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Mediating Effect of Metacognitive Awareness on the Correlation between 21st Century Skills and Self-regulation in Learning among Students of Science and Technology, Engineering, and Mathematics Strand

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Abstract — Poor self-regulation impedes science learning. This study examined the mediating effect of metacognitive awareness on the correlation between 21st century skills and self-regulation using a predictive design, stratified random sampling of 209 respondents, and mediation analysis. Finding revealed that metacognitive awareness partially mediates this relationship, supporting Social Cognitive Theory. Future studies may explore additional variables through qualitative methods and factor analysis to account for the remaining 0.651 variance.

Keywords: Mediating effect of metacognitive awareness, 21st century skills, self-regulation in learning, students of science, technology, engineering, mathematics

I. INTRODUCTION

The Problem and Its Scope

Globally, poor self-regulation in science learning has become more evident as curricula demand higher-order thinking, problem solving, and independent learning. The shift to blended and online learning further exposed learners' regulatory deficits, especially in virtual STEM

settings requiring strong self-regulation (Liu et al., 2024; Najah & Indriyanti, 2024). Overall, these findings highlight persistent weaknesses in students' ability to sustain engagement and manage learning effectively.

Cross-national evidence shows persistent challenges in students' self-regulation in science. Studies in Turkey, Indonesia, and Israel report limited self-regulatory skills despite innovative digital interventions, alongside teachers' difficulties in fostering these abilities (Akdeniz, 2022; Faza & Lestari, 2025; Arvatz et al., 2025). These findings suggest that self-regulation issues cut across contexts, reflecting a global challenge in translating instructional innovations into sustained self-regulated learning.

In the Philippines, the education system also struggles to develop self-regulation in science learning. Physics studies show uneven self-regulation, particularly low in problem-solving and communication, indicating weak higher-order thinking (Paderna & Monterola, 2021). Other studies report low monitoring among low-performing students and difficulties in independent laboratory work and capstone projects, pointing to self-regulation deficits (Buot, 2023; De Manuel, 2023). Collectively, these findings highlight similar self-regulatory weaknesses among Filipino learners, emphasizing the need for targeted interventions.

Persistent low self-regulation is not only an individual concern but also a threat to the nation's future workforce, as it limits competencies needed in STEM careers (Blackmore et al., 2023; Paz-Baruch & Hazema, 2023). Despite promising interventions, gaps remain in addressing senior high school STEM students, ensuring contextual relevance, and resolving measurement inconsistencies. These gaps explain ongoing challenges in science education. This study examines metacognitive awareness as a mechanism through which 21st century skills lead to effective self-regulation in science learning.

Significance of the Study

By providing empirical evidence on metacognitive awareness, 21st century skills, and self-regulation, the study benefits students by enhancing their metacognitive awareness and improving

their ability to regulate learning and apply scientific knowledge. Teachers, curriculum designers, and policymakers may use the results to integrate metacognitive strategies that promote autonomous, reflective, and globally competitive learners.

Statement of the Problem

This study was aimed at determining the significance of the mediating effect of metacognitive awareness on the correlation between 21st century skills and self-regulation in science learning. Specifically, it aims to determine:

1. To describe the levels of metacognitive awareness in terms of declarative knowledge, procedural knowledge, conditional knowledge, planning, information management, monitoring, debugging, and evaluation; 21st century skills in terms of collaboration, critical thinking, creativity, and communication; and self-regulation of learning in terms of planning, self-monitoring, evaluation, reflection, effort, and self-efficacy;

2. To determine the significant relationship between metacognitive awareness, 21st century skills, and the self-regulation of learning;

3. To determine the significance of the direct effect of 21st century skills on self - regulation in science learning, controlling for metacognitive awareness;

4. To determine the significance of the indirect effect of 21st century skills on self - regulation in science learning through metacognitive awareness;

5. To determine the significance of the total effect of 21st century skills on self - regulation in science learning;

Hypotheses:

H01: There is no significant relationship between metacognitive awareness, 21st century skills, and self-regulation in science learning.

H02: The direct effect of 21st century skills on self-regulation in science learning, controlling for metacognitive awareness is not significant.

H03: The indirect effect of 21st century skills on self-regulation in science learning through metacognitive awareness is not significant.

H04: The total effect of 21st century skills on self-regulation in science learning is not significant.

