

connections with their peers, resulting in the unmet fulfillment of these three basic psychological needs. Furthermore, according to the Stress-Coping Theory, AP may become a major stressor for students, and how they cope with this pressure will impact their AE and academic achievement. If students fail to cope effectively with AP, it may lead to emotional issues, physical discomfort, and other problems, which can negatively affect their motivation to learn and academic performance (Mukesh et al., 2023). For example, in a study on the relationship between AP and AE, Vansoeterstede et al. (2024) found in their study on the relationship between AP and AE that excessive AP is often associated with lower self-esteem and higher levels of depression symptoms. Additionally, students are more likely to experience fatigue and insomnia. These issues not only affect physical and mental health but also interfere with cognitive function, making it difficult for students to concentrate on their studies. Hence, this study hypothesizes that the impact of AP on middle school students' MAA is related to AE.

2.4. The potential chain-mediating role of ASC and AE

According to existing literature, most studies focus on the isolated effects among ASC, AE, AP, and academic achievement. Researches have consistently shown that a positive ASC is significantly positively correlated with higher AE (Schnitzler et al., 2021; Zhang, 2024; Zhang et al., 2022). The self-system model of motivation suggests that an individual's motivation is not only a result of external rewards and punishments but also the outcome of interactions among various parts of the internal self-system, such as self-concept, self-efficacy, and emotional responses (Connell & Wellborn, 1991). When students have a positive self-evaluation and their basic needs are met, they engage in learning actively on behavioral, cognitive, and emotional levels, and this engagement ultimately enhances academic performance. Therefore, self-system processes indirectly influence academic achievement through students' engagement (Schnitzler et al., 2021). At the same time, Zhang (2024) in his study on the impact of ASC and student engagement in Chinese adolescents pointed out that students with a strong ASC tend to demonstrate greater resilience when faced with classroom setbacks and challenges, leading to more active participation in learning activities, which in turn promotes academic achievement. Thus, not only do ASC and AE individually influence academic achievement, but their potential chain-mediating effect also warrants attention. This study aims to further explore how AP affects middle school students' MAA through the chain-mediating effects of ASC and AE. Identifying these adjustable factors is expected to provide new intervention strategies for alleviating AP among middle school students and improving their MAA.

3. Current research

This study is the pioneering research to explore the mediating roles of ASC and AE in the relationship between AP and MAA among middle school students. Based on prior empirical studies, we proposed a theoretical hypothesized model, as shown in Fig. 1, and tested the following hypotheses: (1) AP is significantly negatively correlated with MAA among middle school students. (2) ASC mediates the relationship

between AP and MAA among middle school students. (3) AE mediates the relationship between AP and MAA among middle school students. (4) AP alleviates its impact on MAA through the chain-mediating roles of ASC and AE.

3.1. Methodology

3.1.1. Sample and data collection

This study collected data using anonymous electronic questionnaires distributed via the online platform Sojump (www.sojump.com) between June 15 and September 25, 2024. The project was conducted anonymously, utilizing digital questionnaires to attract participants. Data collection commenced only after ensuring that each respondent fully understood the research purpose and consented to participate. Given that the target population was middle school students, participants were randomly selected from QL Middle School and LP Middle School in X City, Yunnan Province. The research team first communicated with teachers from both schools, who explained the survey's significance and objectives to the students during class. Teachers then shared the questionnaire link in class communication groups, allowing students to decide whether to participate after school, with parental consent and based on their own willingness. Only responses from students who completed all questionnaire items without duplicate submissions were included in the final data analysis. The survey covered various aspects of respondents' information, such as grade level and household registration location. A total of 454 valid responses were collected. Of these, 54.0 % were male and 46.0 % were female. The majority of participants were in the seventh (45.6 %) and eighth grades (42.7 %), with most students coming from rural areas. Ethical approval for this study was obtained from the Ethics Committee of Qujing Normal University (Approval Number: QJNU-STE-2024-520), and all research procedures adhered to relevant ethical guidelines and standards. For more details on demographic characteristics, please refer to Table 1.

