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Structural Equation Modeling of Self-regulated Learning Strategies and Problem-solving with the Mediating Role of Metacognition among High School Students in Khorramabad

Yasin Bazgirpour[1], and Elham Heidari[2]

1. PhD Candidate, Department of Educational Management and Planning, Faculty of Educational Sciences and Psychology, Shiraz University, Shiraz, Iran. E-mail: yasin.bazgirp@hafez.shirazu.ac.ir
2. *Corresponding author*, Associate Professor, Department of Educational Management and Planning, Faculty of Educational Sciences and Psychology, Shiraz University, Shiraz, Iran. E-mail: eheidari@shirazu.ac.ir

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ABSTRACT

Objective: Self-regulated learning and problem-solving are recognized as essential for academic achievement, yet many students have not fully developed effective strategies in these areas. This study examined whether metacognition mediates the relationship between self-regulated learning strategies and problem-solving skills among senior high school students in Khorramabad. The study focused on understanding the cognitive mechanisms underlying these relationships within the local educational context.

Method: A descriptive-correlational design using structural equation modeling was employed. The sample consisted of 384 senior high school students selected through stratified random sampling. Data were collected using three standardized instruments: the Self-Regulated Learning Strategies Questionnaire, the Problem-Solving Inventory, and the Meta-Cognitions Questionnaire (adolescent version). Reliability and validity of the instruments were confirmed prior to analysis. The study examined the direct effect of self-regulated learning on metacognition and the mediating role of metacognition in problem-solving.

Results: The results indicated a significant direct effect of self-regulated learning strategies on metacognition ($\beta = .357$, $t = 5.785$) and a significant indirect effect on problem-solving through metacognition ($\beta = .528$, $t = 13.855$). The measurement and structural models demonstrated strong psychometric properties, with satisfactory factor loadings, composite reliability, and goodness-of-fit indices, confirming the stability and robustness of the observed relationships.

Conclusions: Findings confirm that metacognition serves as a key mediator in transmitting the influence of self-regulated learning strategies to problem-solving performance. The results underscore the importance of developing educational programs that simultaneously enhance self-regulatory and metacognitive skills to improve students' problem-solving abilities and academic outcomes.

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Introduction

Self-regulated learning and problem-solving are recognized as critical capacities for academic success and adaptation to contemporary educational challenges. Students who possess the ability to plan, direct, and evaluate their own learning processes tend to perform more effectively and successfully in educational settings (Bolori et al., 2024). Problem-solving skills contribute to deeper conceptual understanding and the application of knowledge in real-life contexts, thereby enhancing critical thinking (Caliskan & Altun, 2025; Pangaribuan et al., 2025). Nonetheless, evidence indicates that a considerable proportion of students have yet to master effective self-regulatory learning strategies and problem-solving methods (Nugraeni & Akhiriyah, 2025). Hence, identifying the cognitive and motivational factors influencing these constructs, especially in under-researched regions such as Khorramabad , is of paramount importance.

Recent studies emphasize that self-regulated learning encompasses cognitive, metacognitive, and motivational components and plays a pivotal role in academic progress (Arianto & Hanif, 2024). Effective self-regulation strategies enhance metacognition and intrinsic motivation, enabling learners to adopt systematic and analytical approaches when confronting complex problems (Ambaryani & Putranta, 2022; Cabrera & Distor, 2022). Problem-solving abilities heavily rely on the capacity to monitor and adjust mental strategies. Findings underscore the significance of metacognition as the connecting element between self-regulated learning and problem-solving, whereby mental processes regulation and performance evaluation increase the likelihood of success in problem resolution (Zhang et al., 2024; Zhao & Saleh, 2025). These relationships warrant further investigation within diverse contexts to develop more effective educational interventions.

Despite the expansion of international research on self-regulation, metacognition, and problem-solving, most studies have been conducted in non-Iranian educational systems (Siswati et al., 2025). Cultural and educational differences may affect the mechanisms of these variables. In Iran, particularly in Khorramabad, there is a paucity of research examining causal models and the mediating role of metacognition between self-regulated learning strategies and problem-solving skills. Thus, this study aimed to fill this gap by applying internationally validated theories, such as Zimmerman's self-regulation and Flavell's metacognitive frameworks, using structural equation modeling to analyze these relationships within a localized context (Yendi et al., 2025).

Previous research findings indicate that self-regulated learning strategies enhance metacognitive processes, ultimately boosting motivation and academic achievement (Ambaryani & Putranta, 2022; Cabrera & Distor, 2022). Also, it is shown that there is a positive and significant relationship between self-regulation and problem-solving skills (Zhao & Saleh, 2025;

Zhang et al., 2024). Metacognition as an intervening variable may improve problem-solving ability, and increases in self-regulation through metacognitive processes are expected to impact academic success. The findings of this study, hence, may contribute theoretically to educational psychology and provide a foundation for pragmatic interventions in Iranian schools.

The present study was designed to model the structural relationships among self-regulated learning strategies, metacognition, and problem-solving skills among secondary school students in Khorramabad. It investigated the direct effects of self-regulation on metacognition and examined metacognition's mediating role in problem-solving. Data were collected via standardized questionnaires and analyzed using specialized statistical software employing structural equation modeling (Arianto & Hanif, 2024). This approach enables concurrent analysis of multiple causal paths and model adequacy evaluation, providing deeper insights into the interplay of learning variables. Accordingly, the primary research question of this study was:

- Does metacognition act as a mediator in the relationship between self-regulated learning strategies and problem-solving skills among secondary school students in Khorramabad?