Theoretical and Conceptual Framework

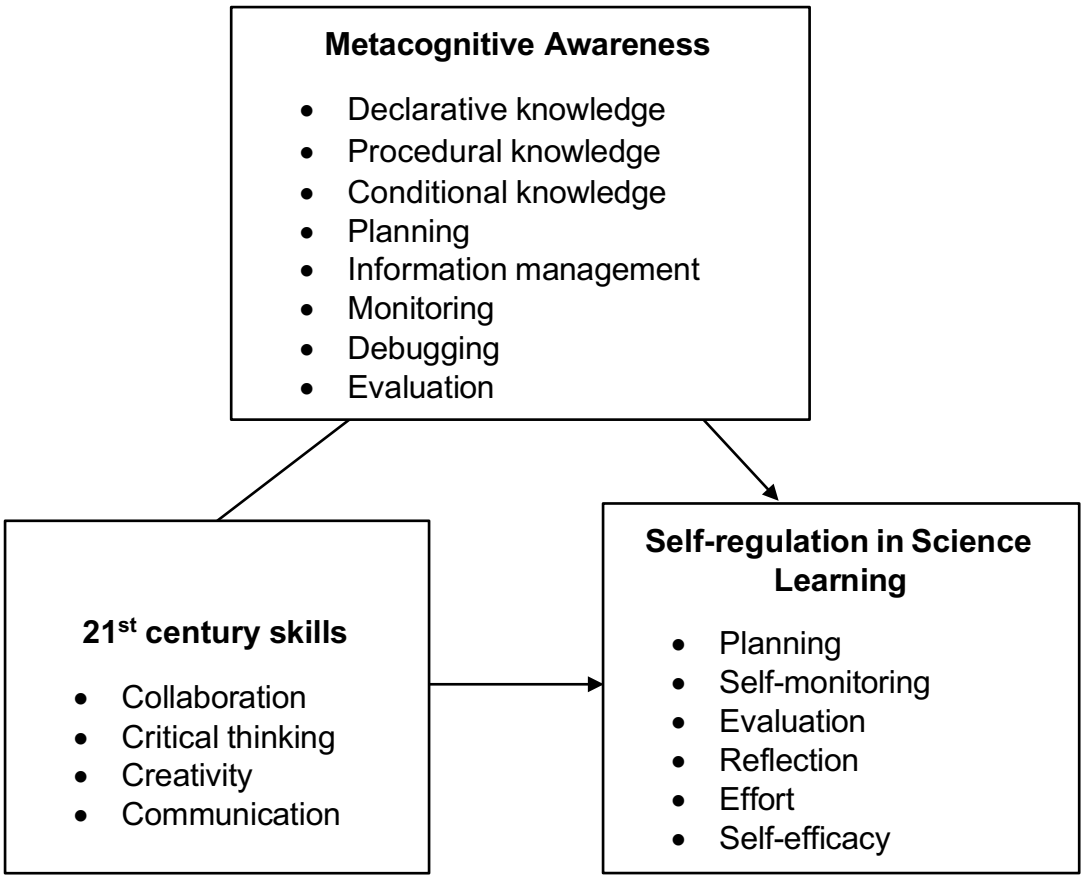
This study is anchored on Albert Bandura's Social Cognitive Theory (1986), which posits that learning is a product of human behavior in terms of the dynamic triadic interaction of personal factors, behavior, and environmental influences.

One of the main concepts of this theory is reciprocal determinism. In this study, where metacognitive awareness as mediating variable indicated by declarative knowledge, procedural knowledge, conditional knowledge, planning, information management, monitoring, debugging, and evaluation (Schraw & Dennison, 1994) relates to the personal factors of the theory; the self-regulation in science learning indicated by planning, self-monitoring, evaluation, reflection, effort, and self-efficacy (Kelley et al., 2019) is associated with the behavioral factors of the theory; and finally the 21st century skills indicated by collaboration, critical thinking, creativity, and communication (Toering et al., 2012) relates to the environmental influences of the theory. These variables interact and influence one another. Grounded in Social Cognitive Theory, the study

highlights the role of metacognitive awareness in transforming externally developed skills into sustained self-regulatory habits that improve academic performance.

Hence, this study is fully anchored on the Social Cognitive Theory.

Mediating Variable



Independent Variable. **Dependent Variable**

II. METHODOLOGY

This chapter includes the research design, study locale, sample and sampling technique, data gathering and analysis techniques, and ethical considerations.

Research Design

The study employed a predictive research design to examine direct and indirect relationships among variables without data manipulation. This design forecasts outcomes using existing data and statistical relationships and is widely applied in education, health, and social sciences. Its advantages include supporting data-driven decisions, enabling early intervention, and handling complex variables, making it valuable for planning and theory testing (González-Díaz & Bustamante-Cabrera, 2021; Relich, 2023; Dejardin et al., 2022).

