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Research Article

The power of practicum in science education: An analysis of the role of practical-based learning on learning satisfaction and deep learning

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Despite growing demands for deeper scientific understanding and practical competence, empirical evidence on how microlearning and teaching style interact with practical-based learning to strengthen learning quality across ASEAN school contexts remains limited. This study analyzes the effects of microlearning, teacher teaching style, and practical-based learning on students' learning satisfaction and deep learning in science education contexts in Indonesia and Malaysia. Employing a quantitative approach with a descriptive–correlational design, the research involved 437 high school students who completed an online survey using instruments validated by experts and pilot-tested prior to data collection. Data were analyzed using PLS-SEM across two models: Model I, which incorporated practical-based learning as a mediating variable, and Model II, which excluded the mediator. Results show that microlearning is the strongest predictor of learning satisfaction and deep learning, followed by teacher teaching style and practical-based learning. Additionally, Model I demonstrates the highest predictive power for deep learning with no significant differences between Indonesia and Malaysia. The findings affirm that the integrated implementation of microlearning, teacher teaching style, and practical-based learning effectively enhances learning quality and promotes the development of deep learning in science education. These findings imply that educational institutions and teachers should institutionalize microlearning-supported practicum design alongside responsive teaching practices, while policymakers can prioritize guidance and infrastructure that scale such integrated models to improve science learning outcomes.

Keywords: Deep learning; Learning satisfaction; Microlearning; Practical-based learning; Teacher teaching style

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1. Introduction

Science education in Association of Southeast Asian Nations [ASEAN] countries has undergone significant transformation in recent years, marked by a growing emphasis on preparing students to meet the increasingly complex demands of the modern world (Situmorang et al., 2024). A key shift has been the movement away from traditional instructional methods toward more interactive and outcome-oriented approaches (Trullàs et al., 2022). One such approach that has gained

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considerable prominence in educational practice is Practical-Based Learning [PRB], which encourages students to engage directly in hands-on experiences and apply scientific concepts in real-world contexts (Baxmann et al., 2024). PRB has been shown to be effective in enhancing critical thinking, problem-solving abilities, and teamwork, skills that are essential in the scientific domain. Beyond improving students' cognitive abilities, PRB also provides opportunities to connect theoretical knowledge with practice, a critical aspect in mastering complex scientific concepts (Zeng et al., 2021). Through practical engagement, students are better able to grasp abstract ideas and apply them in relevant and authentic situations.

However, the effectiveness of PRB cannot be separated from other pedagogical factors that shape student engagement and satisfaction in the learning process. One of these key factors is microlearning, an approach that delivers content in concise, easily digestible segments. Microlearning facilitates the assimilation of complex information within a short time frame, allowing students to learn more flexibly and efficiently (Dolowitz et al., 2022). Integrating PRB with microlearning can create a stronger and more coherent learning experience, as the two approaches complement each other by combining efficient information delivery with rich experiential engagement. In addition, teacher teaching style plays an equally vital role in fostering a supportive learning environment. Interactive, student-centered teaching styles can enhance students' motivation and engagement because they promote a sense of value and empowerment in the learning process (Cubacub & Jimenez, 2025; Orsini et al., 2020). Tailoring instructional approaches to students' needs further supports deeper understanding, particularly in science education, where practical skills are indispensable. A supportive teaching style also functions as social support, both emotional and instructional, and teacher support is positively associated with students' perceived social support and adaptive learning related outcomes in high school contexts (Yıldız & Eldeleklioğlu, 2024).

The application of microlearning, teacher teaching style, and Practical-Based Learning (PRB) is inherently linked to another important aspect of learning: student satisfaction. Learning satisfaction refers to the extent to which students feel content with their educational experiences, encompassing the quality of instructional materials, the teaching methods employed, and their level of engagement in learning activities. Research indicates that students who are satisfied with their learning experiences tend to have higher motivation and demonstrate deeper learning (Huang et al., 2020; Yang et al., 2022). Deep learning itself becomes a central outcome, as it is the aspect most likely to be shaped by microlearning, teacher teaching style, and PRB. Deep learning emphasizes meaningful understanding rather than rote memorization, enabling students to connect new knowledge with prior understanding and apply it in varied relevant contexts. As Pan et al. (2023) notes, deep learning occurs when students not only recall information but also analyze, evaluate, and apply it creatively. Thus, the attainment of deep learning is strongly influenced by the quality of learning experiences provided.

Although PRB, microlearning, and teacher teaching style have each been shown to positively influence learning outcomes, research examining their combined influence within a holistic context remains limited. Much of the existing literature focuses on the benefits of PRB for practical skill development, yet insufficient attention is given to its impact on learning satisfaction and deep learning. Likewise, microlearning is often studied within technology-enhanced learning environments, with few studies exploring how it might collaborate with PRB to create more comprehensive learning experiences. This reveals a critical gap in the literature concerning how PRB, microlearning, and teacher teaching style may interact to enhance learning satisfaction and foster deep learning, both of which are central goals in science education.

Therefore, this study aims to address this gap by investigating the combined effects of microlearning, teacher teaching style, and Practical-Based Learning on learning satisfaction and deep learning in science education. A more comprehensive understanding of how these three approaches interact is expected to provide meaningful contributions to the development of more effective instructional practices, particularly in science learning. Additionally, this study explores the substantial mediating role of Practical-Based Learning in educational processes. Through this research, it is anticipated that new insights will emerge regarding strategies to enhance the quality of science education through more modern, integrated, and effective approaches. Effective integration of microlearning, PRB, and teacher teaching style will not only strengthen student engagement, meaningful thinking, and learning satisfaction but also contribute significantly to the achievement of deep, relevant, and contextually grounded learning outcomes.

2. Conceptual Framework and Hypothesis Development

Microlearning is an instructional approach that delivers content in concise, structured segments designed to facilitate students' comprehension within a relatively short period of time (Yao & Ho, 2024). In science education, microlearning can serve as an effective preparatory tool before students engage in practical activities, whether in the field or in the laboratory. By presenting foundational concepts in a brief and accessible format, microlearning helps students recall and understand the theoretical knowledge needed before applying it in practice (Liew et al., 2023). This enables Practical-Based Learning to become more effective, as students enter practical sessions with stronger foundational understanding and readiness to participate actively. The segmented and easily accessible learning structure encourages students to construct knowledge actively (Tennyson et al., 2021), thereby supporting the development of PRB, which emphasizes hands-on experiences and the application of theory in authentic contexts.