3.2. Measurement

3.2.1. Academic pressure

This study utilized the Academic Pressure Scale revised by Chyu and Chen (2022a), specifically designed for East Asian middle school students to assess their AP. The scale consists of 17 items across four dimensions, AP from parental expectations (5 items), AP from teacher expectations (3 items), AP from self-expectations (6 items) and Excessive demands (3 items). For example, "My method of learning mathematics is inadequate." This study employed a 5-point Likert scale, ranging from 1 ("strongly disagree") to 5 ("strongly agree"). Higher scores on the scale indicate greater levels of AP among students. The Cronbach's α coefficient for the Academic Pressure Scale in this study was 0.844.

3.2.2. Academic self-concept

This study assessed middle school students' ASC using the Academic Self-Concept Subscale from the School Attitude Assessment Survey (Arslan, 2021). The scale consists of 5 items. For example, "I find it easy to do my homework." Although the number of items is relatively small, it has been proven to exhibit good reliability, high unidimensionality,

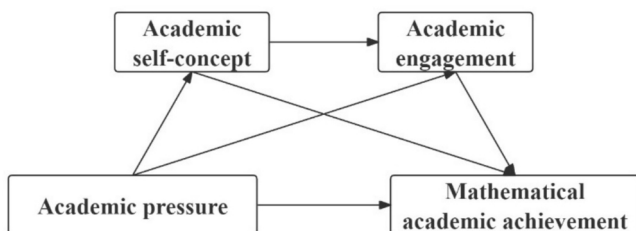


Fig. 1. Hypothetical model.

Table 1
Demographic characteristics of the sample.

Demographic characteristic	Category	Number	Percentage
Gender	Male	245	54.0 %
	Female	209	46.0 %
Grade	Seventh	207	45.6 %
	Eighth	194	42.7 %
	Ninth	53	11.7 %
	Tenth	0	0.0 %
Household registration	Rural	309	68.1 %
	Urban	145	31.9 %

and satisfactory fit indices (González-Nuevo et al., 2023). The study utilized a 5-point Likert scale, ranging from 1 (“strongly disagree”) to 5 (“strongly agree”). Higher scores indicate a more positive ASC among students. In this study, the Cronbach’s α coefficient for the Academic Self-Concept Scale was 0.864.

3.2.3. Academic engagement

This study used the Academic Engagement Scale, developed by Schaufeli et al. (2002) and translated and revised by Chinese scholars (Li et al., 2022; Meng & Zhang, 2023), to assess middle school students’ AE. The scale consists of 17 items, divided into three dimensions, vigor (6 items), dedication (5 items), and absorption (6 items). For example, “As soon as I wake up in the morning, I am eager to study.” Given the study’s focus on the relationship between AE and middle school students’ MAA, the scale was partially modified to suit the research needs, and its reliability and validity were re-verified. The scale employs a 5-point Likert scale, ranging from 1 (“strongly disagree”) to 5 (“strongly agree”). Higher scores indicate greater levels of AE. In this study, the Cronbach’s α coefficient for the Academic Engagement Scale was 0.934.

3.2.4. Mathematical academic achievement

The assessment of students’ MAA is typically conducted using their performance on standardized mathematics tests (Balsamo et al., 2019; Huang et al., 2021; Starling-Alves et al., 2024). Specifically, this study first collected student questionnaire data between June 15 and September 25, 2024, covering measurements of PA, ASC, and AE. After the students completed their final exams, their grades were officially released in late September, and the research team obtained their mathematics scores from the school’s academic management department.

3.3. Statistical analysis

First, the reliability and validity of the adapted Academic Engagement Scale were examined using Cronbach’s α coefficient and factor analysis. Subsequently, data analysis was conducted using SPSS version 26.0. First, common method bias analysis was performed on the scales used in this study. Then, the relationships among AP, ASC, AE, and MAA were examined using Spearman correlation analysis. Finally, mediation analysis was conducted using the bootstrap method in the SPSS PROCESS macro. Model 6 was chosen for the mediation analysis, with AP (X) as the independent variable, ASC (M1) and AE (M2) as mediators, and MAA (Y) as the dependent variable. The statistical significance of the mediators was set at a 95 % confidence interval (CI), using 5000 bootstrap samples (Fang et al., 2024; Preacher & Hayes, 2008). A significant mediation effect was determined if the bias-corrected bootstrap 95 % CI did not include zero, indicating statistical significance at the $\alpha = 0.05$ level (Hayes & Rockwood, 2017).