The conceptual model of the study is presented in Figure 1.

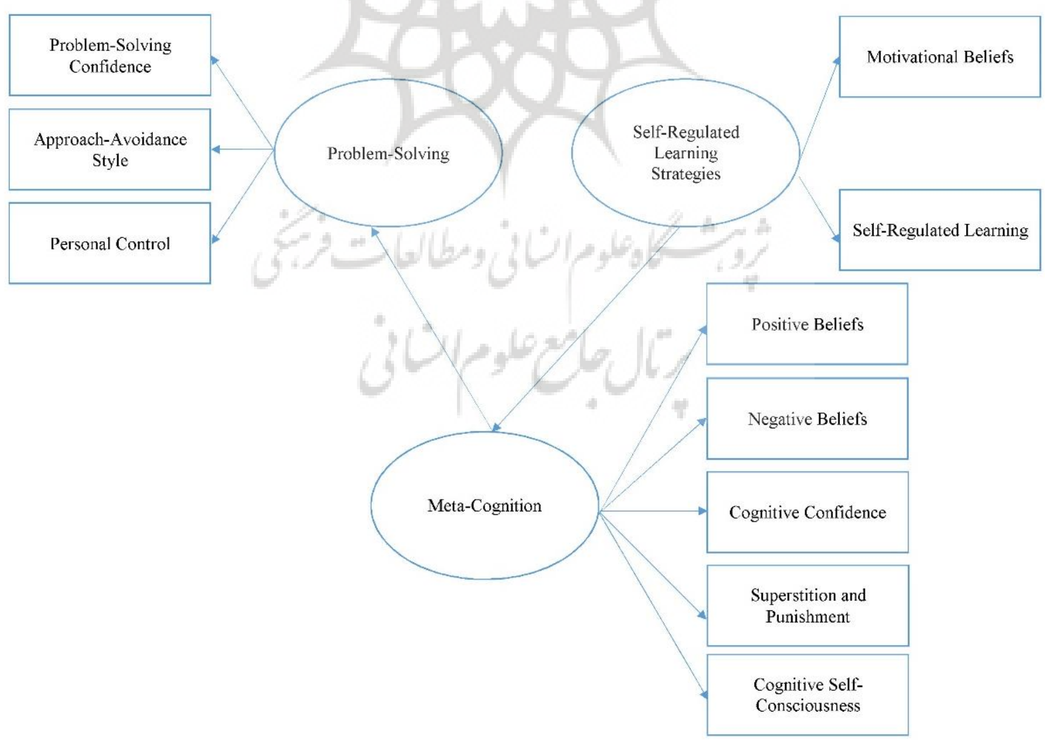

Figure 1. Conceptual model of the study

Materials and Methods

The present study was applied in terms of purpose; descriptive-correlational in data collection method, specifically of the structural equation modeling type; and quantitative in terms of data nature (Hassanzadeh et al., 2022; Khaljipour & Mojtabazadeh, 2024).

Participants

The statistical population of the present study consisted of all high school students (senior secondary school) in Khorramabad during the 2024–2025 academic year, totaling approximately 13,000 individuals. Considering the requirements of structural equation modeling—including the necessity of a minimum of 200 participants and maintaining a ratio of 5 to 10 participants per latent variable (Kline, 2023; MacCallum et al., 1999)—the sample size was determined accordingly. Ultimately, 384 students were selected as the study sample using a stratified random sampling method. In this research, the classification of students was carried out based on their fields of study. Of the total 384 students, 156 (40.6%) were enrolled in experimental sciences, 138 (35.9%) in mathematics and physics, and 90 (23.5%) in humanities. This distribution indicates that the field of experimental sciences had the highest frequency. The distribution of the sample across grade levels was as follows: 132 students (34.4%) in the first grade, 128 (33.3%) in the second grade, and 124 (32.3%) in the third grade. This distribution reflects a relatively balanced dispersion of students across grades, although the first grade included the highest number of participants.

Instruments

The research instruments consisted of the following:

Self-Regulated Learning Strategies Questionnaire

The Self-Regulated Learning Strategies Questionnaire developed by Pintrich and De Groot (1990) is a comprehensive tool designed to assess learning strategies and the motivational factors associated with them. The questionnaire consists of 47 items organized into two main sections: “Motivational Beliefs” and Self-Regulated Learning Strategies,” which encompass cognitive, metacognitive, and resource management strategies. The subscale of self-regulated learning strategies contains 22 items and evaluates three key components of academic self-regulation: cognitive strategies, metacognitive strategies, and resource management. Of these, 13 items assess cognitive strategies. The cognitive section includes items related to rehearsal (items 29, 37, and 44), elaboration (note-taking in item 34 and summarizing in items 31 and 45), organization (items 26, 27, 39, 42, and 47), and comprehension (items 32 and 33). The metacognitive and resource management section, comprising nine items, measures dimensions such as planning (items 38 and 46), monitoring (items 28, 35, 41, and 43), regulation and persistence (items 30 and

36), and activity regulation (item 40). In addition, the motivational beliefs section includes 25 items assessing constructs such as self-efficacy (items 2, 6, 9, 10, 12, 14, 19, 21, and 22), goal orientation (items 1, 4, 11, 16, and 24), intrinsic value (items 5, 8, 17, and 20), and test anxiety (items 3, 7, 13, 15, 18, 23, and 25). Scoring is based on a five-point Likert scale ranging from 1 (“strongly disagree”) to 5 (“strongly agree”). With 47 items, total scores range from 47 to 235: scores of 47–94 indicate limited use, 94–141 reflect moderate use, and scores above 141 indicate extensive use of self-regulated learning strategies. In determining the construct validity of the instrument, Pintrich and De Groot (1990) employed factor analysis and found that the motivational beliefs section comprised three factors: self-efficacy, intrinsic value, and test anxiety. The self-regulated learning strategies section contained two factors: cognitive strategies and metacognitive/resource management strategies. Reported reliability coefficients for the subscales were as follows: self-efficacy = .89, intrinsic value = .87, test anxiety = .75, cognitive strategies = .83, and metacognitive/resource management strategies = .74.

