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The Mediating Effect of Digital Literacy on the Academic Self-Regulation and Problem-Solving Attitude of Science Students

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Abstract
This study examined the mediating role of digital literacy in the relationship between academic self-regulation and students' attitudes toward problem-solving in science. The participants were 300 Senior High School STEM students enrolled in public schools within the Division of Cotabato. Utilizing a descriptive-correlational research design, data were collected through validated Likert-scale instruments and analyzed using descriptive statistics, Pearson correlation, regression analysis, and the Sobel z-test. The findings indicated that students generally exhibited high levels of academic self-regulation and digital literacy, whereas their problem-solving attitudes were at a moderate level. Correlational analysis revealed significant positive associations among all variables, suggesting that students with stronger self-regulatory capacities and higher digital literacy tend to demonstrate more favorable attitudes toward problem-solving in science. Furthermore, regression and mediation analyses confirmed that digital literacy partially mediated the relationship between academic self-regulation and problem-solving attitudes. This implies that academic self-regulation not only exerts a direct influence on students' problem-solving attitudes but also indirectly enhances them through digital literacy. These findings highlight the need to integrate digital literacy enhancement into science instruction to foster students' confidence, perseverance, and engagement in technology-supported learning environments.

Keywords: self-regulation, digital literacy, problem-solving attitude, perseverance, mediation and regression, confidence, stem education

1. INTRODUCTION

Science education continues to evolve to equip students with the competencies necessary to address complex global and technological challenges. As noted by Anthonysamy et al. (2021), this progression is vital for preparing learners to thrive in digitally advanced societies. Moneva et al. (2020) emphasize that students' attitudes toward problem-solving are crucial determinants of engagement, motivation, and confidence in science learning. Similarly, Cheng and Tsai (2020) found that intrinsic motivation and self-regulation significantly influence learners' attitudes in scientific contexts. In response, the Department for Education and Skills (DfES, 2005) has advocated for more innovative pedagogical approaches, asserting that traditional methods are insufficient in fostering 21st-century learning skills. [3, 12, 13, 30]
Within the STEM curriculum, problem-solving is considered a central component of effective learning (van Gog et al., 2020). However, many students find structured problems challenging because they require

sequential reasoning and procedural understanding. Several studies highlight that successful problem solvers must possess not only procedural knowledge but also an understanding of the rationale behind each step. Consequently, the ability to self-regulate learning becomes essential. According to Hacker and Bol (2019), students must manage their own learning processes, particularly when working independently. Empirical findings by Lee et al. (2022) reveal that self-regulated learners exhibit higher levels of persistence, confidence, and proactive engagement in scientific problem-solving, while Zimmerman et al. (2020) further demonstrate that goal setting and self-monitoring behaviors are predictors of positive problem-solving attitudes. [18, 26, 38, 46]

On the other hand, self-regulated learning (SRL), as described by Cai et al. (2020), involves self-control, motivation management, and decision-making throughout the learning process. The concept of academic self-regulation has also been closely linked to digital literacy in contemporary educational environments. Azevedo et al. (2021) observed that students with strong self-regulatory capacities navigate digital learning platforms more efficiently, enhancing both their academic outcomes and digital competence. Similarly, Lim and Jung (2022) found that students who adopt self-regulated learning strategies are better equipped to critically evaluate digital resources, indicating that digital literacy mediates autonomous learning. It is further asserted that improving digital literacy leads to enhanced self-regulation, particularly in online and hybrid learning environments. [5, 10, 27]

The prevalence of digital learning environments offers flexibility and promotes self-paced learning, yet, as Istifci and Göksel (2022) point out, students' digital literacy skills remain unevenly developed. Studies suggest that educators can address this disparity by designing technology-rich projects that engage learners while simultaneously strengthening digital and self-regulatory skills. Anthonysamy et al. (2020) emphasize that developing self-regulation is a crucial factor in digital learning success, a view supported by Ejubovic and Puška (2019), who found that technology integration enhances both student performance and teacher practice. [2, 15, 21]

Furthermore, integrating digital tools into science education not only improves communication and collaboration but also promotes critical analysis and adaptability. According to Anthonysamy et al. (2020), students who actively use digital resources demonstrate stronger analytical thinking and more positive problem-solving attitudes. Bergdahl et al. (2020) further note that digitally literate students are more inclined to participate in academic discussions and peer interactions. In line with these findings, Pala and Başıbüyük (2020) report that students with high digital literacy exhibit superior analytical and adaptive problem-solving skills. [2, 8, 33]

