Predominant Learning Styles and Metacognitive Skills among STEAM undergraduate students: A Quantitative Study

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Abstract: The present study examined the relationship between learning styles and metacognitive skills among STEAM undergraduate students. Grounded in Honey and Mumford's learning style framework, the study investigated four learning styles—Activist, Reflector, Theorist, and Pragmatist—and their predictive association with metacognitive skills. A quantitative correlational research design was employed with a sample of 400 STEAM undergraduate students selected through stratified random sampling from Arts, Engineering, Mathematics, Science, and Technology disciplines. Data were collected using the Learning Styles Questionnaire (LSQ) developed by Honey and Mumford (1992) and the Metacognitive Activities Inventory (MCAI) by Cooper and Sandi Urena (2009). Statistical analyses included reliability analysis, Confirmatory Factor Analysis (CFA), Pearson correlation, regression analysis, Kruskal–Wallis H test, and Mann–Whitney U test, SEM model.

The findings demonstrated satisfactory psychometric properties for all learning style scales (Cronbach's α = .787–.837; KMO = .790–.863). Significant disciplinary differences were observed across all four learning styles. Arts students reported comparatively higher learning style mean scores, whereas Technology students demonstrated lower scores and greater variability. Reflector ($r = .150$, $p = .003$) and Pragmatist ($r = .137$, $p = .006$) learning styles showed significant positive relationships with metacognitive skills. Regression analysis further revealed that Reflector ($B = 0.483$, $p = .003$) and Pragmatist ($B = 0.475$, $p = .006$) learning styles significantly predicted metacognitive skills. Regression analysis indicated significant positive predictive effects for Reflector and Pragmatist orientations, whereas structural path analysis revealed a significant negative effect for Activist orientation on metacognitive skills.

The study concludes that reflective and practical learning orientations contribute positively to metacognitive regulation among STEAM undergraduate students. The findings underscore the importance of integrating reflective learning activities and metacognitive strategy instruction within interdisciplinary STEAM education..

Keywords: STEAM education, Honey and Mumford learning styles, metacognitive skills.

INTRODUCTION

Metacognition is widely recognized as a central component of self-regulated learning and academic success in higher education. It refers to learners' awareness and regulation of their own cognitive processes

, including planning, monitoring, evaluating, and adapting learning strategies during problem-solving activities (Flavell, 1979; Schraw & Dennison, 1994). Contemporary educational psychology conceptualizes metacognition through two interconnected dimensions: knowledge of cognition and regulation of cognition. Knowledge of cognition includes declarative, procedural, and conditional knowledge, whereas regulation of cognition involves planning, monitoring, debugging, and evaluative control of learning processes (Veenman et al., 2006; Stanton et al., 2021).

Within Science, Technology, Engineering, Arts, and Mathematics (STEAM) education, metacognitive regulation has become increasingly important due to the interdisciplinary and problem-centered nature of STEAM learning environments. STEAM curricula require students to integrate conceptual knowledge across disciplines, manage cognitive complexity, and adapt strategies in response to ill-structured and authentic learning tasks (Quigley et al., 2017; Wahba et al., 2022). Previous research has consistently associated strong metacognitive skills with improved academic achievement, critical thinking, problem-solving ability, and self-regulated learning behaviors in higher education contexts (Dent & Koenka, 2016; Tuononen et al., 2022).

Despite the established importance of metacognition, students differ considerably in how they engage with learning activities and regulate cognitive processes. One framework frequently used to understand these differences is Honey and Mumford's experiential learning model, which categorizes learners according to four experiential learning styles: Activist, Reflector, Theorist, and Pragmatist (Honey & Mumford, 1992). Derived from Experiential Learning Theory, the framework describes learners' preferred tendencies toward action, reflection, conceptualization, and practical application during learning experiences.

However, learning style theory remains theoretically contested within contemporary educational psychology. Critics have argued that empirical evidence supporting the instructional "matching hypothesis" is limited and that learning styles should not be interpreted as stable cognitive traits or deterministic predictors of academic performance (Coffield et al., 2004; Pashler et al., 2008). Consequently, recent scholarship increasingly interprets learning styles as flexible learning preferences or experiential orientations that may shape learners' approaches to reflection, experimentation, and self-regulation rather than fixed psychological categories.

Within this perspective, experiential learning styles may still provide meaningful insight into metacognitive engagement in interdisciplinary educational environments. Reflective and theory-oriented learning tendencies, for example, may encourage strategic planning and evaluative monitoring, whereas strongly action-oriented approaches may place less emphasis on reflective regulation processes (Kolb & Kolb, 2005), At the same time, contemporary studies suggest that the relationship between learning styles and metacognition is likely influenced by contextual and psychological factors, including emotional regulation, reflective habits, and self-regulated learning capacity.