Problem Solving Inventory (PSI)

The Problem Solving Inventory (PSI) was initially developed by Heppner and Petersen (1982) but its full version was published in 1988 by Heppner (1988). It is a valid self-report instrument designed to assess an individual's perception of their problem-solving abilities. This questionnaire measures three main components: Problem-Solving Confidence (PSC), Approach-Avoidance Style (AAS), and Personal Control (PC). Various studies have demonstrated that the three-factor structure of the PSI is psychometrically stable, and both exploratory and confirmatory factor analyses have validated its construct validity. Furthermore, the instrument’s convergent validity has been confirmed through correlations with the Social Problem-Solving Inventory–Revised (SPSI-R) and other related tools such as self-efficacy scales, indicating strong content and construct validity of the PSI (D’Zurilla et al., 2002; Heppner & Goug-Gwi, 2002). The reliability of this questionnaire has also been reported as satisfactory across multiple studies. Heppner (1988) reported Cronbach’s alpha coefficients of .85 for Problem-Solving Confidence, .84 for Approach-Avoidance Style, .72 for Personal Control, and .90 for the total score. Test-retest reliability of the PSI over various time intervals has ranged from .83 to .89, indicating the stability of scores over time. Later studies have shown that individuals’ self-assessment of their problem-solving skills correlates with indicators of psychological adjustment and everyday functioning (Heppner & Goug-Gwi, 2002). Therefore, the Problem Solving Inventory is considered a suitable and robust tool for measuring individuals’ problem-solving skills in psychological and educational research, due to its solid theoretical foundation, reliable validity evidence, and high reliability coefficients. The questionnaire contains 35 items answered on a six-point Likert scale ranging from "strongly agree" to "strongly disagree." Subscales include 11 items for Problem-Solving Confidence, 16 items for Approach-Avoidance Style, and 5 items for

Personal Control. Higher scores indicate lesser familiarity with effective problem-solving skills and deficiencies in the ability to solve problems, while lower scores indicate better awareness and proficiency in problem-solving abilities. Scoring involves reversing 15 items to reduce response bias. The total possible score ranges from 32 to 192. The PSI addresses behavioral, cognitive, and emotional responses individuals utilize to manage interpersonal and external challenges. It provides comprehensive assessment of self-perceived problem-solving competence and style, making it a valuable tool for research and applied settings.

Meta-cognitions Questionnaire—Adolescent Version (MCQ-A)

The Meta-cognitions Questionnaire—Adolescent Version (MCQ-A) is a standardized and valid tool designed to measure metacognitive beliefs and their various dimensions in adolescents, developed by Cartwright-Hatton et al. (2004). This questionnaire contains 30 items that assess five key metacognitive dimensions: positive beliefs, negative beliefs, cognitive confidence, superstition and punishment, and cognitive self-consciousness. Respondents answer on a four-point Likert scale with scores ranging from 1 to 4; "Disagree" is scored as 1, "Slightly agree" as 2, "Somewhat agree" as 3, and "Strongly agree" as 4. Each dimension's score is calculated by summing the responses to its related questions, and the total score is obtained by summing all the items. The reliability and validity of this instrument have been confirmed in multiple studies. The predicted five-factor structure of the MCQ-A has been validated through factor analysis, and convergent validity evidence is found through correlations with emotional symptom measures in adolescents (Cartwright-Hatton et al., 2004). Cronbach's alpha for the total score and subscales ranges from .70 to .92, with test-retest reliability between .72 and .95, indicating strong internal consistency and stability of the instrument (Myers et al., 2019). Given the robust evidence for its validity and reliability, the MCQ-A is regarded as a reliable and valid tool for assessing metacognitive beliefs in adolescents and has been used for this purpose in the present study.

Before the data collection process began, the study's objective—focused on examining the relationships between self-regulated learning strategies and problem-solving with the mediating role of metacognition among secondary school students in Khorramabad—was clearly explained to the participants. Participants were also assured that all collected information would remain confidential and be used solely for research purposes. After obtaining informed consent from the participants, the questionnaires related to self-regulated learning strategies, problem-solving, and metacognition were distributed and administered among the students. During the data analysis phase, the Kaiser-Meyer-Olkin (KMO) sampling adequacy measure and Bartlett's test of sphericity were used to assess the suitability of the data. Subsequently, the proposed model was evaluated using structural equation modeling.

Results

Initially, the validity and reliability of the instruments were calculated. The results of the validity and reliability coefficients are reported in Tables 1 and 2.