Furthermore, microlearning allows students to absorb information gradually and subsequently apply it within practical settings. According to Theory of Learning Satisfaction, individuals experience satisfaction when learning goals are achieved effectively and efficiently. Microlearning delivers content efficiently and aligns with students' needs, it is believed to enhance learning satisfaction (Liew et al., 2023). When instructional materials are presented in a relevant, accessible, and comprehensible manner, students tend to feel more satisfied with their learning experience, contributing to greater engagement and motivation (Abbasi et al., 2023). Deep learning, which refers to the meaningful, applicable understanding of content, can be achieved when students feel engaged in an effective learning process. Microlearning supports the repetition-based learning necessary for strengthening comprehension and organizing information into long-term memory. This process encourages students to think critically and make connections across knowledge domains, which serves as the foundation of deep learning (Tennyson et al., 2021). Additionally, microlearning provides opportunities for students to focus on a single topic or concept in a short time span, making it easier for them to understand and integrate new knowledge with prior understanding.

H1: Microlearning influences practical-based learning.

H2: Microlearning influences learning satisfaction.

H3: Microlearning influences deep learning.

Teaching style plays a critical role in shaping the effectiveness of instruction. Interactive, experience-based teaching styles can create a conducive environment for Practical-Based Learning (Botelho & Boubaker, 2024). In science education, theoretical concepts often require connection to real-world applications, making teaching styles that facilitate discussion, experimentation, and hands-on activities in the laboratory or field especially important. Teachers who encourage active exploration and experimentation can enhance students' understanding of the material and deepen their practical experiences (Dulai et al., 2022). By providing opportunities for students to learn through direct experimentation and apply theory in real-world situations, teaching styles that support PRB significantly reinforce instructional effectiveness (Li et al., 2022). When teachers adopt approaches that encourage practical exploration, students are better able to link theory and practice, resulting in learning experiences that are more meaningful and relevant (Abbasi et al., 2023). Thus, a teaching style that engages students actively in practical activities has the potential to enhance the overall success of PRB, enabling students to learn more effectively and to apply concepts more directly.

Moreover, according to Motivation and Learning Satisfaction Theory, students who feel satisfied with the teaching methods employed are more motivated to learn (Pérez- Guillén et al., 2022). Teaching styles that are interactive and responsive to students' needs can enhance their satisfaction with the learning process. Instruction that considers students' learning preferences and provides space for interaction and inquiry can increase their sense of satisfaction (Baherimoghadam et al., 2021; Guzelergene et al., 2025). Teaching style also influences students' deep learning. Deep learning occurs when students move beyond memorizing information to understanding concepts deeply and linking them with prior knowledge (Curtis et al., 2020; Sim & Ewan Matore, 2022). Teaching styles that emphasize conceptual understanding, encourage critical thinking, and facilitate active discussion promote deeper learning (Panwar & Sharma, 2025). Teaching approaches that engage students in reflection and analysis also improve their depth of understanding. Approaches rooted in exploration and intellectual challenge further strengthen students' conceptual mastery, an essential aspect of deep learning.

H4: Teacher teaching style influences practical-based learning.

H5: Teacher teaching style influences learning satisfaction.

H6: Teacher teaching style influences deep learning.

Students learn more effectively when they are given opportunities to engage in direct practical activities, whether in the field or laboratory (Kolil et al., 2020). Practical and application-oriented activities support students in linking theoretical knowledge to real-world contexts, thereby enabling them to understand how abstract concepts function within authentic situations (Insorio, 2024). In addition to enriching learning experiences, PRB fosters greater student engagement, which directly contributes to learning satisfaction. When students can see the relevance of their learning in real-life contexts, they experience greater satisfaction with their learning activities (Le et al., 2023; Young & Tullo, 2020). PRB not only enables students to understand theory but also to experience its application firsthand, enhancing their sense of achievement and satisfaction (Kong, 2021). Therefore, greater involvement in PRB leads to increased learning satisfaction, as students perceive direct benefits from engaging in more applicable and contextually relevant learning experiences.

Beyond enhancing satisfaction, PRB also plays a vital role in the development of deep learning. Deep learning occurs when students do not simply memorize information but connect it to prior knowledge and apply it across various contexts (McLeod & Hopfe, 2021; Prate & Hsu, 2025). PRB encourages students to think critically, reflectively, and problem-solve in real-world situations, deepening their understanding of the material (Modran et al., 2024; Ramasamy et al., 2022). By offering opportunities to link theory with direct experience, PRB reinforces comprehension and enables students to develop deeper and more applicable knowledge within real-world contexts.

H7: Practical-based learning influences learning satisfaction.

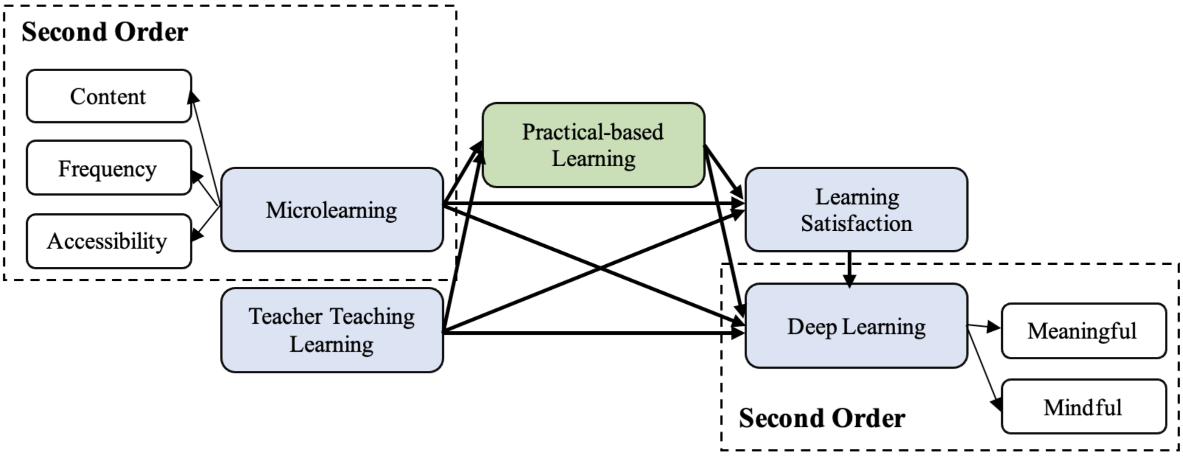
H8: Practical-based learning influences deep learning.