In STEAM education specifically, the interaction between experiential learning styles and metacognitive regulation remains underexplored. Existing studies have primarily relied on descriptive or bivariate approaches and have rarely investigated these relationships using multivariate statistical modeling across interdisciplinary STEAM populations (Broadbent & Poon, 2015; Schunk & Greene, 2018). Furthermore, limited evidence exists regarding how different experiential learning orientations relate to metacognitive skills among students enrolled in diverse STEAM disciplines.

Therefore, the present study investigates the relationship between learning styles and metacognitive skills among STEAM undergraduate students. Using correlational and structural modeling approaches, the study examines whether Activist, Reflector, Theorist, and Pragmatist learning preferences are associated with variations in metacognitive regulation across interdisciplinary STEAM contexts. By situating experiential learning preferences within broader self-regulated learning frameworks, the study aims to contribute to current discussions regarding cognitive engagement and metacognitive development in higher education.

Review of Literature

2.1 Learning Styles and Honey and Mumford's Framework

Honey and Mumford's learning styles framework, derived from Experiential Learning Theory, identifies four experiential orientations through which learners tend to engage with educational activities: Activist, Reflector, Theorist, and Pragmatist (Honey & Mumford, 1992). The framework was developed from Kolb's experiential learning cycle and describes how learners may prefer to approach reflection, experimentation, conceptualization, and practical application during learning processes. Contemporary educational research increasingly interprets these orientations as flexible learning preferences rather than fixed psychological categories, suggesting that they may shape learners' engagement with instructional environments and cognitive regulation during academic tasks.

Activist-oriented learners generally prefer immediate participation, concrete experiences, and active engagement in learning activities. While such learners may demonstrate enthusiasm toward experiential tasks, highly action-oriented approaches may place comparatively less emphasis on reflective evaluation and strategic monitoring processes (Craig et al., 2020). Reflectors, in contrast, tend to adopt a more observational and deliberate approach by collecting information, reviewing multiple perspectives, and evaluating experiences before making decisions. These tendencies may support metacognitive monitoring and evaluative thinking because learners continuously compare new information with existing understanding (Tuononen et al., 2022).

Theorists typically emphasize logical organization, conceptual coherence, and systematic planning during learning activities. Such tendencies are often associated with procedural metacognitive knowledge and structured problem-solving approaches (Stanton et al., 2021). Pragmatists, meanwhile, focus on the practical application and testing of ideas in authentic contexts, which may support adaptive problem-solving and evaluative regulation through experimentation and iterative feedback. In interdisciplinary STEAM environments, where learners must integrate knowledge across multiple domains and respond to complex problems, these experiential preferences may influence students' self-regulated learning behaviors and metacognitive engagement.

Although Honey and Mumford's framework remain widely applied in higher education research, its theoretical validity continues to be debated. Critics have questioned the empirical support for the instructional matching hypothesis and cautioned against interpreting learning styles as stable determinants of cognition or academic performance (Coffield et al., 2004). Consequently, recent scholarship recommends treating learning styles as adaptive learning tendencies or experiential preferences rather than deterministic cognitive traits. From this perspective, experiential learning preferences may provide insight into how students approach reflection, strategic planning, experimentation, and cognitive regulation within specific educational contexts rather than serving as fixed indicators of learning capability.

2.2 Metacognitive Skills and Self-Regulated Learning

Metacognition is widely recognized as a central component of Self-Regulated Learning and refers to learners' awareness and regulation of their cognitive processes during learning activities (Pintrich, 2004; Zimmerman, 2002). Rather than functioning as a fixed trait, metacognition is generally understood as a dynamic and adaptive process that enables learners to plan, monitor, evaluate, and regulate their thinking in response to academic tasks and problem-solving situations. Foundational models proposed by Flavell (1979) and Brown (1987) conceptualize metacognition through two interconnected dimensions: knowledge of cognition and regulation of cognition. Knowledge of cognition includes declarative, procedural, and conditional knowledge, whereas regulation of cognition involves planning, monitoring, information management, debugging, and evaluative control of learning strategies.

Research consistently demonstrates that strong metacognitive regulation contributes to improved academic achievement, critical thinking, problem-solving ability, and adaptive learning behaviors across higher education contexts (Dent & Koenka, 2016; Stanton et al., 2021). In interdisciplinary STEAM environments, metacognitive skills are particularly important because learners are required to integrate concepts from multiple disciplines, manage cognitive complexity, and adapt strategies when responding to authentic and ill-structured problems (Quigley et al., 2017; Wahba et al., 2022). Such environments demand continuous reflective monitoring and strategic regulation during collaborative and inquiry-based learning activities.