Table 1. Reliability and Convergent Validity Coefficients

Variables	Cronbach's Alpha	Composite Reliability	Homogeneous Reliability	Average Variance Extracted
Meta-Cognition	.772	.746	.778	.701
Problem-Solving	.881	.856	.887	.863
Self-Regulated Learning Strategies	.774	.735	.787	.774

The results presented in Table 1 indicate that the constructs of meta-cognition, problem-solving, and self-regulated learning strategies demonstrate acceptable reliability and convergent validity. The values of Cronbach's alpha, composite reliability, and homogeneous reliability for all three constructs exceed the commonly accepted threshold of .7, indicating satisfactory internal consistency and reliability of the measurement instrument. Among these constructs, problem-solving shows the highest level of reliability, with a Cronbach's alpha of .881, composite reliability of .856, and homogeneous reliability of .887, reflecting a high degree of precision in measuring this construct. In addition, the constructs of meta-cognition and self-regulated learning strategies also exhibit adequate reliability, with Cronbach's alpha values of .772 and .774, respectively, along with other reliability coefficients above the acceptable criterion. Furthermore, the average variance extracted (AVE) values for all three constructs are greater than .5, with AVE values of .701 for meta-cognition, .863 for problem-solving, and .774 for self-regulated learning strategies. These findings indicate that a substantial proportion of the variance in the observed indicators is explained by their underlying latent constructs, thereby confirming convergent validity. In general, the results suggest that the measurement instrument used in the present study possesses satisfactory psychometric properties and is suitable for conducting further statistical analyses, including structural equation modeling.

Table 2. Discriminant validity coefficients (Fornell and Larcker Test)

Variable	Meta-Cognition	Problem-Solving	Self-Regulated Learning Strategies
Meta-Cognition	.861		
Problem-Solving	.848	.882	
Self-Regulated Learning Strategies	.836	.872	.889

The results presented in Table 2 report the discriminant validity coefficients of the study constructs based on the Fornell and Larcker criterion. According to this approach, the square root of the average variance extracted (AVE) for each construct, shown on the main diagonal of the matrix, should be greater than the correlations between that construct and the other constructs in order to confirm discriminant validity. In this regard, the diagonal value for the construct of meta-cognition is .861, which is higher than its correlations with problem-solving (.848) and self-regulated learning strategies (.836). This finding indicates that meta-cognition has adequate conceptual distinctiveness from the other constructs. Similarly, the diagonal value for the problem-solving construct is .882, which exceeds its correlations with meta-cognition (.848) and self-regulated learning strategies (.872), demonstrating satisfactory discriminant validity for this construct. Furthermore, the construct of self-regulated learning strategies shows a diagonal value of .889, which is greater than its correlations with meta-cognition (.836) and problem-solving (.872). Overall, since in all cases the square roots of AVE for each construct are higher than the corresponding inter-construct correlation coefficients, it can be concluded that the discriminant validity of the constructs of meta-cognition, problem-solving, and self-regulated learning strategies is confirmed based on the Fornell and Larcker criterion, and that each construct measures a distinct yet related concept.

Before conducting structural equation modeling, it is necessary to assess the Kaiser–Meyer–Olkin (KMO) and Bartlett's test of sphericity indices. The KMO index is one of the main criteria for evaluating sample adequacy; when its value exceeds .60, it indicates that the data are suitable for path analysis and structural modeling. On the other hand, Bartlett's test of sphericity is used to examine the significance of the correlation matrix, and a significant result implies that the data are appropriate for advanced statistical analyses. Once these conditions are confirmed, the researcher can proceed with subsequent stages of analysis with greater confidence. The results related to the KMO index and Bartlett's test of sphericity are reported in Table 3.

Table 3. Values of the Kaiser–Meyer–Olkin (KMO) Test and Bartlett's Test of Sphericity

Test/Indicator	Statistic	Value
Sampling Adequacy (Kaiser–Meyer–Olkin Test)	—	.939
Bartlett's Test of Sphericity	Chi-square	8621.279
	Degrees of Freedom	45
	Significance Level	.000

The results presented in Table 3 indicate that the Kaiser–Meyer–Olkin (KMO) sampling adequacy index, with a value of .939, is at a highly desirable level. This value suggests that the dataset possesses sufficient adequacy for conducting factor analysis and structural modeling. The high KMO value demonstrates that the correlations among variables are strong enough to allow for an accurate examination of their underlying relationships. In addition, Bartlett's test of sphericity, with a chi-square statistic of 8621.279 and 45 degrees of freedom, is significant at the

.000 level. The significance of this test implies that the correlation matrix differs from the identity matrix, indicating adequate intercorrelations among the study variables for multivariate analyses. Overall, these findings confirm that the data meet the required quality standards for subsequent analyses, including factor analysis and structural equation modeling.

Table 4. Descriptive statistics of research variables

Variable	Mean	SD	Median	Min	Max
Meta-Cognition (MCQ-A, range 30–120)	79	12.5	80	42	113
Problem-Solving (PSI, range 32–192)	104	18.7	102	59	161
Self-Regulated Learning Strategies (SRLQ, range 47–235)	148	21.4	150	92	208

Based on the data presented in Table 4, the mean scores of the three research variables fall within a moderate to desirable range. The meta-cognition variable, with a mean score of 79 and a standard deviation of 12.5, indicates that the participants possess relatively adequate metacognitive beliefs. The mean score for problem-solving was 104, which—considering the scoring system of the PSI—reflects a moderate to relatively favorable level of problem-solving skills. In addition, self-regulated learning strategies, with a mean of 148 and a standard deviation of 21.4, suggest that the use of these strategies among the respondents is relatively high. Overall, the descriptive indicators show that the participants demonstrate acceptable performance and an appropriate distribution of scores across the three main research variables.

Given that the necessary statistical assumptions were confirmed, structural equation modeling was employed to test the hypothesis that metacognition mediates the relationship between self-regulated learning strategies and problem-solving among secondary school students in Khorramabad. The findings from this modeling are reported in Table 5 as well as Figures 2 and 3.