The study is grounded in Cognitive Load Theory (CLT) proposed by Sweller (1988), which explains how instructional design influences learners' ability to process information. As Asma and Sarnou (2020) explain, CLT clarifies how educational materials can optimize cognitive functioning. It highlights that excessive cognitive load can hinder students' capacity to acquire new information, particularly in problem-solving tasks. Academic self-regulation, therefore, becomes essential in helping students plan, monitor, and evaluate their learning performance (Cai et al., 2020). Complementing this, Deci and Ryan's (1985) Self-Determination Theory (SDT) focuses on motivation as a continuum from intrinsic to extrinsic drivers. It shows that autonomy, competence, and relatedness core tenets of SDT are critical in promoting deeper learning engagement. [4, 10, 13]

Building on these frameworks, Yaniawati et al. (2019) argue that academic self-regulation and problem-solving attitudes are interrelated concepts. CLT provides insight into how cognitive resources can be efficiently allocated to enhance self-regulated learning, while SDT highlights the motivational factors that sustain engagement (Sweller, 2020). Studies also observe that digital literacy strengthens both cognitive and motivational aspects by enabling autonomy and efficient cognitive processing. It indicates that digital literacy minimizes extraneous cognitive load, allowing students to focus on higher-order reasoning. In addition, Yang et al. (2024) and Huang et al. (2022) emphasize that SRL facilitates cognitive load management by using digital tools that provide real-time feedback, supporting sustained engagement and reflection during complex problem-solving. [20, 36, 40, 41]

Finally, the integration of self-regulated learning strategies with digital tools enhances germane cognitive load, the mental effort devoted to understanding and applying core material (Huang et al., 2022). Through goal-setting, monitoring, and reflection, students can break down complex scientific problems into manageable components. As Sweller (2020) and Yang et al. (2024) conclude, Cognitive Load Theory and Self-Determination Theory together illustrate that learning is most effective when cognitive efficiency and motivation are jointly cultivated. Digital literacy thus serves as a bridge, reducing unnecessary mental strain while promoting autonomy, engagement, and effective problem-solving in science education. [20, 36, 40]