Locale of the Study

This study was conducted in Region XI in the southern Philippines, specifically in a private institution in Davao City offering the STEM strand. The site was appropriate as STEM emphasizes scientific inquiry, science learning, and higher-order thinking, aligning with the study's focus on metacognitive awareness, 21st century skills, and self-regulation. The institution was chosen because STEM students engage in research-driven, problem-based tasks requiring these competencies, ensuring data reflected authentic science learning experiences.

Sample and Sampling Technique

The study included 209 respondents from 457 Grade 12 STEM students for SY 2025–2026. It used stratified random sampling, dividing the population into homogeneous strata and randomly selecting samples proportionate to each group (Etikan & Bala, 2017). This method ensures representation in heterogeneous populations and improves accuracy, reduces bias, and enhances

reliability (Thomas, 2023; Triveni et al., 2024). Sample size was determined using the Raosoft Sample Size Calculator to ensure appropriateness.

Data Gathering Technique

The survey technique was used to collect data through structured questions, enabling efficient large-scale data gathering in education and social sciences. Its advantages include cost-effectiveness, standardized responses, and strong generalizability (Goodfellow, 2023).

Three adapted questionnaires were used: the Metacognitive Awareness Inventory (Schraw & Dennison, 1994) with 52 items ($\alpha = 0.92$), a 21st century skills questionnaire (Kelley et al., 2019) ($\alpha = 0.95$), and a self-regulation scale (Toering et al., 2012) ($\alpha = 0.95$). All used Likert-type scales to describe respondents' conditions and underwent reliability testing, with all instruments obtaining Cronbach's alpha values above 0.90, indicating high reliability.

Data Analysis Technique

The study used descriptive, correlation, and mediation analyses. Descriptive analysis summarizes data using measures like mean and standard deviation to identify patterns and present findings clearly (Wolniak, 2024). Correlation analysis measures the strength and direction of relationships among variables without implying causation, using Pearson product-moment correlation (Madhuri & Negi, 2023). Mediation analysis examines how an independent variable influences a dependent variable through a mediator, determining whether effects are direct or indirect (Schuler et al., 2024).

The following are the matrix showing the scale, descriptive level, and interpretation for each variable in this study. This measure is specifically used to describe the level of metacognitive awareness.

Scale	Level	Metacognitive Awareness	21st century skills	Self-regulation in Science Learning
1.00 – 1.74	Very low	Very poor	Very poor	Very poor
1.75 – 2.49	Low	Poor	Poor	Poor
2.50 – 3.74	High	Good	Good	Good
3.75 – 4.00	Very high	Very Good	Very Good	Very Good

Standard Deviation Value Ranges and Interpretation

Range	Description	Interpretation
SD ≤ 0.50	Highly Consistency Response	No intention
SD = 0.51	Moderately Consistency Response	Less intention
SD = 1.01 – 1.50	Low Consistency Response	More intention
SD > 1.50	Very Low Consistency Response	Much intention

In this study, the significance of the correlation is tested at 0.05 confidence level. The following is the standard measure for the interpretation scale of r-value, the following scheme is used:

Computer r	Descriptive Interpretation
+/-1.00	Perfect correlation
Between +/- 0.75 – +/- 0.99	High correlation
Between +/- 0.51 – +/- 0.74	Moderately high correlation
Between +/- 0.31 – +/- 0.50	Moderately low correlation
Between +/- 0.01 – +/- 0.30	Low correlation
0.00	No correlation

The standard measure for the interpretation of the strength of the mediation is as follows:

Proportion Mediated	Interpretation
< 0.20	Weak Mediation
0.20 – 0.50	Moderate Mediation
> 0.50	Strong Mediation

Ethical Consideration

The study strictly adhered to ethical standards in educational research. The researcher followed the guidelines of the Holy Cross of Davao College – Society for Moral Integrity and Legal Ethics, which reviewed and approved the study and instruments, and also secured approval

from the Department of Education. Participants were informed of the study's purpose, scope, and procedures, and participation was voluntary. Written informed consent was obtained, with respondents free to withdraw at any time. Confidentiality and anonymity were ensured, and all data were securely stored without disclosing identities.

III. RESULTS

This chapter presents the descriptive, correlation, and mediation tables, along with the analysis and interpretation of results. It ends with a summary of findings.

Descriptive Results

Table 1 is the descriptive table. This includes the variables involved in the study: metacognitive awareness, 21st century skills, and self-regulation, and the corresponding indicators of each variable. Furthermore, it also contains the standard deviation, the mean, and the corresponding descriptive level.