Several instruments have been developed to assess metacognitive processes in educational settings. Among the most widely used is the Metacognitive Awareness Inventory (MAI), developed by Schraw and Dennison (1994), which measures learners' awareness and regulation of cognition. Recognizing the need for more domain-specific assessment tools, Cooper and Sandi-Urena (2009) later introduced the Metacognitive Activities Inventory (MCAI), designed specifically for scientific and problem-solving environments. The MCAI focuses on observable metacognitive regulation during complex learning activities, including planning, monitoring, evaluation, and strategic adaptation during problem-solving tasks.

Previous studies utilizing the MCAI indicate that collaborative, inquiry-based, and problem-centered learning environments can strengthen learners' metacognitive monitoring and evaluative abilities (Sandi-Urena et al., 2011, 2012). Such findings are particularly relevant in STEAM education, where students frequently encounter cognitively demanding tasks requiring interdisciplinary reasoning and adaptive thinking. Research further suggests that effective metacognitive regulation supports cognitive flexibility, reflective thinking, and innovative problem-solving, all of which are essential competencies for contemporary scientific and technological learning environments (Kaufman & Beghetto, 2009; Li et al., 2024).

2.3 Relationship Between Learning Styles and Metacognition

The relationship between experiential learning preferences and metacognitive regulation is theoretically supported by Information Processing Theory and self-regulated learning frameworks. From this perspective, learners' preferred approaches to engagement and problem-solving may influence how they plan, monitor, evaluate, and regulate learning strategies during academic activities.

Previous studies suggest that Reflector and Theorist learning styles may be positively associated with metacognitive regulation because these orientations emphasize observation, analysis, logical organization, and evaluative thinking (De Blume & Londoño, 2021). Learners demonstrating reflective tendencies are often more likely to engage in monitoring and self-evaluation processes, whereas theory-oriented learners may emphasize systematic planning and conceptual organization during learning activities. Pragmatist style may also support metacognitive regulation through practical experimentation, iterative testing, and evaluation of solutions in authentic contexts.

In contrast, highly action-oriented learning styles may place greater emphasis on immediate engagement and experimentation than on reflective evaluation and strategic monitoring processes (Craig et al., 2020). However, contemporary educational research cautions against deterministic interpretations of these relationships. Learning styles should not be interpreted as fixed predictors of metacognitive ability, as multiple contextual and psychological variables may influence the development and expression of self-regulatory behaviors.

Recent studies indicate that emotional regulation, reflective habits, motivation, and instructional context may mediate or moderate the relationship between experiential learning preferences and metacognitive engagement. Furthermore, learners with similar experiential preferences may still demonstrate substantially different levels of metacognitive regulation depending on environmental, social, and pedagogical conditions.

Within STEAM education, metacognitive regulation is increasingly viewed as an adaptive process that supports interdisciplinary learning, cognitive flexibility, and academic engagement (Örs & Titrek, 2018; Sultana et al., 2025). Collaborative and inquiry-oriented learning environments may further strengthen reflective regulation and strategic learning behaviors among students. Nevertheless, empirical evidence examining the predictive association between experiential learning preferences and metacognitive skills within interdisciplinary STEAM populations remains limited.

Most existing studies have primarily relied on descriptive statistics or simple correlational analyses and have rarely applied advanced multivariate approaches to examine these relationships comprehensively. Therefore, further research using structural and predictive modeling techniques is needed to better understand how experiential learning preferences relate to metacognitive regulation in higher education STEAM contexts.

3. Objectives of the Study

To identify learning styles among STEAM undergraduate students

To examine the relationship between Activist learning style and metacognitive skills.

To examine the relationship between Reflector learning style and metacognitive skills.

To examine the relationship between Theorist learning style and metacognitive skills.

To examine the relationship between Pragmatist learning style and metacognitive skills.

To examine the predictive effect of learning styles on metacognitive skills.

Methodology

3.1 Research Design

The present study employed a quantitative, cross-sectional correlational research design to examine the relationship between experiential learning preferences and metacognitive skills among STEAM undergraduate students. A predictive correlational approach was considered appropriate because the study aimed to investigate associations among variables and evaluate the extent to which experiential learning preferences were related to variations in metacognitive regulation within interdisciplinary educational contexts. The design also supported the application of multivariate statistical techniques, including confirmatory factor analysis (CFA) and regression-based modeling, for examining structural relationships among the study constructs (Kline, 2023).

3.2 Population and Sample

The target population consisted of undergraduate students enrolled in STEAM-related programs across higher education institutions in Haryana. To enhance representativeness across academic disciplines and geographic regions, a multistage stratified random sampling strategy was employed across the six administrative divisions of the state. Stratification was conducted according to academic discipline, and participants were selected from accredited first year undergraduate programs including B.Tech, BCA, B.Sc. IT, B.Sc. Computer Science, B.Sc. Mathematics, and Arts-related STEAM disciplines.