Conceptual Framework

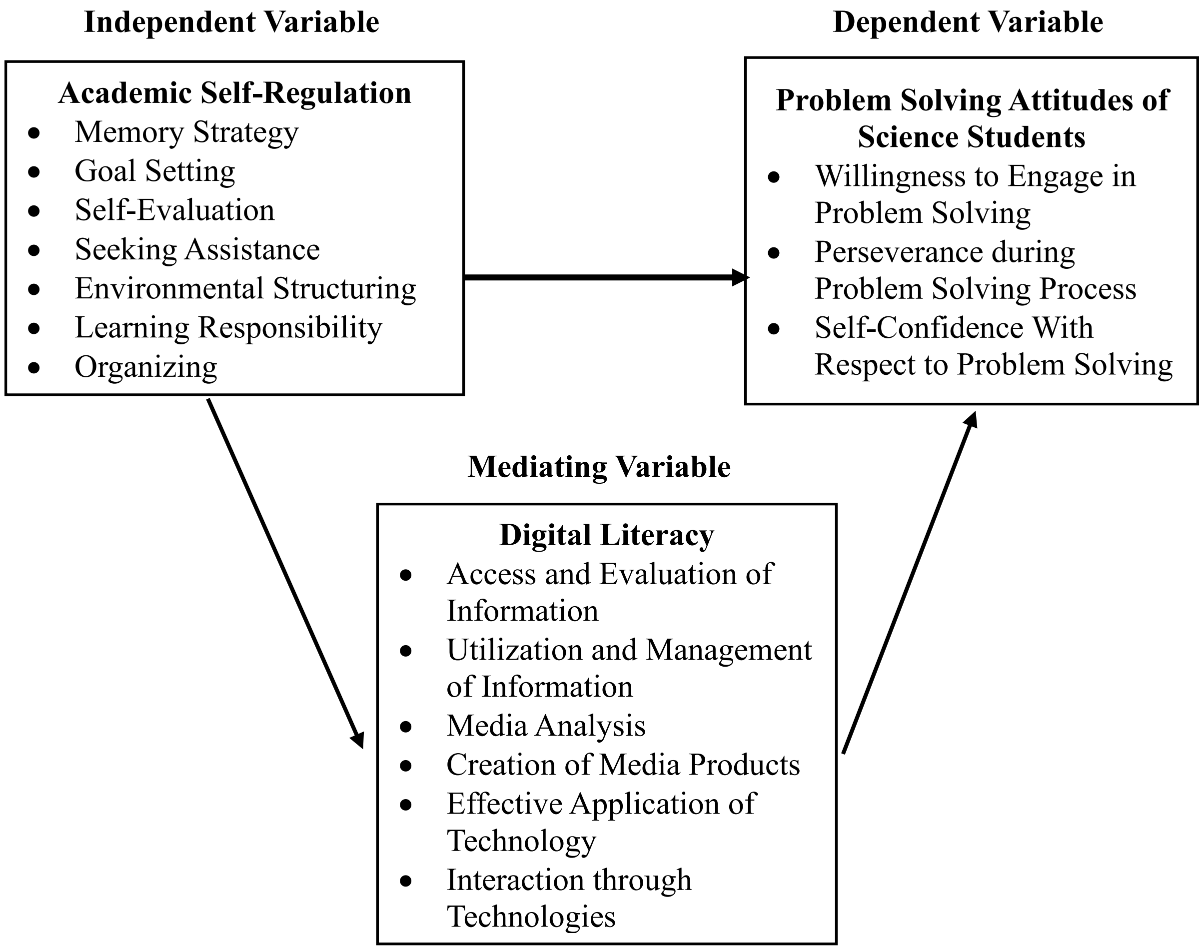

Figure 1. Conceptual Framework of the Study

The main objective of this study is to determine the mediating effect of digital literacy on the academic self-regulation and attitudes towards problem solving of students in science. Specifically, the study sought to answer the following questions: to determine the level of academic self-regulation when analyzed by memory strategy, goal setting, self-evaluation, seeking assistance, environmental structuring, learning responsibility and organizing; to ascertain the attitudes towards problem solving of students in science when analyzed by willingness to engage in problem solving, perseverance during problem solving process, and self-confidence with respect to problem solving; to measure the level of digital literacy when analyzed by access and evaluation of information, utilization and management of information, media analysis, creation of media products, effective application of technology and interaction through technologies; to find out the significant relationship between academic self-regulation and attitudes towards problem solving of students in science; to identify the significant relationship between academic self-regulation and digital literacy; to measure the significant relationship between digital literacy and attitudes towards problem solving of students in science; and to find the significance of the mediation of digital literacy on the relationship between academic self-regulation and attitudes towards problem solving of students in science.

The hypothesis of the study states that there is no significant relationship between academic self-regulation and attitudes towards problem solving of students in science; academic self-regulation and digital literacy; digital literacy and attitudes towards problem solving of students in science; and there is no significance of the mediation of digital literacy on the relationship between academic self-regulation and attitudes towards problem solving of students in science.

This study is significant as it provides valuable insights for educators, students, parents, and school administrators on the importance of integrating digital literacy to enhance self-regulation and problem-solving attitudes in science education. For teachers, the findings can inform the development of instructional strategies that promote engagement and independent learning, while students can benefit from improved self-management, motivation, and confidence in solving complex tasks. Parents and administrators, meanwhile, may gain a deeper understanding of their roles in supporting digital learning environments that nurture responsible and self-directed learners. Beyond its educational implications, this study aligns with Sustainable Development Goal 4 (Quality Education) by promoting inclusive and equitable access to quality learning opportunities. It underscores that integrating digital literacy and self-regulation into science education fosters critical thinking, creativity, and innovation which are key competencies that empower learners to thrive in a technology-driven society and contribute to sustainable national and global development.

2. Method

Research Respondent

The research respondents for this study comprised 300 senior high school students enrolled in the STEM (Science, Technology, Engineering, and Mathematics) strand at various schools within the Cotabato Division. These students are from the different senior high schools who is enrolled for academic year 2025-2026. The population of the study covered schools from District two such as Magpet National High School, Antipas National High School, Greenfield High School - Arakan, Makilala National High School and President Roxas National High School.

Materials and Instrument

The research objectives guided the development of the questionnaires, which were carefully designed based on relevant scientific literature. Three distinct instruments were utilized in this study, each measured using a 5-point Likert scale. The first instrument assessed the independent variable, Academic Self-Regulation, using a tool developed by Magno (2010) to evaluate various aspects of self-regulation in academic contexts. It includes seven key indicators with a total of 35 statements that measure students' goal-setting, monitoring, and learning management behaviors. The second instrument measured the dependent variable, Problem-Solving Attitude, based on a scale developed by Zakaria et al. (2004), consisting of 15 statements distributed across three key indicators, motivation, strategy, and perception, to capture students' attitudes toward problem-solving in science. The third instrument assessed the mediating variable, Digital Literacy, adapted from Baterna et al. (2020), and consists of six core indicators with five statements each, totaling 30 items that evaluate different dimensions of digital competence. The initial draft of all instruments was evaluated by a panel of experts for content validity, focusing on clarity, relevance, and appropriateness, with at least 80% agreement required per item. After expert validation, the questionnaires were pilot-tested with 30 randomly selected STEM students. The items were refined through item analysis and reliability testing using Cronbach's alpha to ensure internal consistency and validity of the instruments. [7, 28, 42]