Learning satisfaction is shaped by various factors, including instructional methods, the relevance of content, and student engagement in the learning process (Adapon Doño & Mangila, 2021; Alda, 2023; Pagcamaan, 2024). Satisfied students tend to hold positive perceptions of their learning experience, which increases their motivation and engagement in subsequent learning (Kalmakov, 2026). Learning satisfaction, in turn, can influence the depth of students' understanding (Cheng et al., 2023; Yu et al., 2020). Students who feel satisfied are more likely to engage in critical, analytical, and reflective thinking, key characteristics of deep learning (Kwambaza & Basela, 2024). Deep learning involves constructing meaningful understanding by connecting newly acquired knowledge with prior experiences or knowledge, cultivating self-awareness, and applying it within broader contexts (Nishino, 2017). Learning satisfaction creates favorable conditions for students to pursue deeper, more applicable comprehension of subject matter.

H9: Learning satisfaction influences deep learning.

The conceptual framework integrating Microlearning, Teacher Teaching Style, Practical-Based Learning, Learning Satisfaction, and Deep Learning is illustrated in Figure 1.

Figure 1
Research Framework Diagram



3. Methods

3.1. Research Design

This study employed a quantitative research approach with a descriptive correlational (cross sectional) design aimed at identifying the combined effects of Microlearning, Teacher Teaching Style, and Practical-Based Learning on students' Learning Satisfaction and Deep Learning in science education. This design was selected because it enables the statistical examination of relationships among these variables and allows for the testing of the proposed hypotheses. To enhance the analytical rigor of the study, a comparative analysis was conducted using two structural models (Hair et al., 2019; Muis et al., 2025). Model I incorporates Practical-Based Learning as a mediating construct, whereas Model II excludes Practical-Based Learning as a mediator.

3.2. Data Collection

Data were collected in Indonesia and Malaysia (Indonesian School of Kuala Lumpur and the Senior High Schools in Gowa Regency), two countries that, despite having distinct educational contexts, share similar challenges in developing effective instructional methods in science education. The cultural and policy differences between the two countries provide broader insight into the implementation of Microlearning, Teacher Teaching Style, and Practical-Based Learning across diverse contexts, as well as how the interaction among these three factors may enhance students' Learning Satisfaction and Deep Learning. The data were obtained through an online survey distributed to students in selected schools in Indonesia and Malaysia using Google Forms. The survey adopted a self-reported method, in which students independently completed the questionnaire, ensuring that their responses reflected their personal experiences and perceptions. Data collection targeted students in Grades X, XI, and XII who had previously participated in laboratory or field practicum activities and had utilized microlearning media in their learning process. Sample selection was conducted through a pilot study in which the hypothesized model was tested using a smaller sample drawn from the same population (37 students) (Hair et al., 2021). The pilot analysis yielded a path coefficient of 0.175 (with p_{min} ranging from 0.11 to 0.2 at a 5% significance level), indicating that the minimum required sample size for the study was 155 students. The final sample consisted of 437 students who met all research criteria, as presented in Table 1. Participation in this study was voluntary, and written informed consent was obtained from each respondent.

Table 1
Demographic Profile of Research Samples in Two Countries

Variable	*Total (n)*	*Percentage (%)*
Country		
Indonesia	235	53.77
Malaysia	202	46.22
Grade Level		
Grade X	134	30.66
Grade XI	158	36.15
Grade XII	145	33.18

3.3. Instruments

The research instruments were developed through modifications of several supporting studies. The instruments were validated by three experts using the expert validation method (Jamaluddin et al., 2025), namely one science education expert, one biology learning expert, and one educational psychology expert. The validation results indicated a very high level of validity, with an average score of 3.82, demonstrating that the instruments are appropriate for measuring the variables in this study. Prior to distribution, a limited pilot test was administered to 25 students to ensure that the items did not generate ambiguity or bias during completion. The instruments were implemented only after confirming that no bias emerged during the pilot phase. The research instruments consisted of 38 items representing five major constructs: microlearning (content: 4 items; frequency: 4 items; accessibility: 4 items), teacher teaching style (9 items), practical-based learning (6 items), learning satisfaction (6 items), and deep learning (meaningful learning: 4 items; mindful learning: 4 items). All items were measured on a 4-point Likert scale (4 = strongly agree, 3 = agree, 2 = disagree, 1 = strongly disagree). Examples of validated items for each variable are presented in Table 2.

Table 2
Example Items for the Five Constructs

Construct and Item Code	*Sample Item Statement*	*Source of Modification*
Microlearning [CON3]	The materials provided in microlearning are sufficiently in-depth to enhance my understanding.	(Alias & Razak, 2023; Al-Zahrani, 2024)
Microlearning [FRE5]	Microlearning allows me to review the learning materials periodically.	(Ramírez & Ruíz Cansino, 2023; Závodná et al., 2024)
Microlearning [ACC1]	Microlearning is easily accessible through the device I use.	(Leong et al., 2020; Samala et al., 2023)
Teacher Teaching Style [TTS2]	The teacher’s instructional style encourages me to think actively and participate in class.	(Inayat & Ali, 2020; Lu et al., 2023)
Practical-Based Learning [PRB5]	Practical activities give me the opportunity to directly apply the concepts learned in class.	(Farah-Franco et al., 2020; Kurz et al., 2021; Suthipiyapathra, 2022)
Learning Satisfaction [LSN6]	I feel that the classroom atmosphere supports an enjoyable learning process.	(Iravani et al., 2022; Wang et al., 2021)
Deep Learning-Meaningful [MLG4]	I find it easier to understand the subject matter because I can relate it to my personal experiences.	(Bansal et al., 2021; Suthipiyapathra, 2022)
Deep Learning-Mindful [MDL2]	I am aware of when I begin to feel confused or struggle during learning, and I try to find ways to overcome it.	(Farah-Franco et al., 2020; Jiang et al., 2025)

3.4. Data Analysis

3.4.1. Measurement model assessment

Before conducting further analyses, validity and reliability tests were performed to ensure the quality of the research instruments. Indicator contributions to latent variables were examined using outer loadings; indicators with outer loading values greater than .70 were considered significant and acceptable (Syamsiah et al., 2024). Internal consistency reliability was assessed using Cronbach's Alpha, where values exceeding .70 indicated good reliability. Composite Reliability was also used to evaluate the extent to which the indicators within each construct were dependable; values greater than .70 signified that the constructs possessed strong reliability. Convergent validity was assessed using the Average Variance Extracted [AVE]. An AVE value greater than .50 implied that the construct explained more than 50% of the variance of its indicators (Benitez et al., 2020; Hair et al., 2021; Henseler et al., 2015). After confirming convergent validity and reliability, discriminant validity was examined using the Heterotrait–Monotrait Ratio [HTMT]. This method evaluates the distinctiveness of different constructs. HTMT values below .85 indicated satisfactory discriminant validity, while values exceeding .85 suggested potential issues requiring further evaluation (Hair et al., 2019; Hair et al., 2021).