4. Results

4.1. Reliability and validity of the academic engagement scale

The Academic Engagement Scale demonstrated good reliability and validity in this study. The reliability test results showed that the Cronbach’s α coefficient for the Academic Engagement Scale was 0.934, indicating excellent reliability. The validity test results showed a KMO

Table 2
KMO and Bartlett’s test.

AE		
KMO measure of sampling adequacy	0.962	
Bartlett’s test of sphericity	Chi-square	3348.250
	Degrees of freedom	78
	Significance (p-value)	0.000

value of 0.962, and the Bartlett’s test of sphericity yielded $P = 0$, suggesting that the scale is suitable for factor analysis (see Table 2). Additionally, the factor analysis results indicated that all items were well-explained by the factor model, demonstrating good validity for the scale.

4.2. Common method bias (CMB) and multicollinearity tests

This study employed Harman’s single-factor test and the marker variable technique to assess CMB. Exploratory factor analysis identified 27 factors with eigenvalues exceeding 1. The variance explained by the first factor was 33.3 %, which falls below the critical 40 % threshold, indicating the absence of severe common method bias in the dataset (Ibikunle et al., 2021). Additionally, to test for multicollinearity, the study used Variance Inflation Factor (VIF) and Tolerance as diagnostic tools to ensure that no significant multicollinearity existed among the independent variables in the chain mediation model. The results revealed that the highest VIF value for the independent variables was 2.975, and the lowest Tolerance value was 0.336, indicating that the correlations among the independent variables did not pose a multicollinearity problem. Therefore, from a statistical perspective, there is no severe multicollinearity among the independent variables in this study (Cheah et al., 2021).

4.3. Descriptive and correlation analysis

To examine the research hypotheses, the mean, standard deviation, and correlation coefficients for each variable were computed. The detailed results are shown in Table 3. Significant relationships were found among the variables, AP was significantly negatively correlated with ASC ($r = -0.337, P < 0.001$), AE ($r = -0.311, P < 0.001$), and MAA ($r = -0.197, P < 0.001$). ASC was significantly positively correlated with AE ($r = 0.810, P < 0.001$) and MAA ($r = 0.381, P < 0.001$). AE was significantly positively correlated with MAA ($r = 0.398, P < 0.001$). Therefore, H1 was supported.

4.4. Mediation effect analysis

The regression analysis results are presented in Table 4. AP had a significant negative effect on ASC ($\beta = -0.337, P < 0.001$), while its effect on AE was not statistically significant. At the same time, ASC had a significant positive effect on AE ($\beta = 0.795, P < 0.001$). Furthermore, the direct effect of AP on MAA was not significant. However, ASC ($\beta = 0.155, P < 0.05$) and AE ($\beta = 0.252, P < 0.001$) were both significant predictors of MAA.

As shown in Table 5 and Fig. 2, the effect value of indirect path 1 was -0.052 (95 % CI: $[-0.112, 0.003]$), the effect value of indirect path 2 was -0.011 (95 % CI: $[-0.033, 0.004]$), and the effect value of indirect path 3 was -0.068 (95 % CI: $[-0.117, -0.026]$), the total indirect effect accounted for 66.5 % of the variance. Thus, in the hypothesized model of this study, H2 and H4 were supported, while H3 was not supported.

5. Discussion

This study employed a chain mediation model to investigate the effects of AP, ASC, and AE on middle school students’ MAA, while also

Table 3
Mean, standard deviation, and correlation coefficients of each variable.

Variable	M	SD	AP	ASC	AE	MAA
AP	3.105	0.659	1	−0.337***	−0.311***	−0.197***
ASC	3.517	0.949		1	0.810***	0.381***
AE	3.447	0.906			1	0.398***
MAA	77.578	19.722				1

Note: $N = 454$.
*** $P < 0.001$, similarly hereinafter.

Table 4
Regression analysis of variables in the chain mediation model.