An a priori power analysis was conducted using G*Power version 3.1 (Faul et al., 2009) to estimate the minimum sample size required for multiple regression analysis with five predictors. Assuming a medium effect size ($f^2 = 0.15$), a significance level of $\alpha = .05$, and statistical power of .80, the required minimum sample size was estimated at 92 participants.

A total of 450 questionnaires were distributed, of which 412 were returned, yielding a response rate of 91.6%. After preliminary screening for incomplete responses and multivariate outliers, 400 valid responses were retained for final analysis. The final sample size substantially exceeded the minimum requirement identified through power analysis, thereby providing sufficient statistical power for the planned analyses. Prior to data collection, informed consent was obtained from all participants, and the study procedures adhered to institutional ethical guidelines for research involving human participants.

3.3 Data Analysis Strategy

All statistical analyses were conducted using R. Preliminary analyses included descriptive statistics, assessment of normality, and evaluation of internal consistency reliability using Cronbach's alpha and McDonald's omega coefficients. Confirmatory Factor Analysis (CFA) was performed to evaluate the construct validity and dimensional structure of the study instruments.

Pearson correlation analysis was used to examine bivariate relationships between experiential learning styles and metacognitive skills. Multiple linear regression analysis was subsequently employed to investigate the predictive association between learning styles and metacognitive regulation. In addition, non-parametric statistical tests, including the Mann–Whitney U test and

Kruskal–Wallis H test, were conducted where assumptions of normality were not fully satisfied. Statistical significance was evaluated at the .05 level.

3.4 Instrumentation

Data were collected using two standardized instruments that have been widely utilized in educational and psychological research contexts.

Learning Styles Questionnaire (LSQ)

The Learning Styles Questionnaire (LSQ), developed by Honey and Mumford (1992), was used to assess experiential learning styles across four dimensions: Activist, Reflector, Theorist, and Pragmatist. Consistent with contemporary educational psychology perspectives, the LSQ was utilized in the present study as a measure of learners' preferred experiential learning orientations rather than as an assessment of fixed cognitive traits.

To evaluate the construct validity of the LSQ within the present sample, confirmatory factor analysis (CFA) was conducted using established psychometric criteria for model evaluation (Hu & Bentler, 1999; Kline, 2023). The Reflector scale demonstrated strong model fit indices (CFI = .985, TLI = .983, RMSEA = .029), while the Theorist scale also showed satisfactory fit (CFI = .960, TLI = .956, RMSEA = .039). The Activist and Pragmatist scales demonstrated acceptable model fit, although some indices suggested moderate measurement variability across constructs.

The findings generally support the applicability of the LSQ for examining experiential learning styles within interdisciplinary STEAM populations. However, consistent with previous critiques of learning style frameworks (Coffield et al., 2004; Pashler et al., 2008), the present study does not interpret these dimensions as deterministic or fixed indicators of cognitive ability. Rather, the scales are treated as exploratory measures of learners' preferred approaches to engagement, reflection, conceptualization, and practical application during academic learning activities.

Metacognitive Activities Inventory (MCAI)

Metacognitive skills were assessed using the Metacognitive Activities Inventory (MCAI) developed by Cooper and Sandi-Urena (2009). The MCAI was designed specifically for scientific and problem-solving environments and measures active metacognitive regulation during complex learning tasks.

Preliminary reliability analyses indicated satisfactory psychometric properties for the instrument. The overall metacognitive skills scale demonstrated strong internal consistency, with Cronbach's alpha (α) 0.84 and McDonald's omega (ω) 0.86, both exceeding recommended thresholds for educational research (Hair et al., 2019; Hayes & Coutts, 2020). Sampling adequacy was confirmed through the Kaiser–Meyer–Olkin (KMO) measure (0.88), indicating suitability for factor analysis. Bartlett's test of sphericity was statistically significant, $\chi^2(351) = 2334.53, p < .001$, suggesting that the correlation matrix was appropriate for factor extraction (Tabachnick & Fidell, 2019).

A confirmatory factor analysis was subsequently conducted to examine the dimensional structure of the MCAI. The three-factor model demonstrated acceptable fit indices: $\chi^2(321) = 564.82, p < .001$, CFI = 0.881, TLI = 0.870, RMSEA =0.044, and SRMR = 0.074. Although the CFI and TLI values were slightly below the conventional 0.90 benchmark, previous psychometric research suggests that values approaching 0.90 may be considered acceptable for multidimensional educational constructs measured in applied settings (Marsh et al., 2004; Perry et al., 2015). Collectively, the results support the suitability of the MCAI for assessing metacognitive regulation among STEAM undergraduate students in the present study.