TABLE 1
DESCRIPTIVE STATISTICS (N = 209)

Variables	Standard Deviation	Mean	Descriptive Level
Metacognitive Awareness	**0.53**	**3.19**	**High**
Declarative Knowledge	*0.40*	*3.23*	*High*
Procedural Knowledge	*0.47*	*3.36*	*Very High*
Conditional Knowledge	*0.44*	*3.35*	*Very High*
Planning	*0.43*	*3.26*	*Very High*
Information Management	*0.39*	*3.31*	*Very High*

Debugging Strategies	*0.43*	*3.24*	*High*
Evaluation	*0.38*	*3.49*	*Very High*
21st Century Skills	**0.34**	**3.38**	**Very High**
Collaboration	*0.31*	*3.30*	*Very High*
Critical Thinking	*0.35*	*3.43*	*Very High*
Creativity	*0.38*	*3.36*	*Very High*
Communication	*0.44*	*3.35*	*Very High*
Self-Regulation	*0.47*	*3.40*	*Very High*
Planning	*0.34*	*3.38*	*Very High*
Self-monitoring	**0.43**	**3.38**	**Very High**
Evaluation	*0.42*	*3.57*	*Very High*
Reflection	*0.43*	*3.54*	*Very High*
Effort	*0.44*	*3.34*	*Very High*
Self-efficacy	*0.47*	*3.23*	*High*

The table shows that metacognitive awareness has an overall mean of 3.19 (high), with declarative knowledge at a high level and procedural and conditional knowledge at very high levels, indicating strong ability in applying learning strategies. Metacognitive skills—planning, information management, debugging, and evaluation—are consistently very high, reflecting strong self-directed learning. 21st century skills have an overall mean of 3.38 (very high), with collaboration, critical thinking, creativity, and communication all rated very high, indicating well-developed competencies. Self-regulation has an overall mean of 3.40 (very high), with planning, self-monitoring, reflection, and effort also very high, though self-efficacy remains slightly lower at a high level. Overall, low standard deviations indicate uniform responses, reflecting a strong and homogeneous profile across variables in science learning. In general, low standard deviations

indicate uniform responses, reflecting a robust and homogeneous profile of metacognitive awareness, 21st century skills, and self-regulation in science learning.

Correlation Results

Table 2 is the correlation table. It discusses the correlation analysis between 21st century skills and self-regulation in science learning. The 21st century skills were treated as the independent variable, and the self-regulation was treated as the dependent variable. It also contains the r-value, p-value, decision of the H0 and its interpretation.

The table shows a significant correlation between metacognitive awareness and self-regulation ($p < .001$), leading to the rejection of the null hypothesis. The r-value of 0.752 indicates a high positive relationship, meaning higher metacognitive awareness is associated with better self-regulation in science learning. Similarly, the correlation between 21st century skills and self-regulation is also significant ($p < .001$), resulting in the rejection of the null hypothesis. The r-value of 0.761 shows a high positive relationship, indicating that as students' 21st century skills increase, their self-regulation in science also improves.

TABLE 2
CORRELATION TABLE (N=209)

Variables	Self-regulation			
	r-value	p-value	Decision on H_0	Interpretation
Metacognitive Awareness	0.752	<.001	Reject H0	High, Significant correlation
21st Century Skills	0.761	<.001	Reject H0	High, Significant correlation

Level of Significance: 0.05 Decision Rule: Reject H_0 if $p < 0.05$

Overall, the findings show that students' self-regulation is strengthened by higher metacognitive awareness and well-developed 21st-century skills, highlighting the need to integrate these components into instructional practices.

Mediation Results

Table 3 is mediation table showing the mediating effect of metacognitive awareness on the correlation between 21st century skills and self-regulation. It contains the number of samples, and the independent, mediating, and dependent variables. It also contains the direct, indirect and total effect of feeling stress variable controlling and going through the mediator, and its total effect, respectively. Finally, it contains the estimate beta, standard error, Z-value, p-value, decision on null hypothesis and corresponding interpretation.

The table shows that the direct effect of 21st century skills on self-regulation, controlling for metacognitive awareness, yielded a Beta of 0.43 with $p < .001$, leading to the rejection of the null hypothesis. This indicates a significant direct effect. The indirect effect through metacognitive awareness produced a Beta of 0.28 with $p < .001$, also rejecting the null hypothesis and indicating a significant mediated effect. The total effect of 21st century skills on self-regulation yielded a Beta of 0.71 with $p < .001$, confirming a significant overall effect.