Outcome variable	Predictor variable	β	SE	T	CI(95 %)		R ²	F
					LLCI	ULCI		
ASC	AP	−0.337***	0.044	−7.609	−0.424	−0.250	0.114	57.894***
	AE	−0.043	0.029	−1.457	−0.100	0.015		
AE	ASC	0.795***	0.029	27.176	0.738	0.853	0.657	432.814***
	AP	−0.066	0.046	1.453	−0.023	0.156		
MAA	ASC	0.155*	0.074	−2.094	−0.300	−0.010	0.173	31.289***
	AE	0.252***	0.073	−3.442	−0.396	−0.108		

*** $P < 0.001$, similarly hereinafter.

Table 5
Mediation effect analysis of ASC and AE.

Effect	Path	Estimated	Percentage	CI(95 %)	
				LLCI	ULCI
Total effect	AP → MAA	−0.197	100 %	−0.106	−0.197
Direct effect	AP → MAA	−0.066	33.5 %	0.023	−0.066
	AP → ASC → MAA	−0.052	26.4 %	−0.112	0.003
Indirect effect	AP → AE → MAA	−0.011	5.6 %	−0.033	0.004
	AP → ASC → AE → MAA	−0.068	34.5 %	−0.117	−0.026

Note: The specific indirect effect paths are as follows: Indirect path 1: AP → ASC → MAA. Indirect path 2: AP → AE → MAA. Indirect path 3: AP → ASC → AE → MAA.

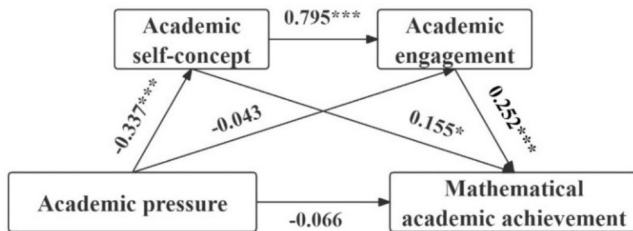


Fig. 2. Sequential intermediary model.

exploring the mediating roles of these variables. By reviewing existing literature, the study hypothesized that AP, ASC, and AE have significant impacts on MAA. Furthermore, ASC and AE were proposed to play simple mediation and chain mediation roles, respectively, in the association between AP and MAA. Using SPSS to test the model, the results indicated that excessive AP reduces students' MAA. However, enhancing the positivity of ASC can alleviate the adverse impacts of AP on MAA. Additionally, the chain mediation effect of ASC and AE further alleviates the impact of AP on MAA. These findings provide a novel theoretical perspective on how AP affects students' MAA by influencing psychological and behavioral factors. They also offer valuable insights for developing intervention strategies in educational practice.

5.1. The relationship between AP and MAA among middle school students

The findings of this study indicate that AP is significantly negatively correlated with MAA among middle school students, supporting H1. This finding aligns with previous research, suggesting that excessive AP can result in emotional distress, including anxiety, tension, and fatigue. These emotional responses can impair students' learning efficiency and ability to concentrate, thereby reducing their MAA (Wijaya et al., 2022). AP can disrupt students' learning strategies, particularly in high-pressure environments, where students are more likely to adopt coping-oriented learning approaches rather than deep learning. Thereby impacting MAA (Zimmer-Gembeck et al., 2023). Moreover, AP

potentially affects the psychological state and learning motivation in middle school students. When AP becomes excessive, students may experience self-doubt and low self-esteem, particularly when facing academic challenges. A lack of confidence and motivation under such circumstances can hinder their ability to maintain sustained engagement in mathematics learning (Liu, 2024). This psychological state not only weakens students' ability to cope with challenges but also exacerbates academic anxiety, ultimately affecting their MAA (Xu et al., 2022). In addition, excessive AP may disrupt students' time management, leading them to devote excessive energy to mathematics study or review while neglecting rest and relaxation. This imbalance can result in physical and mental exhaustion, thereby undermining students' focus and efficiency in mathematics learning and further reducing their MAA (Lin et al., 2020).