The results presented in Table 5 report the path coefficients and bootstrap test statistics for the effects of latent variables on manifest variables, indicating the significance and strength of the direct relationships specified in the research model. Overall, the values of the path coefficients and t-statistics show that all hypothesized relationships in the model have been confirmed. Regarding self-regulated learning strategies as an exogenous latent variable, the findings indicate a strong and significant direct effect on motivational beliefs, with a path coefficient of .801 and a t-value of 13.399. In addition, its direct effect on self-regulated learning is very strong, with a path coefficient of .925 and a t-value of 36.211. The high t-values (greater than 2.58) demonstrate that these relationships are statistically significant at a high confidence level, highlighting the crucial role of self-regulated learning strategies in explaining motivational and learning-related components. With respect to meta-cognition as an endogenous latent variable, the results reveal significant direct effects on all dimensions of metacognitive beliefs. Specifically, the effect of meta-cognition on positive beliefs is confirmed with a path coefficient of .725 and a t-value of 16.070, while its effect on negative beliefs shows a path coefficient of .776 and a t-value of 18.929. Furthermore, meta-cognition has a significant direct effect on cognitive confidence (path coefficient = .588, t = 8.612), superstition and punishment (path coefficient = .550, t = 8.619), and cognitive self-consciousness (path coefficient = .368, t = 5.008).

Table 5. Path coefficients and bootstrap results for the effects of latent variables on manifest variables

Latent Variable	Manifest Variable	Type of Latent Variable	Path Coefficient	t Statistic	Type of Effect	Path Coefficient Result	t Statistic Result
Self-Regulated Learning Strategies	Motivational Beliefs	Exogenous Latent Variable	.801	13.399	Direct	Confirmed (<.30)	Confirmed (>2.58)
	Self-Regulated Learning		.925	36.211	Direct	Confirmed (<.30)	Confirmed (>2.58)
Meta-Cognition	Positive Beliefs	Endogenous Latent Variable	.725	16.070	Direct	Confirmed (<.30)	Confirmed (>2.58)
	Negative Beliefs		.776	18.929	Direct	Confirmed (<.30)	Confirmed (>2.58)
	Cognitive Confidence		.588	8.612	Direct	Confirmed (<.30)	Confirmed (>2.58)
	Superstition and Punishment		.550	8.619	Direct	Confirmed (<.30)	Confirmed (>2.58)
	Cognitive Self-Consciousness		.368	5.008	Direct	Confirmed (<.30)	Confirmed (>2.58)
Problem-Solving	Problem-Solving Confidence	Endogenous Latent Variable	.582	7.978	Direct	Confirmed (<.30)	Confirmed (>2.58)
	Approach-Avoidance Style		.809	20.557	Direct	Confirmed (<.30)	Confirmed (>2.58)
	Personal Control		.680	11.954	Direct	Confirmed (<.30)	Confirmed (>2.58)

Although the path coefficient for cognitive self-consciousness is relatively lower than those of the other dimensions, it remains statistically significant, indicating the meaningful contribution of meta-cognition to explaining this component. Finally, the results related to problem-solving as an endogenous latent variable indicate significant and direct effects on its associated dimensions. The effect of problem-solving on problem-solving confidence is confirmed with a path coefficient of .582 and a t-value of 7.978. In addition, strong direct effects are observed on approach–avoidance style (path coefficient = .809, t = 20.557) and personal control (path coefficient = .680, t = 11.954). These findings suggest that the latent construct of problem-solving plays an important role in shaping the cognitive and behavioral dimensions associated with problem-solving processes. In summary, given the statistical significance of all path coefficients and the high t-values obtained from the bootstrap analysis, it can be concluded that the structural relationships proposed in the research model are fully supported. The latent variables examined in this study exert strong, direct, and significant effects on their corresponding manifest variables, providing evidence for the good fit and strong explanatory power of the proposed model. The results of the structural equation modeling are presented in Table 6 and Figures 2 and 3.

Table 6. Path coefficients and bootstrap results for direct and indirect effects between variables

Path Relationship	Type of Effect of the Latent Variable	Type of Effect	Path Coefficient	t-value	P-value
Self-Regulated Learning Strategies → Meta-Cognition	Effect of the Exogenous Latent Variable on the Endogenous Latent Variable	Direct	.357	5.785	.000
Self-Regulated Learning Strategies and Meta-Cognition → Problem-Solving	Effects of the Exogenous Latent Variable and the Endogenous Latent Variable on the Endogenous Latent Variable	Indirect	.528	13.855	.000

The results presented in Table 6 report the path coefficients and bootstrap statistics for the direct and indirect effects among the latent variables, highlighting the structural relationships specified in the research model. For the path self-regulated learning strategies → meta-cognition, self-regulated learning strategies, as an exogenous latent variable, exert a direct, positive, and statistically significant effect on meta-cognition as an endogenous latent variable. The path coefficient of .357 indicates a moderate effect size, while the t-value of 5.785, which exceeds the critical threshold of 2.58, confirms the statistical significance of this relationship at a high confidence level. In addition, the p-value of .000 further supports the strong statistical significance of this effect. This finding suggests that the effective use of self-regulated learning strategies contributes to the enhancement and development of meta-cognition. For the path self-regulated learning strategies and meta-cognition → problem-solving, the results indicate a positive and statistically significant indirect effect. The indirect path coefficient is .528, demonstrating the mediating role of meta-cognition in transmitting the effect of self-regulated learning strategies to problem-solving. The t-value of 13.855 and the p-value of .000 indicate that this indirect effect is highly significant. These results imply that self-regulated learning strategies influence problem-solving not only directly but also indirectly through the strengthening of meta-cognition. By and large, the findings in Table 6 demonstrate that meta-cognition plays a significant mediating role in the relationship between self-regulated learning strategies and problem-solving, and that the causal structure of the proposed research model is supported by strong statistical evidence.