3.4.2. Structural model assessment

Subsequently, a bootstrapping procedure with 5.000 subsamples was conducted to estimate the path coefficients in the structural model. A t-statistic value greater than 1.96 indicated that the path coefficient was statistically significant at the .05 level (5% significance threshold) (Hair et al., 2021). A 95% confidence interval was also used to assess the significance of each relationship; significance was confirmed when the confidence interval did not include zero (Aisyah et al., 2025). Furthermore, microlearning (content, frequency, and accessibility) and deep learning (meaningful and mindful learning) were modeled as reflective second-order constructs. This analysis followed the embedded two-stage approach within the PLS-SEM framework.

To evaluate the explanatory power of the structural model, the R-squared (R^2) value was examined to determine the proportion of variance in the dependent variables explained by the independent variables. Higher R^2 values indicated a stronger model. Interpretative thresholds were $R^2 > .75$ (substantial), $.50 < R^2 \leq .75$ (moderate), $.25 < R^2 \leq .50$ (weak), and $R^2 \leq .25$ (very weak). Predictive relevance was assessed using Q^2 values, where $Q^2 > 0$ indicated predictive relevance. Thresholds included $Q^2 > .50$ (high), $.25 < Q^2 \leq .50$ (moderate), and $Q^2 \leq .25$ (low). Effect size (f^2) was used to determine the magnitude of influence of each independent construct on its dependent counterpart. Values greater than 0.35 indicated a large effect, $0.15 < f^2 \leq 0.35$ a medium effect, and $f^2 \leq 0.15$ a small effect (Hair et al., 2019).

Model fit was examined using the Standardized Root Mean Square Residual (SRMR). An SRMR value below .08 indicated a good model fit. Additionally, the d_ULS statistic was used to measure the discrepancy between the empirical covariance matrix and the model-implied matrix; values below .05 indicated adequate model fit (Hair et al., 2012, 2019). The final model was selected based on optimal fit indices and superior predictive capability. Finally, a Multigroup Analysis [MGA] was conducted to assess differences in structural relationships between the Indonesian and Malaysian student groups. The analysis focused on three endogenous constructs, Practical-Based Learning, Learning Satisfaction, and Deep Learning. MGA tested whether the relationships among these constructs differed significantly across groups. When significant differences were detected, the findings were interpreted as evidence of group-specific variations in how the constructs influenced one another.

4. Results

Table 3 presents the correlation matrix among the constructs, illustrating statistically significant relationships among most of the variables examined. For instance, the construct CON exhibits

Table 3

Descriptive Statistics and Inter-Construct Correlations

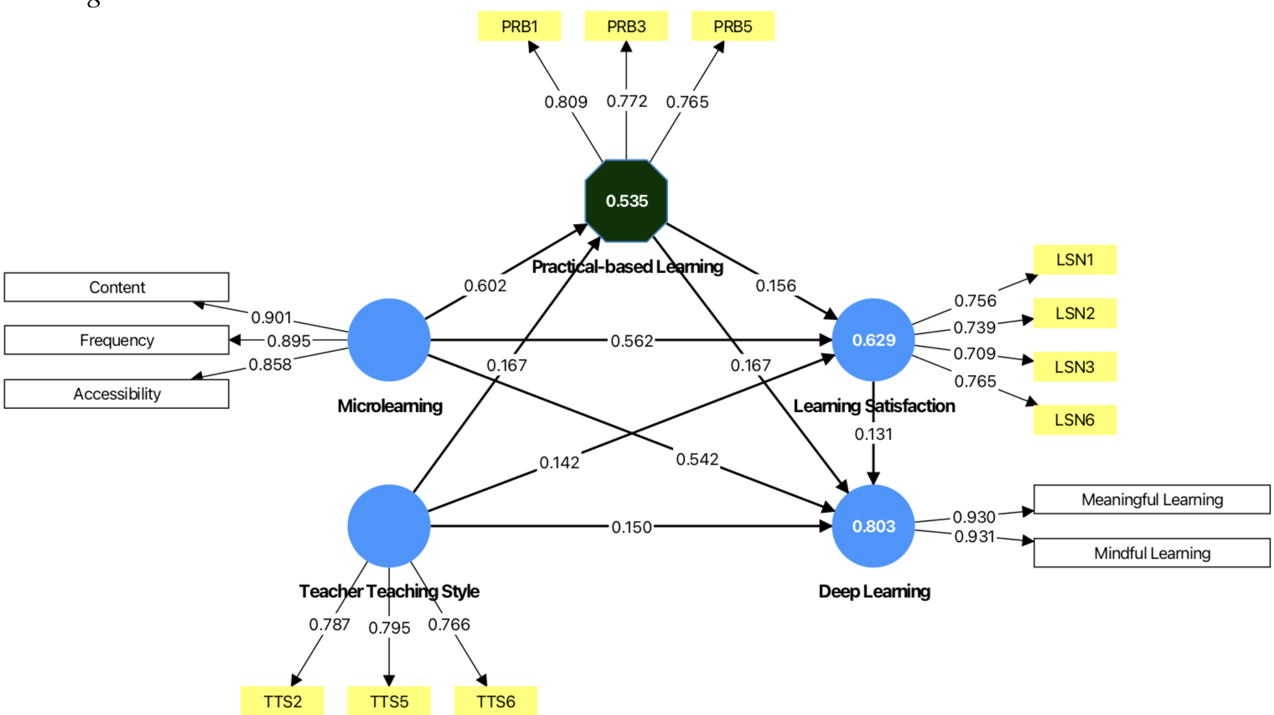
Construct	*M*	*SD*	*CON*	*FRE*	*ACC*	*MIC*	*TTS*	*PRB*	*LSN*	*DLG*	*MLG*	*MDL*
CON	3.30	0.342	–									
FRE	3.30	0.333	.726***	–								
ACC	3.28	0.331	.681***	.690***	–							
MIC	3.30	0.300	.900***	.900***	.882***	–						
TTS	3.29	0.314	.751***	.770***	.736***	.841***	–					
PRB	3.30	0.318	.752***	.737***	.751***	.835***	.784***	–				
LSN	3.30	0.321	.738***	.771***	.724***	.832***	.800***	.788***	–			
DLG	3.31	0.319	.778***	.797***	.789***	.881***	.845***	.815***	.816***	–		
MLG	3.30	0.336	.702***	.736***	.734***	.809***	.777***	.765***	.759***	.927***	–	
MDL	3.32	0.349	.744***	.746***	.733***	.828***	.793***	.750***	.759***	.933***	.730***	–