TABLE 3
MEDIATION TABLE (N = 209)

Label	Path / Effect	Estimate (B)	SE	Z-Value	p-value	Decision on H_0	Interpretation
A	21st Century Skills → Metacognitive Awareness	0.63	0.04	14.35	<.001	Reject H_0	Significant
B	Metacognitive Awareness → Self-regulation	0.44	0.06	6.91	<.001	Reject H_0	Significant
c'	21st Century Skills→ Self-regulation (Direct Effect)	0.43	0.05	7.93	<.001	Reject H_0	Significant
a × b	Indirect Effect (Mediation)	0.28	0.04	6.27	<.001	Reject H_0	Significant
c (Total Effect)	21st Century Skills→ Self-regulation (Total)	0.71	0.04	17.32	<.001	Reject H_0	Significant

Level of Significance: 0.05
Decision Rule: Reject H_0 if $p < 0.05$
% Mediation: Direct – 60.7%; Indirect – 39.3%

The table shows a mediated proportion of 0.394, indicating a moderate mediating effect of metacognitive awareness on the relationship between 21st century skills and self-regulation in science. Since both the direct and indirect effects are significant, metacognitive awareness is a significant partial mediator.

Overall, the findings show that metacognitive awareness is a meaningful but partial explanatory mechanism linking 21st century skills and self-regulation. These results have important implications for teaching and curriculum development, suggesting that developing 21st century skills alone is insufficient; educators must also integrate metacognitive instruction to strengthen students' self-regulatory abilities.

Summary of Findings

Based on statistical results, it specifically was found that:

1. There is a significant relationship between metacognitive awareness, 21st century skills, and self-regulation in science learning.
2. The direct effect of 21st century skills on self-regulation in science learning, controlling for metacognitive awareness, is significant.
3. The indirect effect of 21st century skills on self -regulation in science learning through metacognitive awareness, is significant.
4. The total effect of 21st century skills on self -regulation in science learning, is significant.

IV. DISCUSSIONS

Discussed in this section are the findings of the study. The correlation and mediation analysis are presented.

Metacognitive Awareness and 21st Century Skills, and the Self-regulation Correlations

The findings show a significant relationship between metacognitive awareness and self-regulation in science learning, indicating that greater awareness of thinking processes improves learners' ability to manage and regulate learning. This aligns with studies showing that metacognitive awareness strengthens self-regulation in science and STEM contexts (Dignath & Veenam, 2021). However, it contrasts with Dahlstrom-Hakki et al. (2020), who argued that the relationship may be overestimated, dynamic, or only moderate, as some learners overrate their metacognitive skills or show inconsistency across science tasks. The present study is more robust due to its larger sample of 209 respondents compared to 105 in Dahlstrom-Hakki et al. (2020), enhancing reliability and generalizability.

The findings show a significant relationship between 21st century skills and self-regulation in science learning, indicating that higher-order competencies such as collaboration, critical thinking, creativity, and communication improve when learners effectively regulate their learning. This supports research suggesting that these skills rely on self-regulatory processes like planning and monitoring (Lee & Portillo, 2022). However, this contradicts Bygstad et al. (2024), who found the relationship to be weak or indirect, noting that self-regulation does not always strongly predict critical thinking, communication, and collaboration. The present study is more reliable due to its larger sample of 209 respondents compared to 160 in Bygstad et al. (2020), improving generalizability and reliability.

Metacognitive Awareness Partially Mediates the Correlation Between 21st Century Skills and Self-regulation in Science Learning

The findings show that metacognitive awareness has a significant but partial mediating effect on the relationship between 21st century skills and self-regulation in science learning, explaining only part of the connection. This aligns with Akcaoğlu et al. (2023), who found that while 21st century skills directly influence self-regulation, metacognitive awareness serves as an important intervening mechanism. It also supports Karataş & Arpacı (2021), showing that stronger 21st century skills enhance metacognitive awareness, which in turn improves self-regulated and reflective science learning. However, this contradicts Wang et al. (2025), who noted that mediation effects are often inconsistent or not clearly isolated in intervention studies, suggesting other factors also influence self-regulation outcomes.

Conclusion

Based on the findings, metacognitive awareness partially but significantly mediates the relationship between 21st century skills and self-regulation in science learning at a moderate strength (0.349). This supports Social Cognitive Theory, which explains learning as a result of the

dynamic interaction of personal factors, behavior, and environmental influences that produce positive feedback.

Recommendations

Based on the conclusion, future research may include additional variables that could mediate the relationship between 21st-century skills and self-regulation in science education. Qualitative studies may be conducted to identify themes that explain the remaining 0.651 variance in the mediation effect. Lastly, exploratory factor analysis may be used to develop assessment tools for these potential variables.

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