Design and Procedure

This study utilized a quantitative correlational design to examine the relationships among digital literacy, academic self-regulation, and problem-solving attitudes among science students (Pala & Başıbüyük, 2020). This design was appropriate for identifying the strength and direction of associations among the variables without manipulating them. Furthermore, the study investigated the mediating role of digital literacy in the relationship between academic self-regulation and problem-solving attitudes. Data were analyzed using the IBM Statistical Package for the Social Sciences (SPSS). Correlational analyses were performed to determine the relationships among the variables, employing a significance level of 0.05 and a 95% confidence interval. Prior to data collection, formal letters were submitted to the Division Office and participating school principals to request permission and outline the study's objectives, timeline, and ethical considerations. [33]

A pilot test was conducted with a small group of students to ensure clarity and appropriateness of the questionnaire items. The survey was distributed both online and in paper format, depending on students' access to digital devices, ensuring inclusivity. Clear instructions were provided, and all responses were treated with strict confidentiality. Following data collection, responses were encoded and analyzed using descriptive and inferential statistics. Descriptive measures, including mean and standard deviation, were computed to profile participants and assess levels of digital literacy, academic self-regulation, and problem-solving attitudes. Correlation analyses were conducted using the Pearson Product Moment Correlation to evaluate the strength of relationships among the three variables. Mediation analysis was further performed to test whether digital literacy mediated the relationship between academic self-regulation and problem-solving attitudes. The MedGraph and Sobel z-test were applied to assess the mediation effect, following the Baron and Kenny (1986) framework. [6]

The results were then interpreted to provide insights into how digital literacy influences students' academic behaviors and to inform recommendations for enhancing digital competence in educational settings. This study strictly followed ethical standards to ensure participants' safety, rights, and confidentiality. Participation was voluntary, with no academic consequences for non-participation or withdrawal. Parental consent and student assent were obtained, and all procedures were explained in clear, age-appropriate language. The study posed minimal risk and offered small tokens of appreciation for participation. Data were securely stored in password-protected files and retained for five years before deletion. These measures ensured that the research was conducted transparently, responsibly, and in accordance with the ethical standards expected in scholarly inquiry.

3. Results and Discussion

Level of Academic Self-regulation of Science Students

The data in Table 1 revealed that science students demonstrated a high level of academic self-regulation with a mean score of 3.90, indicating that they set clear goals, manage their time effectively, and take responsibility for their learning outcomes. Among the seven indicators, seeking assistance obtained the highest mean of 4.16, suggesting that students frequently engage in collaborative learning and seek peer or teacher support. This was followed by environmental structuring with a mean of 4.12, which implies that learners prefer quiet and organized study settings conducive to focus and productivity. Similarly, organizing and learning responsibility scored high, showing that students maintain consistent study routines and accountability for their academic progress. Meanwhile, memory strategy and self-evaluation indicate that learners regularly reflect on their learning outcomes and are receptive to feedback. Although goal setting had a relatively lower mean of 3.51, it still denotes a high level of regulation, implying that while students possess goal-setting abilities, there remains room for improving their daily and weekly planning habits.

These findings are consistent with Kim et al. (2022), who emphasized that peer collaboration enhances self-regulated learning outcomes in science education. Similarly, Kim, Lim, and Kim (2022) highlighted that students who engage in peer-assisted and collaborative learning exhibit stronger motivation and higher academic performance, supporting the present results where seeking assistance was most pronounced. The emphasis on environmental structuring also aligns with Gonzalez et al. (2020) and Boekaerts (2021), who asserted that conducive learning environments optimize concentration and task performance. The observed high scores in organizing and learning responsibility are in agreement with Wang and Wang (2021) and Zhao et al. (2023), who linked effective organization and self-reflection with academic success. [9, 16, 22, 23, 39, 44]

However, the relatively lower mean in goal setting reflects Hadwin et al. (2020) observation that students often struggle to convert long-term goals into manageable daily routines without structured guidance. This gap reinforces Omodan and Ige's (2021) argument that explicit instruction in goal-setting strategies is essential for fostering time management and prioritization skills. The overall findings support Self-Determination Theory (SDT) highlighting autonomy and relatedness in students' learning behaviors and Cognitive Load Theory (CLT), suggesting that effective self-regulation helps minimize extraneous cognitive load, thereby facilitating deeper and more meaningful learning in science education. [19, 32]

Table 1: Level of Academic Self-regulation of Science Students

Indicators	SD	Mean	Descriptive Level
Memory Strategy	0.72	3.85	High
Goal Setting	0.89	3.51	High
Self-evaluation	0.69	3.80	High
Seeking Assistance	0.62	4.16	High
Environmental Structuring	0.62	4.12	High
Learning Responsibility	0.67	3.83	High
Organizing	0.70	4.03	High
Overall	**0.52**	**3.90**	**High**