Note. *p < .05; **p < .01; ***p < .001; CON: Content; FRE: Frequency; ACC: Accessibility; MIC: Microlearning; TTS: Teacher Teaching Style; PRB: Practical-Based Learning; LSN: Learning Satisfaction; DLG: Deep Learning; MLG: Meaningful Learning; MDL: Mindful Learning.

strong positive correlations with FRE (r = .726), ACC (r = .681), and MIC (r = .900), indicating that changes in one construct are likely to be accompanied by meaningful changes in the others. Moreover, the strongest correlations were observed between MDL and DLG (r = .933), as well as between MIC and DLG (r = .881), suggesting very strong relationships and potential interdependence among these constructs. Notably, Practical-Based Learning (PRB) demonstrates strong positive correlations with MIC (r = .835), TTS (r = .784), ACC (r = .751), and DLG (r = .789), indicating that increases in PRB tend to closely correspond with increases in these related constructs. In addition, PRB shows significant associations with LSN (r = .732), MLG (r = .765), and MDL (r = .750), reflecting its strong linkage to factors pertaining to practical learning experiences and depth of understanding. These correlation values signify that PRB exerts a broad influence on other components of the model, underscoring its central role in the learning dynamics under investigation. Overall, the findings suggest that the constructs examined in this study are highly interrelated, and these relationships provide meaningful insights into the underlying dynamics among variables within the proposed model.

The outer loading results for the second-order constructs involving Practical-Based Learning (Model I) indicate that the indicators contribute significantly to their respective constructs. For the Practical-Based Learning construct, indicators such as PRB1 (.809), PRB3 (.772), and PRB5 (.765) exhibit relatively high outer loading values, demonstrating that these indicators strongly represent the construct. Furthermore, within the Learning Satisfaction construct, outer loading values for indicators such as LSN1 (.756), LSN2 (.739), LSN3 (.709), and LSN6 (.765) indicate substantial contributions, confirming that these items reliably measure Learning Satisfaction. Indicators associated with the Deep Learning construct, specifically Meaningful Learning and Mindful Learning, also display very high outer loading values, namely .930 and .931, respectively. These values signify a strong influence of both indicators in capturing the dimensions of deep learning. The consistently high outer loading values across these second-order indicators confirm strong measurement validity within the model, particularly for the Practical-Based Learning and Learning Satisfaction constructs.

Figure 4
Logarithmic Results of Second-Order Constructs in the Research Framework Incorporating Practical-Based Learning



In Model II, which excludes Practical-Based Learning, the outer loading results for the second-order constructs demonstrate strong and statistically meaningful contributions from the relevant indicators. For the Learning Satisfaction construct, indicators such as LSN1 (.755), LSN2 (.740), LSN3 (.708), and LSN6 (.766) exhibit robust outer loading values, indicating that these items effectively capture and measure the construct. For the Deep Learning construct, the indicators Meaningful Learning and Mindful Learning yield exceptionally high outer loadings, measured at .929 and .932, respectively. These values confirm that both indicators play a highly significant role in representing the dimensions of deep learning within the model. Furthermore, the Teacher Teaching Style construct is also measured reliably, with indicators TTS2 (.783), TTS5 (.795), and TTS6 (.770) showing strong outer loadings. These results collectively confirm the validity and reliability of the measurement model for Model II, even in the absence of the Practical-Based Learning mediator.

Figure 5

Logarithmic Results of Second-Order Constructs in the Research Framework Without Practical-Based Learning