Table 1

Demographic Characteristics of Participants (N = 400)

Variable	Category	n	%
Gender	Male	185	46.3
	Female	215	53.7
STEAM Discipline	Arts	77	19.2
	Engineering	59	14.7
	Mathematics	53	13.2
	Science	59	14.7
	Technology	152	38.0

Note. Percentages may not total exactly 100 because of rounding.

Table 1 presents the demographic distribution of the participants. Female students constituted 53.7% of the sample, whereas male students represented 46.3%. Regarding academic discipline, Technology students formed the largest subgroup (38.0%), followed by Arts (19.2%), Engineering (14.7%), Science (14.7%), and Mathematics (13.2%). The inclusion of students from multiple STEAM disciplines provided adequate disciplinary representation for comparative analysis across interdisciplinary educational contexts.

Table 2

Mann–Whitney U Test Results for Gender Differences in Learning styles

Learning Preference	Gender	M	SD	U	p
Activist	Female	14.40	4.14	19,461	< .001
	Male	14.30	3.76		
Reflector	Female	15.80	3.86	15,454	< .001
	Male	14.10	4.38		
Theorist	Female	15.80	3.86	15,540	< .001
	Male	14.10	4.38		
Pragmatist	Female	13.90	3.28	13,995	< .001
	Male	15.70	2.80		

Note. M = mean; SD = standard deviation.

The Mann–Whitney U analysis indicated statistically significant gender differences across several experiential learning styles. Female students reported significantly higher Reflector and Theorist scores, suggesting stronger tendencies toward reflective observation and analytical processing. Male students demonstrated comparatively higher Pragmatist scores, indicating a greater preference for practical experimentation and applied problem-solving.

Although the Activist scale yielded statistical significance, the mean difference between genders was extremely small, suggesting limited practical significance. These findings indicate that gender may be associated with variation in reflective and practical learning tendencies; however, such differences should be interpreted cautiously because experiential learning styles are adaptive orientations rather than fixed psychological characteristics. In contrast, the predominant style among Optometry students at Universiti Kebangsaan Malaysia was reflector, with females showing a stronger preference for reflective and analytical patterns (Zainora et al., 2010). This preference is associated with female left-brain dominance, linked to complex processing and analytical problem solving (Guraya et al., 2014). Practical problem-solving characteristics exhibited by male students in technical and skills-based academic contexts reflect such learning behaviors

Table 3

Kruskal–Wallis Test Results for Learning Styles Across STEAM Disciplines

Learning Preference	Arts	Engineering	Mathematics	Science	Technology	H	p
Activist	15.04	13.88	13.17	12.76	14.33	16.042	.003
Reflector	16.88	15.76	16.58	15.75	13.32	45.589	< .001
Theorist	31.61	29.59	29.47	28.41	27.30	16.481	.002
Pragmatist	31.82	28.92	31.51	28.75	25.17	45.170	< .001

Note. Values under STEAM disciplines represent mean ranks.

Interpretation

The Kruskal–Wallis analysis revealed statistically significant disciplinary differences across all four experiential learning styles. A non-parametric analysis of variance revealed significant disciplinary disparities in learning style with Arts students achieving the highest mean ranks across all experiential dimensions, most notably within the Reflector (Mean Rank = 16.88) and Pragmatist (Mean Rank = 31.82) scales. This performance strongly corresponds with their elevated baseline metacognitive scores and supports contemporary literature positing that the visual and performing arts inherently demand continuous, iterative metacognitive loops. Specifically, the constant necessity for strategic planning, monitoring, and critical self-evaluation in the arts naturally cultivates a robust Reflector orientation (Eremić, 2024; Flavell, 1979).

Arts students demonstrated comparatively higher Reflector and Pragmatist mean ranks, whereas Technology students generally reported lower scores across several learning preference dimensions.

The strongest disciplinary differences were observed for Reflector and Pragmatist orientations. These findings suggest that disciplinary learning environments may influence students' preferred approaches to reflection, experimentation, and strategic engagement during learning activities. The results further support previous research indicating that interdisciplinary educational contexts shape self-regulated learning behaviors differently across STEAM domains.

Table 4

Correlation Between Experiential Learning Styles and Metacognitive Skills Across STEAM Disciplines

Discipline	N	Activist r (p)	Pragmatist r (p)	Reflector r (p)	Theorist r (p)
Arts	77	0.102 (0.378)	0.250 (0.028)	0.208 (0.069)	0.094 (0.415)
Engineering	59	−0.230 (0.080)	−0.078 (0.555)	−0.111 (0.404)	−0.104 (0.434)
Mathematics	53	0.096 (0.493)	0.304 (0.027)	0.405 (0.003)	0.277 (0.044)
Science	59	−0.137 (0.302)	−0.066 (0.622)	−0.068 (0.610)	−0.058 (0.664)
Technology	152	−0.178 (0.028)	−0.102 (0.211)	−0.077 (0.348)	−0.072 (0.378)
Overall	400	−0.086 (0.085)	0.137 (0.006)	0.150 (0.003)	0.068 (0.173)

Note. r = Pearson correlation coefficient; p < .05 (), p < .01 (**). Table reports provided values; negative trends dominate technical fields.