Level of Academic Problem-solving Attitudes of Science Students

The data presented in Table 2 show that science students demonstrated a moderate level of academic problem-solving attitude with a mean of 3.26, suggesting that while students generally display curiosity, persistence, and logical reasoning, they still require guidance when dealing with more complex problems. Among the three indicators, perseverance during the problem-solving process obtained the highest mean of 3.59 classified as high, indicating that students are able to sustain effort and persist when faced with difficult academic tasks. Meanwhile, both willingness to engage in problem solving and self-confidence in problem solving were rated moderate, reflecting students' hesitation and occasional lack of motivation when problems appear too challenging or unfamiliar. These results imply that although learners approach problem solving positively, there is still a need to reinforce their confidence and intrinsic motivation, particularly in tackling demanding science concepts.

These results support Zhang et al. (2023), who found that perseverance fosters deeper learning and confidence in science problem solving. However, consistent with Alshammari and Alhoqail (2021), students' engagement often depends on perceived task difficulty and relevance, explaining their moderate willingness. The findings also align with Bandura's Self-Efficacy Theory, emphasizing that low confidence reduces persistence and motivation (Pekrun et al., 2022). Overall, the results reflect a gap in autonomy and competence as described in Self-Determination Theory (SDT), suggesting that promoting self-efficacy and growth-oriented practices can strengthen students' motivation and problem-solving persistence in science. [1, 35, 43]

Table 2: Level of Academic Problem-solving Attitudes of Science Students

Indicators	SD	Mean	Descriptive Level
Willingness to Engage in Problem-Solving	0.81	3.33	Moderate
Perseverance during Problem Solving Process	0.70	3.59	High
Self-confidence with Respect to Problem Solving	0.70	2.86	Moderate
Overall	**0.61**	**3.26**	**Moderate**

Level of Digital Literacy of Science Students

The data presented in Table 3 indicate that science students possess an advanced level of digital literacy with a mean of 3.98, reflecting their strong confidence and proficiency in using various digital tools, adapting to new technologies, and utilizing online resources effectively. Among the six indicators, effective application obtained the highest mean of 4.23, classified as very high, signifying students' adaptability in integrating digital tools to support academic demands in STEM education. Similarly, interaction through technologies and media analysis were rated high, suggesting that students actively engage in digital communication and demonstrate critical thinking in evaluating media content. Meanwhile, creation of media products and access and evaluate information also rated high, indicating students' ability to design digital outputs such as presentations or infographics and assess the credibility of online sources. Although utilization and management of information had the lowest mean of 3.79, it still falls within the high category, suggesting a need to strengthen students' skills in organizing and applying digital information efficiently in academic tasks.

These findings are consistent with Cevikbas and Kaiser (2021), who emphasized that students with strong technological foundations exhibit higher engagement and improved inquiry-based learning in science. Similarly, Tondeur et al. (2020) and Gorbunova et al. (2024) found that digital literacy enhances students' ability to analyze, create, and manage digital content, thereby strengthening critical thinking and reducing cognitive load during complex tasks. It is also noted that evaluating credible online sources is vital for developing responsible digital citizenship in science education. In line with Self-Determination Theory

(SDT), students' high proficiency reflects competence and relatedness, while Cognitive Load Theory (CLT) suggests that their effective use of digital tools minimizes extraneous load, allowing deeper engagement with learning. Overall, the results highlight the need to further enhance students' information management skills and integrate more technology-driven, constructivist learning experiences to foster creativity, ethical digital use, and intrinsic motivation in STEM learning. [11, 17, 37]

Table 3: Level of Digital Literacy of Science Students

Indicators	SD	Mean	Descriptive Level
Access and Evaluation of Information	0.57	3.85	High
Utilization and Management of Information	0.63	3.79	High
Media Analysis	0.61	4.05	High
Creation of Media Products	0.63	3.87	High
Effective Application of Technology	0.62	4.23	Very High
Interaction Through Technologies	0.64	4.10	High
Overall	**0.48**	**3.98**	**High**

Significance of the Relationship between Academic Self-regulation and Problem-solving Attitudes of Science Students