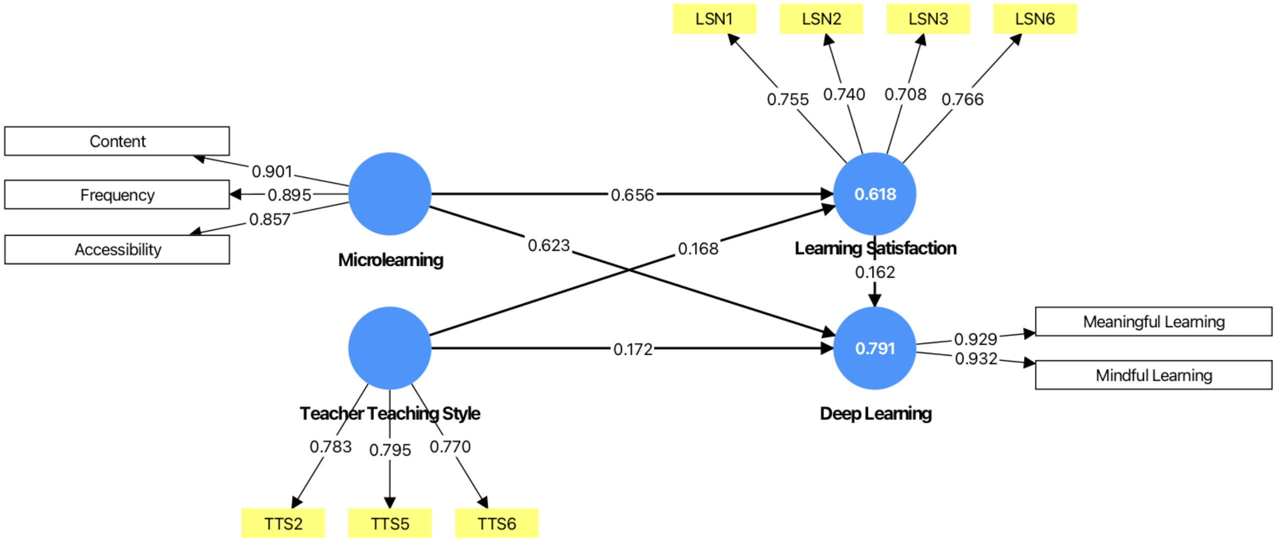


Table 4 presents the results of the reliability and validity analyses of the constructs using several key statistical indicators. For the Microlearning construct, the high Cronbach's alpha value (.861) indicates strong internal consistency, further supported by a Composite Reliability value of .863, which demonstrates excellent reliability. In addition, the AVE value of .783 shows that more than 78% of the variance in this construct is explained by its indicators. The HTMT value of .835 suggests no substantial issues related to discriminant validity, as it falls below the commonly accepted threshold of .85, indicating that the construct is clearly distinguishable from other constructs. Other constructs, such as Teacher Teaching Style and Practical-Based Learning, also exhibit satisfactory measurement quality. For example, Teacher Teaching Style has a Cronbach's alpha of .714 and a Composite Reliability of.786, both of which fall within acceptable reliability ranges. Similarly, the Deep Learning construct demonstrates excellent measurement properties across all indices, with Cronbach's alpha of .846, Composite Reliability of .846, and a high AVE value of .866. These results indicate the strong reliability and robust measurement quality of this construct.

The SRMR results for Model I show a value of .064, which is lower than the SRMR value of Model II (.067). A lower SRMR value indicates a better fit between the model and the observed data, suggesting that Model I demonstrates superior model fit. Additionally, the d_ULS value of Model I (.498) is lower than that of Model II (.513), indicating a smaller discrepancy between the predicted and actual covariance matrices. This further reinforces that Model I exhibits a more

Table 4
Results of Reliability and Validity Testing

Construct	*Cronbach's alpha*	*Composite reliability*	*Average variance extracted (AVE)*	*HTMT*
Microlearning	.861	.863	.783	.835
Content				
Frequency				
Accessibility				
Teacher Teaching Style	.714	.786	.613	.877
Practical-based Learning	.722	.782	.612	.818
Learning Satisfaction	.728	.729	.551	.812
Deep Learning	.846	.846	.866	.822
Meaningful Learning				
Mindful Learning				

favorable model fit. In terms of R-Square and Q^2, Model I yields an R-Square value of .629 for Learning Satisfaction and .803 for Deep Learning, both of which exceed the corresponding values in Model II (.618 and .791, respectively). These higher R-Square values demonstrate that the inclusion of Practical-Based Learning as a mediator enhances the explanatory power of the model regarding the variance in these constructs. Model I also shows higher Q^2 values for Learning Satisfaction (.611) and Deep Learning (.658), indicating stronger predictive relevance.

These findings suggest that the model incorporating Practical-Based Learning as a mediator not only provides a better explanation of the relationships among constructs but also yields more accurate predictions. Nevertheless, a more comprehensive comparison remains essential to fully understand the nuanced dynamics underlying both models.

Table 5
Model Fit Comparison

Model Evaluation	*Model I*		*Model II*	
SRMR	.064		.067	
d_ULS	.498		.513	
	Q^2	*R-Square*	*Q^2*	*R-Square*
Learning Satisfaction	.611	.629	.603	.618
Deep Learning	.658	.803	.635	.791
Meaningful Learning				
Mindful Learning				

Table 6 demonstrates that all direct paths in the model exhibit statistically significant coefficients. The Microlearning construct shows strong and significant relationships with its second-order dimensions (content, frequency, and accessibility) further supported by substantial f values. The total path coefficients from MIC to LSN (.656, $p < .001$) and from MIC to DLG (.729, $p < .001$) indicate that Microlearning contributes significantly, both directly and indirectly, to enhancing the dependent variables Learning Satisfaction and Deep Learning. For Deep Learning, the direct path coefficients also reveal highly significant effects, with Meaningful Learning (.927) and Mindful Learning (.934) demonstrating exceptionally strong contributions to the construct. The very large f^2 values (6.115 and 6.861) further indicate that these pathways contribute substantially to the explained variance in the model. The presence of f^2 values exceeding 0.35 across all paths underscores that the relationships among the Microlearning constructs exert a profound impact on the overall model, particularly those associated with meaningful and deep learning processes.

In addition, indirect pathways such as MIC to LSN (.094, $p < .001$) and MIC to DLG (.187, $p < .001$) provide further insights into the mediating role of Microlearning in deep learning processes, although the direct effects remain more dominant. Conversely, the indirect pathways involving Teacher Teaching Style (TTS to LSN; TTS to DLG) and Practical-Based Learning (PRB to DLG) were not statistically significant, reflected in low path coefficients (.026, .050, and .020) and *p*-values exceeding .05. These findings indicate that these indirect paths exert weaker influences compared to the more dominant direct pathways affecting Learning Satisfaction and Deep Learning. Factors such as variability in teaching styles or less structured practical learning experiences may limit the magnitude of these indirect effects. Overall, the results underscore the central importance of the Deep Learning construct and its associated pathways in strengthening students' meaningful and holistic learning outcomes.

Table 6
Direct and Indirect Path Analysis

Path and Hypothesis	*Path coefficient [95%] Confidence intervals and p-value*			f^2
	Direct	*Indirect*	*Total*	
Microlearning				
Content	0.901 [0.880, 0.920]	-	0.901 [0.880, 0.920]	4.334
Frequency	0.899 [0.875, 0.920]	-	0.899 [0.875, 0.920]	4.203
Accessibility	0.839 [0.805, 0.871]	-	0.839 [0.805, 0.871]	2.387
MIC to PRB (H1)	0.602 [0.490, 0.710]***	-	0.602 [0.490, 0.710] ***	0.375
MIC to LSN (H2)	0.562 [0.444, 0.683]***	0.094 [0.022, 0.170]**	0.656 [0.558, 0.756] ***	0.298
MIC to DLG (H3)	0.542 [0.433, 0.648]***	0.187 [0.114, 0.263]***	0.729 [0.662, 0.797] ***	0.403
TTS to PRB (H4)	0.167 [0.050, 0.289]***	-	0.167 [0.050, 0.289] ***	0.029
TTS to LSN (H5)	0.142 [0.019, 02.60]**	0.026 [0.003, 0.058]	0.168 [0.051, 0.279] ***	0.025
TTS to DLG (H6)	0.150 [0.072, 0.222]***	0.050 [0.022, 0.086]	0.199 [0.123, 0.274] ***	0.052
PRB to LSN (H7)	0.156 [0.038, 0.274]**	-	0.156 [0.038, 0.274] **	0.030
PRB to DLG (H8)	0.167 [0.078, 0.225]***	0.020 [0.003, 0.044]	0.188 [0.102, 0.270] ***	0.064
LSN to DLG (H9)	0.131 [0.037, 0.221]***	-	0.131 [0.037, 0.221] ***	0.032
Deep Learning				
Meaningful Learning	0.927 [0.910, 0.943]	-	0.927 [0.910, 0.943]	6.115
Mindful Learning	0.934 [0.920, 0.947]	-	0.934 [0.920, 0.947]	6.861

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 7 presents the path analysis results for the effect of Practical-based Learning on Learning Satisfaction, revealing a path coefficient difference of 0.175 between the two countries, with a two-tailed *p*-value of .157. This *p*-value, which exceeds the 0.05 threshold, indicates that the difference is not statistically significant. Although the coefficients vary, the effect of Practical-based Learning on Learning Satisfaction remains relatively consistent across Indonesia and Malaysia, providing no strong evidence of a meaningful difference between the two groups.