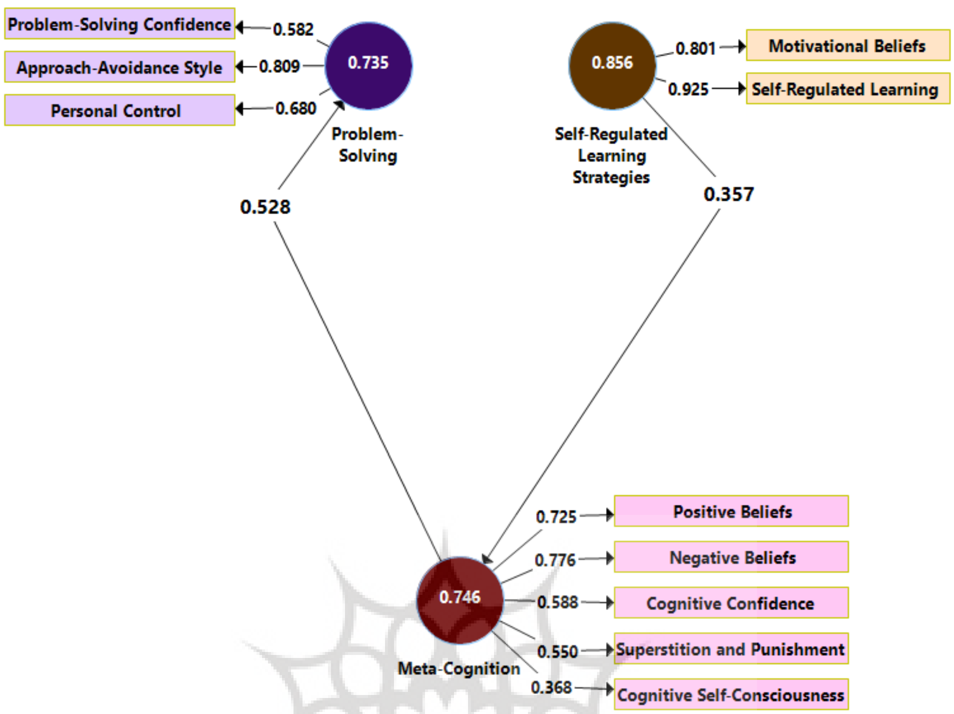

Figure 2. Composite reliability and path coefficients for the relationship between self-regulated learning strategies and problem-solving, with metacognition as a mediating variable

Figure 2 depicts the structural model of the study, in which self-regulated learning strategies serve as an exogenous latent variable, meta-cognition acts as a mediating latent variable, and problem-solving functions as an endogenous latent variable. The path coefficient between self-regulated learning strategies and meta-cognition is .357, indicating a direct, positive, and statistically significant effect. This value suggests that an increase in the use of self-regulated learning strategies is associated with a meaningful enhancement in meta-cognitive abilities. Although the strength of this direct effect is moderate, it is statistically significant and plays an important role in the overall structure of the model. Furthermore, the indirect path coefficient from self-regulated learning strategies to problem-solving through meta-cognition is reported as .528, demonstrating a strong mediating role of meta-cognition in this relationship. This indicates that a substantial portion of the effect of self-regulated learning strategies on problem-solving is transmitted through the enhancement of meta-cognitive processes. In other words, meta-cognition serves as a key cognitive mechanism and an effective bridge linking self-regulated learning strategies to problem-solving ability. In general, the path coefficients displayed in Figure 2 suggest that the proposed model has a good explanatory power and that the relationships among the constructs are both theoretically coherent and statistically supported. The results clearly confirm that self-regulated learning strategies can significantly improve problem-solving ability through the enhancement of meta-cognition, and that meta-cognition plays a meaningful and effective mediating role in this process.