Table 4, Pearson correlation analysis revealed discipline-specific relationships between experiential learning styles and metacognitive skills. Overall, Reflector (r = 0.150, p = 0.003) and

Pragmatist ($r = 0.137$, $p = 0.006$) orientations demonstrated significant positive associations with metacognitive skills, whereas Activist styles showed a weak negative trend.

The strongest positive relationships were observed among Mathematics students, particularly for Reflector and Pragmatist orientations. These findings suggest that reflective and practically oriented learning tendencies may support metacognitive monitoring and strategic regulation in analytically demanding academic environments. Educational literature frequently highlights that successful mathematical reasoning is deeply intertwined with explicit metacognitive monitoring and structured theoretical processing (Schoenfeld, 2016)

In contrast, Engineering, Science, and Technology disciplines demonstrated weaker or nonsignificant relationships. Collectively, the results indicate that experiential learning styles may relate differently to metacognitive engagement across disciplinary contexts.

Furthermore, Pragmatists are characterized by their desire to test theories in practice and actively monitor what works. Research in cognitive processing confirms that learners who consciously select and evaluate their strategies (Reflectors and Pragmatists) demonstrate significantly higher metacognitive awareness than those who rely on impulsive or purely theoretical approaches (Zormanová, 2020).

Table 5 ;Simple Linear Regression Predicting Metacognitive Skills From Learning Styles

Predictor	B	SE	t	p
Activist	−0.31	0.18	−1.73	0.085
Pragmatist	0.48	0.17	2.75	0.006
Reflector	0.48	0.16	3.02	0.003
Theorist	0.25	0.18	1.37	0.173

Note. ($N = 400$). Significant values are reported at ($p < .05$).

Table 5, Regression analysis indicated that for every one-unit increase in the Reflector score, metacognitive skills increased by 0.48 units (unstandardized $B = 0.483$, $p = 0.003$). Similarly, Pragmatist scores positively predicted metacognitive skills ($B = 0.475$, $p = 0.006$). While these predictive relationships are statistically significant, the overall bivariate correlations are small ($r = 0.150$ and $r = 0.137$, respectively). This suggests that while reflective and pragmatic learning orientations positively contribute to metacognitive regulation, they account for a modest portion of the overall variance (Cano, 2005; Taub, 2020). The substantial predictive weight of the Reflector style specifically corroborates research indicating that deliberate cognitive pausing and self-evaluation are prerequisite mechanics for effective self-regulation in complex STEAM disciplines (Veenman, 2006). The marginal negative Activist coefficient suggests experiential "doing" may contribute less to metacognitive planning and monitoring without complementary reflection. This validates experiential learning frameworks which argue that active experimentation without reflective observation often bypasses executive monitoring, leading to impulsive rather than regulated problem-solving (Kolb, 2014; Litzinger, 2011). Furthermore, the nonsignificant Theorist coefficient indicates that pure abstract conceptualization does not necessarily translate to the active regulation and execution of cognitive strategies.

Table 6:Standardized Structural Path Coefficients Predicting Metacognitive Skills

Predictor	Outcome Variable	β	p	Result
Activist	Metacognition	−0.182	.002	Significant
Reflector	Metacognition	0.134	.059	Marginal
Theorist	Metacognition	−0.014	.839	Not significant
Pragmatist	Metacognition	0.144	.064	Marginal

Note. The structural model explained 5.0% of the variance in metacognitive skills (($R^2 = .050$)).

The combined structural model accounted for 5.0% of the total variance in metacognitive skills (R^2= .050). The path analysis revealed a statistically significant, negative predictive relationship between the Activist learning style and metacognition (**β** = -0.182, p = .002). This indicates that higher alignment with spontaneous, trial-and-error experiential learning is associated with lower executive cognitive regulation among STEAM undergraduate students.

Conversely, both the Pragmatist and Reflector learning styles exhibited positive predictive trajectories toward metacognitive skills. While these pathways did not breach the strict α= 0.05 threshold, they demonstrated marginal significance indicative of a meaningful trend. Specifically, the Pragmatist style (**β** = 0.144, p = .064) and the Reflector style (**β** = 0.134, p = 0.059) suggest that learners who prioritize practical utility and observational data collection, respectively, are more likely to exhibit elevated self-regulatory behaviors. Finally, the Theorist learning style yielded a near-zero, non-significant predictive effect on metacognition (**β** = -0.014, p = 0.839), suggesting that an affinity for logical structuring alone does not independently drive active cognitive regulation in this sample.