Table 7
MGA Analysis

Path	*Difference (Indonesia - Malaysia)*	*2-tailed (Indonesia vs Malaysia) p-value*
Practical-based Learning → Learning Satisfaction	0.175	.157
Practical-based Learning → Deep Learning	−0.082	.381
Learning Satisfaction → Deep Learning	−0.122	.215

For the second and third paths, examining the effect of Practical-based Learning on Deep Learning and the effect of Learning Satisfaction on Deep Learning, the coefficient differences are −0.082 and −0.122, respectively, accompanied by high two-tailed *p*-values (.381 and .215). These results similarly indicate a lack of statistically significant differences between the two countries. Nevertheless, the negative mean difference suggests that Malaysian students exhibit slightly stronger associations between Practical-based Learning and Deep Learning as well as between Learning Satisfaction and Deep Learning, although these differences are not significant. Overall, these findings suggest that despite minor variations in coefficient values, the relationships among the constructs do not differ significantly between Indonesia and Malaysia, indicating a general uniformity in the dynamics of practical-based learning and deep learning across both educational contexts.

5. Discussion

5.1. The Role of Microlearning and Teacher Teaching Style in Enhancing Learning Satisfaction and Deep Learning

Microlearning demonstrates a strong and significant direct effect on learning satisfaction. This finding suggests that the more efficiently learning materials are delivered in small, structured units, the higher the students' level of learning satisfaction. This effect is further reinforced by an indirect influence through Practical-based Learning and Teacher Teaching Style [TTS], yielding a strong total effect. This positions microlearning as one of the strongest predictors of learning satisfaction. The concise, focused, and easily accessible structure of microlearning enables students to process information rapidly, reduce cognitive load, and develop more positive perceptions of their learning experiences (Anyichie, 2024; Robles et al., 2023). The significant contributions of the three microlearning indicators, Content, Frequency, and Accessibility, indicate that high-quality, well-structured content, consistent delivery frequency, and ease of access are essential components driving learning satisfaction. Content presented in small, relevant units allows students to grasp core material without barriers (Zarshenas et al., 2022). Regular and structured exposure reinforces understanding through repetition, while high accessibility allows students to regulate their learning pace flexibly (Lopez, 2024). Collectively, these components foster a more personalized, effective, and efficient learning experience, thereby elevating overall learning satisfaction.

Microlearning also exerts a significant direct effect on deep learning. Additionally, microlearning contributes indirectly to deep learning through learning satisfaction, producing one of the largest effects found in the model. These results indicate that microlearning not only enhances surface understanding but also plays a crucial role in fostering more profound conceptual comprehension. Through systematically organized micro-units, students can focus on core concepts and progressively build interconnections between ideas, thereby facilitating meaningful learning (Yao & Ho, 2024). Simultaneously, the concise and flexible nature of microlearning allows students to process, reflect upon, and revisit information based on individual needs, enhancing their metacognitive awareness (Mostrady et al., 2024; Sankaranarayanan et al., 2022). This combination of incremental conceptual building and reflective engagement explains the substantial contribution of microlearning to meaningful and mindful learning. Well-designed microlearning content enables students to integrate new information with prior knowledge, thereby strengthening meaning-making processes (Dixit et al., 2021; Suvandy et al., 2024). Furthermore, the opportunity for independent repetition encourages students to monitor, evaluate, and reflect on their learning strategies, thus promoting mindful engagement with learning tasks.

The influence of teacher teaching style on learning satisfaction indicates a significant contribution to shaping students' positive perceptions of their learning experiences. This effect reflects the importance of instructional clarity, appropriate use of examples, methodological variation, and the creation of a supportive learning environment. When teachers present material with clear structure, rhythm, and approaches aligned with student needs, learners perceive the instruction as valuable and enjoyable, ultimately enhancing their satisfaction (Almufarreh, 2024). The significant effect of teacher teaching style further demonstrates its role as an immediate pedagogical driver capable of directly shaping learning experiences without requiring mediating variables. A responsive teaching style, characterized by adaptation to student understanding, timely feedback, and empathetic communication, fosters a sense of appreciation and support among students (Jaber et al., 2023). These elements strengthen affective engagement, a core determinant of learning satisfaction. Although its effect size is comparatively smaller than that of microlearning, teacher teaching style remains a vital determinant of students' overall satisfaction with the learning process.

Moreover, the direct influence of teacher teaching style on deep learning demonstrates a significant contribution to promoting students' ability to engage in higher-order conceptual understanding. Effective teaching not only emphasizes information delivery but also encourages students to analyze, connect, and critically evaluate concepts. Instruction that incorporates analytical explanations, higher-order questioning, and reflective discussions fosters conditions conducive to deep cognitive processing (Fernandez-Ortega et al., 2022). In this regard, teacher teaching style serves as a cognitive guide that assists students in constructing deeper conceptual structures, moving beyond surface learning toward integrated knowledge formation. Additionally, teacher teaching style influences students' metacognitive activation. Teachers who provide explicit guidance on thinking processes, learning strategies, and reflective practices enable students to become more aware of the steps involved in understanding concepts (Muis et al., 2025; Ngongnpah & Oni, 2025). This instructional support strengthens students' ability to link new information with prior knowledge and apply it to novel contexts. The significant direct effect underscores the capacity of high-quality pedagogical practices to activate deep-level cognitive engagement without reliance on mediating mechanisms such as learning satisfaction. Consequently, teacher teaching style emerges as a key component in facilitating meaningful and reflective learning.