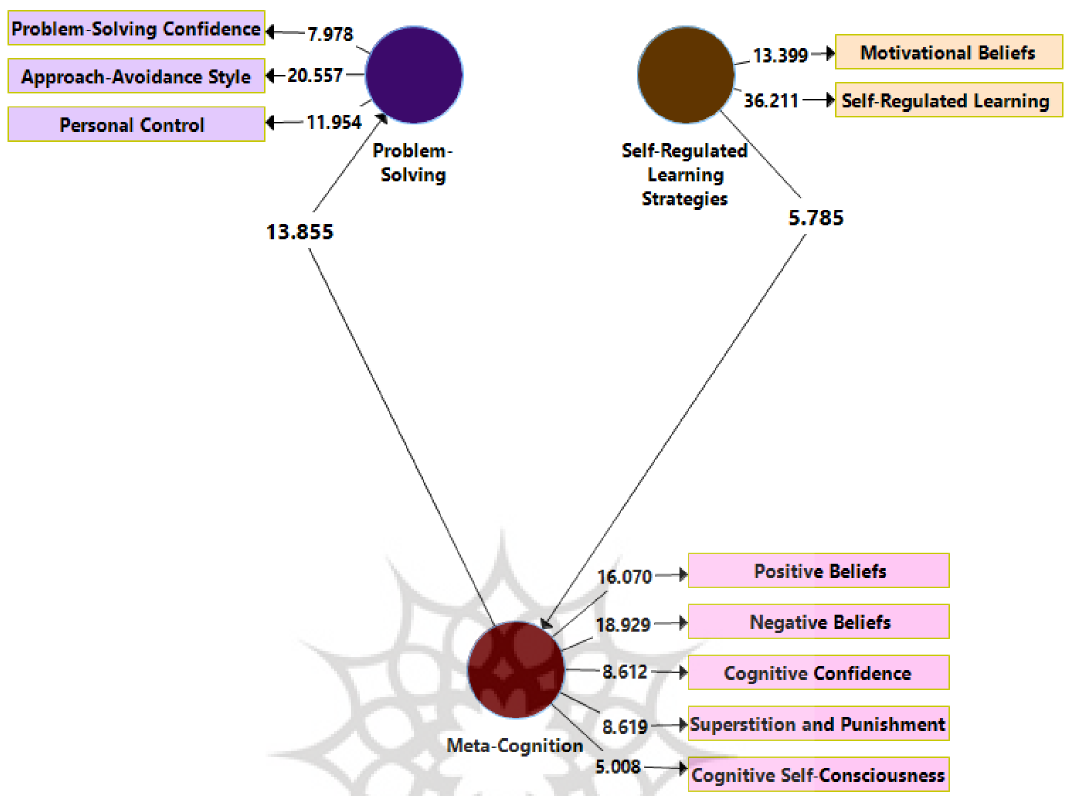

Figure 3. Bootstrap values for the relationship between self-regulated learning strategies and problem-solving with metacognition as a mediating variable

Figure 3 presents the results of the bootstrap analysis, which assesses the significance of direct and indirect paths in the research model. For the path self-regulated learning strategies → meta-cognition, the path coefficient is .357 with a t-value of 5.785. These values indicate that the direct effect of self-regulated learning strategies on meta-cognition is positive, moderate, and statistically significant ($p < .001$). This finding confirms that an increase in the use of self-regulated learning strategies leads to the enhancement of meta-cognitive abilities, and the effect is statistically robust and reliable. Furthermore, the indirect effect of self-regulated learning strategies on problem-solving through meta-cognition has a path coefficient of .528 with a t-value of 13.855. These values demonstrate a strong and statistically significant indirect effect ($p < .001$). In other words, part of the impact of self-regulated learning strategies on problem-solving ability is transmitted through the enhancement of meta-cognition. This finding clearly highlights the significant and effective mediating role of meta-cognition in the relationship between self-regulated learning strategies and problem-solving.

Table 7. Partial Least Squares (PLS) model fit indices

Index	Value	Acceptable Criterion	Result
Standardized Root Mean Square Residual (SRMR)	.033	Less than .10	Confirmed
Squared Euclidean Distance (d_ULS)	.061	Interpreted based on the Normed Fit Index	Confirmed
Geodesic Distance (d_G)	.780	Interpreted based on the Normed Fit Index	Confirmed
Normed Fit Index (NFI)	.835	Greater than .7	Confirmed

Table 7 presents the fit indices for the Partial Least Squares (PLS) model, demonstrating that the structural model achieves an adequate and acceptable level of fit. The SRMR value of .033, well below the recommended threshold of .10, indicates minimal discrepancy between the observed and model-implied correlation matrices, confirming an overall satisfactory model fit. Likewise, the d_ULS (.061) and d_G (.780) values fall within acceptable limits relative to the Normed Fit Index, suggesting that the difference between the empirical data and the estimated model is sufficiently small and supports the internal consistency of the model. Additionally, the NFI value of .835, exceeding the commonly accepted benchmark of .70, provides further evidence of the robustness of the model and its ability to accurately capture the underlying data structure. Collectively, these indices demonstrate that the proposed PLS model exhibits strong goodness-of-fit and aligns well with the empirical observations.

Considering the results from Tables 5 and 6, together with the exceptionally high bootstrap values for both direct and indirect paths, the primary research question is strongly supported. The direct effect of 'self-regulated learning strategies' on metacognitive processes (β = .939, t = 133.085) and the indirect effect of these strategies on Problem-Solving through metacognitive processes (β = .960, t = 131.463) are both substantial and statistically robust. These findings indicate that a significant portion of the impact of 'self-regulated learning strategies' on 'problem-solving' is transmitted via metacognitive processes. Accordingly, the results confirm that metacognition functions as a meaningful and effective mediating variable in the relationship between Self-Regulated Learning Strategies and Problem-Solving among high school students in Khorramabad.

Discussion

The present study examined the mediating role of metacognition in the relationship between Self-Regulated Learning Strategies (exogenous latent variable) and Problem-Solving (endogenous latent variable) among upper-secondary students in Khorramabad. The structural model demonstrated strong psychometric properties, and all hypothesized paths were empirically supported. The path coefficient from self-regulated learning strategies to meta-cognition was .357, with a t-value of 5.785, indicating a positive and statistically significant direct effect.

Moreover, the indirect effect of self-regulated learning strategies on problem-solving through metacognition was .528, with a t-value of 13.855, confirming a significant mediating role of meta-cognition in the model. These values demonstrate that self-regulated learning strategies influence problem-solving both directly and indirectly, with a substantial portion of the effect transmitted via meta-cognition.

These findings align with those of previous research emphasizing the importance of metacognition as a central mechanism underlying the effectiveness of Self-Regulated Learning (SRL). Ambaryani and Putranta (2022) showed that SRL-based instructional approaches significantly enhance metacognitive skills, which in turn improve students' ability to plan, monitor, and evaluate their problem-solving processes. Similarly, Arianto and Hanif (2024) demonstrated that metacognitive strategies and SRL jointly predict students' self-efficacy and problem-solving performance, highlighting their intertwined nature. The present study corroborates these conclusions by demonstrating that SRL, as an exogenous latent variable, exerts its strongest influence on problem-solving indirectly through the activation of metacognition.