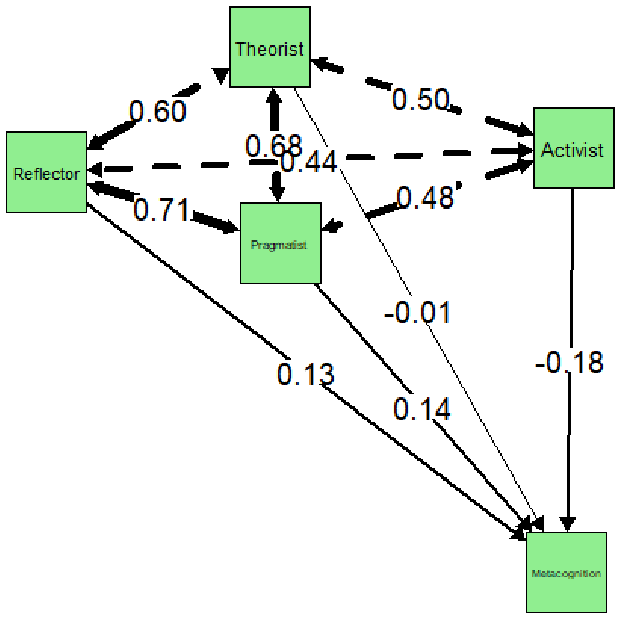

Figure 1. Path Analysis of the Predictive Relationships Between Experiential Learning Styles and Metacognitive Skills

As illustrated in Figure 1, the structural path model was specified to examine the direct predictive relationships between experiential learning styles and metacognitive skills among STEAM undergraduate students. The model incorporated both directional regression pathways and covariance relationships among the four learning style constructs. Overall, the model accounted for 5.0% of the variance in metacognitive skills (R^2 = .050), indicating that experiential learning styles contributed modestly to students' metacognitive regulation.

Among the examined predictors, the Activist learning style demonstrated a statistically significant negative effect on metacognitive skills (β = −0.18, *p* = 0.002). This finding suggests that students who predominantly rely on immediate engagement, spontaneous experimentation, and action-oriented learning approaches may exhibit comparatively lower levels of reflective monitoring and strategic self-regulation.

In contrast, both Reflector and Pragmatist learning styles demonstrated positive predictive relationships with metacognitive skills, although the effects remained marginally significant. Specifically, the Reflector orientation ($\beta = 0.13$, $p = 0.059$) indicated that students who engage in careful observation, information review, and evaluative thinking may be more likely to employ metacognitive regulation strategies during learning activities. Similarly, the Pragmatist orientation ($\beta = 0.14$, $p = 0.064$) suggested that learners who emphasize practical application and adaptive experimentation may also demonstrate stronger self-regulatory tendencies. Although these coefficients did not reach the conventional 0.05 significance threshold, the positive directional trends indicate potentially meaningful associations that warrant further investigation in larger or longitudinal samples.

The Theorist learning style showed a negligible and non-significant effect on metacognitive skills ($\beta = -.01$, $p = 0.839$), suggesting that a preference for conceptual structure and logical organization alone may not directly translate into active metacognitive regulation within interdisciplinary STEAM learning contexts.

The covariance estimates further revealed substantial interrelationships among the learning style constructs, indicating that experiential learning orientations are not independent categories but overlapping and interacting tendencies. The strongest covariance relationships emerged between Reflector and Pragmatist orientations ($r = 0.71$) and between Theorist and Pragmatist orientations ($r = 0.68$). These findings imply that students frequently integrate reflective, theoretical, and practical approaches simultaneously while engaging in complex learning tasks.

Despite the presence of several statistically meaningful pathways, the relatively low explained variance suggests that metacognitive regulation is influenced by multiple additional factors beyond experiential learning styles. Variables such as motivation, academic self-efficacy, emotional regulation, prior academic experiences, instructional environment, and self-regulated learning strategies may contribute substantially to the development of metacognitive skills among STEAM students. Consequently, future research should employ more comprehensive structural models incorporating cognitive, motivational, and contextual variables to better explain variations in metacognitive regulation across interdisciplinary higher education settings.

Discussion

The primary objective of this study was to examine the psychometric properties of the Metacognitive Activities Inventory (MCAI) and Honey and Mumford's learning style scales, and to investigate the intersection of learning styles, gender, and metacognitive skills across diverse STEAM disciplines. The robust reliability coefficients and favorable Confirmatory Factor Analysis (CFA) fit indices, calculated utilizing R software, confirm that both the MCAI and the learning style questionnaire are structurally valid and reliable instruments for assessing higher education cohorts.