5.2. The mediating role of ASC

This research confirmed that ASC acts as a mediator in the association between AP and MAA among middle school students, supporting H2. In other words, AP not only directly affects MAA but also mitigates its negative impact through a positive ASC. This finding aligns with previous studies, which have shown that excessive AP can lead to a negative ASC, causing students to lose confidence, reduce effort, and ultimately impair their MAA (Das et al., 2024; García-Martínez et al., 2023). When students experience excessive pressure, they may develop negative evaluations of their mathematical abilities, perceiving themselves as less capable or unfit for mathematical tasks. Such a negative ASC significantly undermines students' motivation and their ability to employ effective learning strategies (Wang & Yu, 2023). Specifically, a negative ASC often causes students to lack confidence in mathematics learning, leading to reduced effort and commitment. For example, they may be unwilling to actively participate in class discussions, hesitate to seek help proactively, or avoid engaging in effective learning strategies such as regular review and self-reflection. The absence of these behaviors directly undermines their ability to cope with the challenges of mathematics learning (Sunu & Baidoo-Anu, 2024). Additionally, a negative ASC may drive students to adopt avoidance behaviors in mathematics learning. They may, due to a lack of confidence, abandon challenging mathematical tasks or opt to complete only basic-level assignments. Such avoidance behaviors further limit students' deep understanding of mathematical knowledge and hinder their skill development, creating a negative cycle that ultimately leads to a decline in MAA (Peters et al., 2020).

5.3. The mediating role of AE

The findings of this research reveal that AE does not serve as a mediator in the association between AP and MAA in middle school students, which does not support H3. Previous researches have shown that AP is negatively correlated with AE, while AE is positively associated with MAA (Alkharj et al., 2024; Putwain & Wood, 2023). The different outcome in this study could be explained by the fact that although students exhibit a certain degree of AE, excessive pressure

triggers emotional disturbances, which weaken the positive effects of AE. When students experience high levels of pressure, they are more likely to fall into negative emotional states and anxiety, which can interfere with their focus and efficiency in mathematics learning (Alkharj et al., 2024). Moreover, from the perspective of subject characteristics, mathematics learning requires strong logical thinking abilities and long-term accumulation of knowledge. Surface-level AE, such as completing assignments mechanically or engaging in short-term exam-focused review, is insufficient for substantial improvement in academic achievement. In high-pressure environments, some students may demonstrate coping-oriented AE, such as completing daily assignments or reviewing for exams, but such engagement often lacks the characteristics of deep learning, which are essential for the long-term exploration and in-depth understanding required in mathematics (Reinhold et al., 2021). Finally, although there was no significant relationship between AP and AE, we believe this non-significant result may partly stem from the high correlation between ASC and AE. ASC may influence students' AE, and vice versa, with both variables collectively affecting students' learning attitudes and behaviors (Zhang, 2024). Therefore, AP might indirectly influence AE by affecting ASC, rather than having a direct significant impact.

5.4. The chain mediation role of ASC and AE

The findings of this study indicate that ASC and AE serve a chain mediation role in the relationship between AP and MAA in middle school students, with the effect size of this pathway representing 34.5 % of the total effect. In other words, a positive ASC promotes students' AE, which further mitigates the negative impact of AP on MAA. Conversely, the greater the AP perceived by middle school students, the more negative their ASC becomes, leading to lower levels of AE and, ultimately, lower MAA. Previous studies have shown that students who are under prolonged AP often begin to doubt their academic abilities, resulting in a negative ASC (García-Martínez et al., 2023). A negative ASC may manifest as fear and aversion to mathematics learning, leading students to avoid participation in class, complete assignments in a perfunctory manner, or even avoid challenging tasks. Furthermore, students may refuse to try new problem-solving strategies or engage in deep thinking about complex problems due to a lack of confidence, which weakens the effectiveness of their AE (Schnitzler et al., 2021). Insufficient AE directly affects students' depth of understanding and ability to apply mathematical knowledge, thus reducing their MAA (Shao et al., 2024). This study further demonstrates that when AP reduces students' AE through a negative ASC, the effectiveness of mathematics learning is significantly diminished.

6. Implications and limitations

6.1. Implications

Overall, this research is the first to investigate the impact of AP, ASC, and AE on middle school students' MAA. It confirmed the significant negative correlation between AP and MAA and successfully revealed the mediating effect of ASC in the connection between AP and MAA and the chain mediation effect of ASC and AE in this relationship. These results offer theoretical foundation and practical guidance for developing more targeted educational interventions.