The finding that the indirect effect ($\beta = .528$, $t = 13.855$) is stronger than the direct effect ($\beta = .357$, $t = 5.785$) underscores the pivotal mediating role of metacognition. This is consistent with theoretical frameworks that conceptualize metacognition as a higher-order regulatory system guiding cognitive resources during complex tasks (Cartwright-Hatton et al., 2004; Myers et al., 2019). In educational contexts, students with strong metacognitive awareness are better at identifying problem requirements, selecting appropriate strategies, and adapting their actions—skills essential for effective problem-solving (D'Zurilla et al., 2002; Heppner & Goug-Gwi, 2002).

In line with the present results, Ozcan (2016) and Zhao and Saleh (2025) found that metacognitive monitoring plays a decisive role in mathematical and scientific problem-solving. Research in diverse contexts, including augmented-reality learning environments (Siswati et al., 2025) and computational thinking frameworks (Zhang et al., 2024), similarly confirms that metacognition enhances students' ability to structure, analyze, and execute solutions to complex problems. Therefore, the strength of the mediating effect in the current study reinforces metacognition as a universal cognitive mechanism, independent of subject area or instructional modality.

The results also align with findings suggesting that SRL strategies alone, while beneficial, reach their full potential only when students are capable of metacognitive evaluation (Khaljipour & Mojtabazadeh, 2024; Pintrich & De Groot, 1990). SRL provides the motivational and behavioral foundation for learning, but metacognition transforms these regulatory efforts into strategic and goal-directed problem-solving actions. This synergy is reflected in the significant t-values observed in the present model.

Furthermore, the positive influence of problem-solving on academic outcomes reported in prior research (Caliskan & Altun, 2025; Yendi et al., 2025) suggests that the enhancement of metacognition through SRL has broader implications for students' academic trajectories, emotional well-being, and self-efficacy. Studies on academic emotions (Hassanzadeh et al., 2022) and academic well-being (Bolori et al., 2024) further highlight that regulatory and metacognitive competencies equip students with psychological resources that facilitate adaptive learning behaviors.

On the whole, the findings of this study provide strong evidence that metacognition is a critical mediator in the SRL–problem-solving relationship. By demonstrating statistically significant direct and indirect effects and solid model support, this research underscores that educational interventions aimed at improving students' problem-solving abilities should focus not only on fostering Self-Regulated Learning Strategies but also on explicitly cultivating metacognitive awareness, reflection, planning, and monitoring. Future research may explore domain-specific variations in the mediating mechanism, longitudinal changes in metacognitive growth, or the role of contextual factors such as classroom engagement, instructional design, and digital learning environments. Such studies would help further clarify how metacognition operationalizes the influence of SRL and enhances students' capacity to engage with complex academic challenges.

Conclusion

The primary aim of this study was to investigate the mediating role of metacognitive processes (endogenous latent variable) in the relationship between self-regulated learning strategies (exogenous latent variable) and problem-solving (endogenous latent variable) among high school students in Khorramabad. The results obtained through structural equation modeling supported this hypothesis. Specifically, both the direct effect of 'self-regulated learning strategies' on 'metacognitive processes' and the indirect effect of 'self-regulated learning strategies' on 'problem-solving' through metacognitive processes were statistically significant and demonstrated meaningful effect sizes. these findings indicate that metacognitive processes play a central role in transmitting and amplifying the influence of self-regulated learning strategies on students' problem-solving abilities.

The results further suggest that 'self-regulated learning strategies' alone cannot fully account for variations in 'problem-solving performance'; their impact becomes meaningful when students actively engage metacognitive processes such as planning, monitoring, and evaluating their cognitive actions. This provides strong empirical support for theoretical models conceptualizing 'metacognition' as a higher-order regulatory system essential for optimal learning, reasoning, and adaptive problem-solving.

Despite these strong findings, this study has several limitations. First, the cross-sectional design restricts the ability to draw definitive causal inferences. Second, the study was conducted solely among upper-secondary students in Khorramabad, which may limit the generalizability of the results to other regions, age groups, or educational contexts. Third, the data were collected via self-report questionnaires, which may be susceptible to social desirability and response biases.

From an educational perspective, these findings emphasize the importance of designing instructional programs that target both self-regulated learning strategies and metacognitive processes. Teachers should implement interventions that strengthen planning, monitoring, and evaluation as metacognitive processes alongside self-regulated learning strategies. Such programs can enhance students' problem-solving competence, academic self-efficacy, and adaptability across different subject areas.

Future research should employ longitudinal or experimental designs to better establish causal relationships between self-regulated learning strategies, metacognitive processes, and Problem-Solving. Moreover, examining contextual factors such as classroom engagement, instructional methods, and technology-enhanced learning environments could provide deeper insights. Expanding the study to different age groups, academic disciplines, or cultural contexts may further assess the generalizability of these findings and refine theoretical models regarding the interplay between self-regulated learning, metacognitive processes, and problem-solving.

Author Contributions

The contributions of the authors to the article are as follows:

First Author: Preparation and organization of data, data collection, data analysis, analysis and interpretation of information and results, drafting the manuscript.

Second Author: PhD dissertation supervisor, research design, supervision of the research process, review and verification of results, editing, revising, and finalizing the manuscript.

Data Availability Statement

The data that support the findings of this study are available upon reasonable request.

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Ethical considerations

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Conflicts of Interest

This article has no conflicts of interest.

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