A central finding of this investigation is the significant predictive power of the Reflector and Pragmatist learning styles on metacognitive skills. As demonstrated by the linear regression models, both styles operate as primary direct predictors of metacognitive regulation. This aligns with foundational cognitive processing frameworks which assert that learners who deliberately select, execute, and review their strategies—hallmarks of the Reflector and Pragmatist profiles—exhibit significantly higher metacognitive awareness than those relying on impulsive trial-and-error (Adarlo, 2025; Taub, 2020; Zormanová, 2020). The substantial predictive weight of the Reflector style specifically corroborates research indicating that cognitive pausing is a prerequisite mechanic for effective self-regulation in complex academic environments (Veenman, 2006).

Discipline-specific analyses yielded highly nuanced patterns. Arts students demonstrated the highest ranks across styles, particularly as Reflectors and Pragmatists. This reflects the inherently iterative nature of visual and performing arts, where students must physically apply techniques and continuously step back to critically evaluate their creative output against conceptual goals—a studio-based practice that naturally fosters metacognition (Kolb, 2014). Similarly, Mathematics students exhibited the strongest positive links across Reflector, Pragmatist, and Theorist styles. This flawless reflection of the discipline's rigorous cognitive demands suggests that successful mathematical reasoning is deeply intertwined with explicit metacognitive monitoring and structured theoretical processing (Schoenfeld, 2016).

Conversely, Technology and Engineering students consistently ranked lowest in reflective tendencies, with the Activist style showing a weak negative correlation with metacognitive skills. This highlights a critical developmental gap in technical fields. Experiential learning frameworks suggest that active experimentation ("doing") without complementary reflective observation bypasses executive monitoring, leading to impulsive problem-solving (Kolb, 2014; Litzinger, 2011). These findings indicate that while technology students may excel at immediate, action-oriented tasks, they experience pronounced deficits in the reflective and practical tendencies required for advanced debugging and complex application in STEAM contexts.

Gender differences further complexify these learning profiles. Female students exhibited significantly stronger reflective and theoretical tendencies, while male students leaned heavily toward practical application (Pragmatist). This variance aligns with prior investigations into technical and skills-based higher education, suggesting that female students may default to complex processing and analytical problem-solving patterns, whereas male students favor immediate, hands-on resolution (Guraya, 2014; Zainora, 2010).

Educational Implications

The empirical evidence from this study provides highly actionable insights for the pedagogical design of STEAM curricula. The pronounced deficit in reflective practices among Technology and Engineering students necessitates immediate educational intervention. Because technology students frequently default to active, impulsive processing, educators cannot assume that metacognition will develop organically. Curricula must be explicitly scaffolded to force cognitive pausing. Instructors should integrate mandatory reflective methodologies—such as post-debugging journals, peer code-reviews, or structured "evaluate and plan" phases—prior to the execution of technical tasks to bridge this developmental gap (Education Endowment Foundation, 2021)

Furthermore, recognizing the distinct gender variations in learning approaches allows for more inclusive instructional design. While male students may immediately engage with the practical mechanics of a task, they may require targeted prompts to theorize and reflect on their processes. Conversely, female students, who demonstrate high reflective capacity, may benefit from environments that explicitly encourage them to transition their theoretical understanding into immediate, confident practical application.

For Arts and Mathematics disciplines, the current pedagogical frameworks appear highly conducive to metacognitive development. Educators in these fields should continue to leverage studio-based and analytical-regulation models, explicitly framing these disciplinary practices as transferable metacognitive skills that students can apply to broader, interdisciplinary STEAM challenges.

Future Research Directions

While this study provides a robust baseline, several avenues for future research are required to expand upon these findings. First, as the current univariate regression paths position Reflector and Pragmatist styles as primary direct predictors, subsequent quantitative investigations should transition to comprehensive Structural Equation Modeling (SEM). Future SEM frameworks should test multiple regression R, specific effect sizes (e.g., f^2), and crucial mediating variables—such as tangible STEAM task performance or academic GPA—while reporting strict model fit indices ($RMSEA < 0.06$, $CFI > 0.95$) to ensure structural validation (Kline, 2023; Zepeda, 2015).

Second, the data highlights a clear action-reflection gap in technical disciplines, but the underlying causes remain underexplored. Future mixed-methods or qualitative studies utilizing interviews and observational protocols could investigate why Technology and Engineering students default to the Activist style, and whether this is a product of the students' inherent traits or an artifact of how technology curricula are historically structured and assessed.

Finally, future longitudinal research tracking STEAM students from enrollment through graduation is recommended to examine how reflective pedagogical interventions influence the development of metacognitive regulation and adaptive learning behaviors over time. Such research may clarify whether experiential learning styles remain stable or evolve in response to educational environments and self-regulatory training..

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