The correlation matrix in Table 4 revealed a significant and positive relationship between academic self-regulation and problem-solving attitudes among science students. At the 0.05 level, all correlation coefficients were statistically significant, denoted by double asterisks (**), indicating that improvements in students' self-regulatory behaviors are closely associated with stronger problem-solving attitudes. Among the indicators, goal setting showed the highest overall correlation with problem-solving attitudes ($r = .385$, $p < .001$), particularly with self-confidence in problem solving ($r = .357$), suggesting that students who set clear goals tend to be more confident and competent in tackling challenging scientific problems. Likewise, self-evaluation ($r = .377$) and memory strategy ($r = .337$) also exhibited strong correlations, implying that students who monitor their progress and apply memory techniques demonstrate higher perseverance and engagement. Moreover, environmental structuring ($r = .320$) and learning responsibility ($r = .326$) correlated positively with perseverance and self-confidence, showing that students who manage their study environments effectively are better at sustaining effort in demanding tasks. Although seeking assistance showed the weakest correlation ($r = .269$) and a lower link with self-confidence ($r = .165$), it still represents students' willingness to collaborate when facing academic challenges. Overall, the correlation between academic self-regulation and problem-solving attitudes was strong ($r = .450$, $p < .001$), with perseverance showing the highest association ($r = .467$), confirming that highly self-regulated learners are more persistent and confident problem solvers.

These findings are consistent with Panadero and Alonso-Tapia (2021), who noted that goal setting enhances students' intrinsic motivation and perseverance in problem solving. Similarly, Zimmerman and Schunk (2020) and Michalsky (2022) emphasized that reflection and self-monitoring allow learners to adjust strategies when encountering difficulties, fostering cognitive flexibility and resilience. It is also supported that self-regulated learners are more capable of managing complex scientific tasks effectively. Viewed through the lens of Self-Determination Theory (SDT), the strong correlations between self-regulation indicators and problem-solving attitudes highlight students' autonomy and competence as drivers of intrinsic motivation. From the perspective of Cognitive Load Theory (CLT), goal setting and environmental structuring help reduce extraneous cognitive load and optimize strategic thinking. Overall, the results reinforce that enhancing self-regulation not only improves problem-solving performance but also nurtures motivation and persistence essential for success in STEM learning. [34, 47]

Table 4: Significance of the Relationship between Academic Self-regulation and Problem-solving Attitudes of Science Students

Academic Self-regulation	Problem-solving Attitudes			
	Willingness to Engage in Problem-Solving	Perseverance during Problem Solving Process	Self-Confidence with Respect to Problem Solving	**Overall**
Memory Strategy	.222**	.346**	.278**	**.337****
Goal Setting	.284**	.320**	.357**	**.385****
Self-evaluation	.268**	.388**	.288**	**.377****
Seeking Assistance	.176**	.334**	.165**	**.269****
Environmental Structuring	.225**	.375**	.200**	**.320****
Learning Responsibility	.196**	.328**	.297**	**.326****
Organizing	.202**	.334**	.194**	**.292****
Overall	**.308****	**.467****	**.352****	**.450****

** - highly significant
 * - significant

Significance of the Relationship between Academic Self-regulation and Digital Literacy of Science Students

The results reveal a statistically significant and positive correlation between all aspects of academic self-regulation and dimensions of digital literacy among science students ($r = .548$, $p < .001$). This indicates that students with higher self-regulation also demonstrate stronger digital competence. Among digital literacy indicators, media analysis ($r = .469$), effective application of technology ($r = .455$), and interaction through technologies ($r = .449$) showed the strongest associations. Environmental structuring exhibited the highest overall correlation ($r = .480$), particularly with media analysis ($r = .427$) and digital interaction ($r = .417$), suggesting that managing learning environments effectively enhances students' ability to use digital tools critically and responsibly. Similarly, organizing ($r = .476$), self-evaluation ($r = .410$), and seeking assistance ($r = .436$) were significantly correlated, while memory strategy ($r = .391$) and goal setting ($r = .328$) showed moderate but meaningful associations. These findings confirm that academic self-regulation is a strong predictor of digital literacy, warranting interventions that strengthen self-regulated learning to enhance digital competence among science learners.

The result supports the findings of Kimmons et al. (2021) emphasizing that learners who plan, evaluate, and regulate their learning are more capable of managing and interpreting digital tools effectively. Integrating self-regulation strategies in science instruction can foster critical and ethical use of media, while administrative support through digital resources and training programs can sustain these practices. Viewed through Cognitive Load Theory (CLT) and Self-Determination Theory (SDT), the strong association suggests that self-regulated learners manage cognitive resources efficiently and are intrinsically motivated to engage in digital learning environments. [24]

Table 5: Significance of the Relationship between Academic Self-regulation and Digital Literacy of Science Students

Academic Self-regulation	Digital Literacy						
	AEI	UMI	MEA	CMP	EAT	ITT	Overall
Memory Strategy	.278**	.250**	.333**	.254**	.352**	.378**	**.391****
Goal Setting	.226**	.307**	.304**	.280**	.227**	.205**	**.328****
Self-evaluation	.280**	.262**	.354**	.311**	.378**	.351**	**.410****
Seeking Assistance	.275**	.322**	.392**	.281**	.410**	.377**	**.436****
Environmental Structuring	.316**	.346**	.427**	.350**	.408**	.417**	**.480****
Learning Responsibility	.235**	.323**	.240**	.352**	.205**	.258**	**.342****
Organizing	.306**	.355**	.395**	.398**	.415**	.377**	**.476****
Overall	**.368****	**.417****	**.469****	**.428****	**.455****	**.449****	**.548****