Theoretically, this study reveals the indirect pathways through which AP affects MAA via ASC and AE, using a chain mediation model. This provides a new perspective for existing theories. The simple and chain mediation effects of ASC and AE suggest that AP not only directly affects MAA but also exerts an indirect influence through complex psychological and behavioral factors. This exploration fills a gap in understanding the multi-level mediation mechanisms in research on AP among middle school students. As a key psychological variable, ASC plays a critical role in alleviating the negative impact of AP, while AE, as

a behavioral variable, contributes to the chain mediation effect along with ASC. This finding enhances our understanding of how psychological and behavioral factors jointly affect MAA and provides new insights for future research that integrates both psychological and behavioral factors.

Practically, this study suggests that although some schools have already implemented psychological health education programs or academic counseling strategies to help students alleviate pressure, further optimization of intervention measures is still needed. Schools should increase their focus on AP among middle school students by designing course difficulty and task intensity in a way that helps students approach academic challenges in a more positive manner. Additionally, attention should be paid to fostering students' positive ASC, enhancing their academic confidence through positive feedback and personalized support, and stimulating their learning motivation. Schools and teachers can assist students in improving their self-perception of abilities through group counseling or cognitive restructuring activities. Schools and teachers also should monitor students' level of AE, and design more interactive and engaging learning activities to increase students' focus and participation in academic tasks. For instance, through learning strategy training or diverse after-school tutoring, students can be assisted in improving their study methods and their ability to manage academic tasks. These strategies not only effectively mitigate the negative impact of AP on middle school students' MAA but also provide strong support for their long-term academic development.

6.2. Limitations and future research directions

This study contributes to understanding the underlying mechanisms through which AP, ASC, and AE affect middle school students' MAA. Despite its significant findings, the study has several limitations. First, while the Bootstrap method indicates that ASC partially explains the connection between AP and MAA, the confidence interval of the indirect effect includes 0, which suggests it is not statistically significant. This may be due to multiple mediating pathways diluting the total effect in the model. Therefore, future research could explore potential moderating variables (such as gender or subject interest) to assess their impact on this effect. Second, the study primarily relies on cross-sectional data, which cannot reveal causal relationships or the long-term dynamic changes between variables. Future studies might utilize longitudinal designs to explore the long-term impacts of these relationships more thoroughly. Additionally, since this study used survey-based data collection, recall bias and social desirability bias cannot be entirely eliminated. Future studies could include diverse data collection techniques, such as observing behavior, interviews, or experimental designs, to validate the findings obtained from surveys. Finally, this study did not include demographic variables (such as gender, age, family background, etc.) as control variables. Therefore, future research could consider incorporating these control variables to further explore their potential impact on the relationships between AP and MAA.

7. Conclusion

This study proposes and systematically validates four key conclusions: (1) There is a significant negative correlation between AP and MAA in middle school students. (2) ASC mediates the relationship between AP and MAA. (3) AE does not mediate the relationship between AP and MAA. (4) Middle school students' AP alleviates its negative impact on MAA through the chain mediation effect of ASC and AE. This research expands the relationship model between AP and MAA in middle school students, revealing the chain mediation effect of ASC and AE in this relationship, thus enriching the academic understanding of the mechanisms underlying the impact of AP. Additionally, the study provides valuable insights for educational practice, suggesting that enhancing ASC and AE can effectively mitigate the negative effects of AP on MAA, thereby offering practical intervention strategies for schools

and educators.

CRediT authorship contribution statement

Likai Qian: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Conceptualization.

Informed consent

The participants received oral and written information and provided written informed consent before participating in the study.

Ethics approval

The researchers confirms that all research was performed in accordance with relevant guidelines/regulations applicable when human participants are involved (e.g., Declaration of Helsinki or similar). This study was approved by the Ethics Committee of Qujing Normal University (Approval Number: QJNU-STE-2024-520).

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Declaration of competing interest

The authors have no competing interests to declare that are relevant to the content of this article.

Data availability

Data will be made available on request.

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