** - highly significant
* - significant

Legend:
AEI – Access and Evaluation of Information
UMI – Utilization and Management of Information
MEA – Media Analysis
CMP – Creation of Media Products
EAT – Effective Application of Technology
IIT – Interaction Through Technologies

Significance of the Relationship between Digital Literacy and Problem-solving Attitudes of Science Students

The results reveal a significant and positive correlation between all aspects of digital literacy and problem-solving attitudes among science students ($r = .465$, $p < .001$). This suggests that students with higher digital literacy exhibit stronger perseverance, confidence, and willingness to solve problems. Among the domains of digital literacy, the strongest correlations were observed in access and evaluation of information ($r = .431$), utilization and management of information ($r = .426$), and creation of media products ($r = .415$), emphasizing the importance of critical handling and generation of digital content. Perseverance showed the highest correlation with digital literacy ($r = .465$), particularly in creating media products ($r = .446$), implying that students who produce digital outputs demonstrate greater persistence in tackling complex science problems. Although effective application of technology ($r = .237$) and interaction through technologies ($r = .314$) were lower, they remain significant, indicating that digital interaction modestly supports problem-solving confidence and persistence. Overall, these findings confirm that high digital literacy is associated with a more positive attitude toward problem solving, supporting the rejection of the null hypothesis.

The results align with Lameras et al. (2020) who found that integrating digital literacy into STEM education enhances learners' motivation, confidence, and cognitive engagement. Teachers are encouraged to design activities that promote critical evaluation, management, and creation of digital materials, while administrators should strengthen digital infrastructures and curricula that integrate both technical and problem-solving skills. Cultivating these competencies will help science students develop persistence and adaptability, preparing them to succeed in technology-driven learning environments. [25]

Table 6: Significance of the Relationship between Digital Literacy and Problem-solving Attitudes of Science Students

Digital Literacy	Problem-solving Attitudes			
	Willingness to Engage in Problem-Solving	Perseverance during Problem Solving Process	Self-confidence with Respect to Problem Solving	**Overall**
Access and Evaluation of Information	.386**	.358**	.322**	**.431****
Utilization and Management of Information	.343**	.406**	.310**	**.426****
Media Analysis	.281**	.406**	.260**	**.380****
Creation of Media Products	.289**	.446**	.304**	**.415****
Effective Application of Technology	.171**	.303**	.120*	**.237****
Interaction Through Technologies	.197**	.280**	.312**	**.314****
Overall	**.350****	**.465****	**.344****	**.465****

** - highly significant
 * - significant

Influence of academic self-regulation on problem solving attitudes as mediated by digital literacy

The mediation analysis examined whether digital literacy mediates the relationship between academic self-regulation and problem-solving attitudes among science students. As shown in the table, academic self-regulation significantly predicted problem-solving attitudes ($\beta = .450$, $B = .528$, $p = .000$), indicating a strong positive direct effect. It also significantly predicted digital literacy, the mediator ($\beta = .548$, $B = .512$, $p = .000$), suggesting that students with higher self-regulation tend to exhibit stronger digital literacy skills. Furthermore, digital literacy significantly predicted problem-solving attitudes while controlling for academic self-regulation ($\beta = .312$, $B = .391$, $p = .000$). When digital literacy was added to the model, the direct effect of academic self-regulation on problem-solving attitudes decreased from $\beta = .450$ to $\beta = .279$ ($B = .327$, $p = .000$) but remained significant. This reduction in the coefficient indicates a partial mediation, demonstrating that digital literacy partially explains how self-regulated learning enhances students' problem-solving attitudes in science.

The result supports Nguyen and Do (2022) emphasizing that digital literacy is essential in 21st-century learning, particularly in problem-solving. The partial mediation indicates that academic self-regulation directly affects students' problem-solving attitudes while being partly influenced by digital literacy. This aligns with Zhao et al. (2023), who noted that self-regulation is a key factor in academic achievement. Thus, students who effectively self-regulate tend to be more digitally literate, enhancing their problem-solving abilities. The Sobel test further confirms the significant indirect effect of digital literacy in this relationship. [31, 44]

Table 7: Regression analysis showing the influence of academic self-regulation on problem solving attitudes as mediated by digital literacy

Step	Path	B	S.E.	β
1	c	.528	.061	.450***
2	a	.512	.045	.548***
3	b	.391	.074	.312***
4	c’	.327	.069	.279***

* *p*<0.05, ** *p*<0.01, *** *p*=0.000

As shown in Table 8, the Sobel z-test yielded a z-value of 4.77 ($p < 0.05$), confirming that digital literacy significantly mediates the relationship between academic self-regulation and problem-solving attitudes among science students. The partial mediation indicates that while self-regulation directly influences problem-solving attitudes, part of this effect operates through digital literacy. This is evident from the reduction in the beta coefficient from $\beta = .450$ to $\beta = .279$, which remained significant. The result underscores digital literacy’s role as an intermediary and aligns with Zhao et al. (2023), emphasizing that both digital literacy and self-regulated learning must be strengthened to enhance students’ critical and problem-solving skills. [45]

Table 8: Results of statistical analysis on the presence (or absence) of mediating effect

Combination of Variables	Sobel z	p-value	Mediation
academic → digital literacy → problem solving attitudes	4.768557	*p*<0.05	Partial mediation

* *p*<0.05

Results revealed a significant relationship among academic self-regulation, problem-solving attitudes, and digital literacy, with the Sobel z-test confirming that digital literacy significantly mediates the link between self-regulation and problem-solving attitudes. This finding underscores the vital role of digital literacy as a cognitive and motivational scaffold that enables students to manage and process their learning more effectively. Students with higher digital literacy can efficiently navigate digital tools, reduce extraneous cognitive load, and enhance meaningful learning. In line with SDT, their competence, autonomy, and relatedness in digital environments strengthen intrinsic motivation and cognitive efficiency. These results affirm that self-regulated digital literacy skills not only enhance students’ cognitive abilities but also nurture their motivation and engagement in science learning.

4. Conclusion

The findings revealed that science students demonstrated a high level of academic self-regulation, indicating their ability to effectively manage and direct their own learning processes. Their problem-solving attitudes were found to be moderate, reflecting a generally positive yet improvable disposition toward addressing academic challenges. Additionally, students exhibited an advanced level of digital literacy, suggesting strong competence in utilizing digital tools for learning. In terms of correlation analysis, data revealed significant and positive relationships among all three variables. Students who were more self-regulated also tended to display higher digital literacy and more positive problem-solving attitudes. Regression analysis further showed that academic self-regulation predicted both digital literacy and problem-solving attitudes, while digital literacy also predicted problem-solving attitudes even after controlling for self-regulation.

When digital literacy was introduced as a mediating factor, the direct influence of academic self-regulation on problem-solving attitudes decreased but remained significant, indicating partial mediation. This suggests that while self-regulation directly enhances students' problem-solving attitudes, its impact is strengthened when accompanied by strong digital literacy skills. Overall, these findings emphasize the importance of integrating digital competence into self-directed learning to improve students' capacity for effective problem-solving in science education.

The results align with Cognitive Load Theory (CLT) and Self-Determination Theory (SDT), emphasizing the cognitive and motivational foundations of science learning in digital contexts. From the CLT perspective, students with high digital literacy manage cognitive load more effectively by organizing and processing digital information, which supports meaningful learning and scientific reasoning. However, their moderate problem-solving attitudes indicate that these cognitive skills are not yet fully translated into effective application and persistence when solving complex problems.

In the framework of SDT, the students' high self-regulation and digital literacy reflect competence and autonomy, but their moderate problem-solving attitudes suggest a need to enhance relatedness and intrinsic motivation. Strengthening collaboration, feedback, and authentic digital problem-solving tasks can promote engagement and persistence. To improve the partial mediation, instructional designs should integrate metacognitive scaffolds and reflective digital activities that connect self-regulation and digital literacy. Overall, fostering a learning environment that merges cognitive efficiency with motivational support can transform students' digital proficiency and self-regulatory strength into more confident and enduring problem-solving attitudes in science.

5. Recommendation

In science education, enhancing students' digital literacy, academic self-regulation, and problem-solving attitudes requires an integrated approach that aligns technology use with cognitive and motivational principles. Learners should engage in goal setting, reflective thinking, and responsible digital practices to cultivate autonomy, persistence, and critical awareness. Teachers are encouraged to apply inquiry-based and problem-centered pedagogies grounded in Cognitive Load Theory and Self-Determination Theory, embedding self-monitoring, formative feedback, and reflective activities that promote cognitive efficiency and intrinsic motivation. Parents can reinforce these skills by modeling responsible digital behavior, supporting independent learning, and maintaining balanced technology use at home. School administrators should invest in modern digital infrastructure, professional development, and institutional policies that encourage ethical and collaborative technology integration. Future research may explore additional cognitive and affective factors influencing these constructs and conduct longitudinal analyses to strengthen evidence for sustainable 21st-century science education practices.

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