5.2. The Urgency of Integrating Practical-Based Learning

The relationship between PRB and Learning Satisfaction indicates that students' engagement in practical-based learning contributes to their learning satisfaction. Although the magnitude of this effect falls within the small-effect category, this finding aligns with established pedagogical principles asserting that authentic practical experiences enhance students' perceptions of learning relevance, ultimately increasing their satisfaction. The results suggest that when students are provided opportunities to apply concepts directly, they develop a stronger sense of connection between course content and professional requirements, thereby elevating their perceived value and benefits of the learning experience. Practical engagement strengthens the affective dimensions of learning, namely comfort, satisfaction, and confidence that the learning process is genuinely meaningful (Lee et al., 2020; Sánchez et al., 2024). Furthermore, this finding indicates that practical-based learning does not merely add instructional variety but functions as a critical determinant in shaping learning satisfaction. Through hands-on activities, students experience autonomy in exploring, problem-solving, and reflecting on their work outcomes (Gasmi & Nadabi, 2023; Yuk Chan & Wong, 2021). Such processes generate a sense of achievement that cannot be attained through theoretical learning alone. Moreover, hands-on experiences enhance cognitive and social engagement, both of which have been empirically linked to higher levels of learning satisfaction (Le & Nguyen, 2022; Ouyang & Dai, 2021). In other words, although its direct effect size is moderate, PRB consistently enriches the learning experience and strengthens students' satisfaction with the instructional process.

The relationship between PRB and Deep Learning further demonstrates that practical-based learning has a comparatively stronger direct effect on deep learning than on learning satisfaction. This finding reflects that practical activities encourage students not merely to recall information but to construct conceptual understanding through concrete experience. When students engage in experimental tasks, projects, or simulations, they confront complex contexts that require higher-order thinking strategies (Aji, 2022; Wingrove, 2024). Consequently, the impact of PRB on deep learning is more substantial because it directly targets cognitive processes such as analysis, evaluation, conceptual integration, and critical reflection, core components that define deep learning. This finding reinforces that practical-based learning is a key factor in enhancing students' ability to achieve deeper understanding. Practical activities enable students to develop investigative skills, perform knowledge transfer, and cultivate problem-solving abilities in authentic situations. These processes compel students to connect theoretical knowledge with empirical experience, resulting in more coherent and integrated knowledge structures (Maynard et al., 2021; Peisachovich et al., 2020). Ultimately, PRB creates a learning environment that encourages students to go beyond surface-level understanding, as they are no longer passive recipients of information but become active agents in academic exploration. These findings suggest that the implementation of PRB is not simply a supplement to traditional instruction but a pedagogically robust mechanism that effectively cultivates deep learners within higher education settings.

5.3. Interaction between Learning Satisfaction and Deep Learning

Empirical findings reveal that learning satisfaction exerts a direct effect on deep learning. This suggests that the higher students' satisfaction with the learning process, the greater their tendency to engage in deep learning strategies. This relationship aligns with motivational and affective theories of learning, which posit that positive perceptions of the learning experience promote greater cognitive investment. When students are satisfied with the quality of instruction, they develop intrinsic motivation that facilitates deeper exploration of concepts rather than superficial memorization or task completion (Audrin & Hascoët, 2021; Orsini et al., 2020). Moreover, this relationship indicates that learning satisfaction serves as an emotional foundation that supports higher-order thinking skills. Students who exhibit high levels of satisfaction often perceive their learning experience as relevant, well-structured, and academically supportive. These conditions foster the psychological readiness necessary for engaging in activities that demand comprehension, synthesis, and evaluation (Iravani et al., 2022; Jiménez-Bucarey et al., 2021). Thus, learning satisfaction remains a meaningful determinant in promoting deep learning.

This interaction can also be interpreted through the lens of self-determination theory, which asserts that satisfaction in the learning process enhances feelings of competence, autonomy, and relatedness, three essential prerequisites for the development of a deep learning orientation. When students feel competent and valued, they are more likely to adopt active learning strategies such as connecting concepts across topics, engaging in critical reflection, and applying knowledge to authentic contexts (Huerta & Requena-García-Cruz, 2025). In this regard, learning satisfaction functions as a catalyst that transforms the learning experience into a sustained and purposeful higher-order cognitive process. Furthermore, the findings demonstrate that enhancing learning satisfaction affects not only the affective aspects of students but also the quality of their information processing. Satisfied students tend to develop a stronger sense of ownership over their learning, leading to a greater commitment to understanding course material substantively (Kessels et al., 2024; Tarihoran & Nasution, 2024). Therefore, educational institutions should view learning satisfaction as a strategic component in efforts to improve instructional quality. Creating a satisfying learning experience reinforces the foundation for cultivating deep learners, students capable of critical thinking, conceptual integration, and flexible knowledge application across diverse contexts.

6. Conclusion

The findings of this study demonstrate that microlearning constitutes the most dominant factor in enhancing the quality of students' learning experiences. The delivery of instructional content in small, concise, structured, and easily accessible units effectively reduces cognitive load and enables students to internalize concepts more gradually. Its impact extends beyond increasing learning satisfaction; microlearning also facilitates the development of deeper conceptual understanding. Ultimately, microlearning provides a strong foundation for deep learning because it helps students connect new information with their existing knowledge structures. This conclusion is further reinforced by the significant contributions of teacher teaching style and practical-based learning, both of which enrich the overall learning dynamics. A teaching style that is clear, structured, and responsive fosters a supportive classroom climate, enabling students to feel more guided, confident, and motivated to engage in the learning process. Furthermore, practical-based learning offers direct, contextually relevant experiences that challenge students to experiment, observe, and reflect. The interaction between effective instructional explanations and authentic practical activities forms a more comprehensive learning environment, thus strengthening students' cognitive and emotional engagement.

The study also highlights the pivotal role of learning satisfaction in linking learning experiences to students' capacity for deep learning. When students feel satisfied with the learning process, whether through microlearning, effective instructional delivery, or hands-on practice, they are more motivated to think critically, evaluate information at a deeper level, and integrate concepts across various contexts. Thus, the relationship between learning satisfaction and deep learning exhibits a mutually reinforcing pattern, suggesting that well-designed learning experiences foster stronger and more sustainable conceptual understanding. These findings provide an important basis for developing learning strategies that are more innovative, integrated, and responsive to students' future needs.

For educational institutions, these findings imply the need to institutionalize microlearning-supported practicum design by standardizing bite-sized high-quality content, ensuring consistent delivery schedules, and providing easy access through learning platforms that integrate pre-lab preparation, in-lab guidance, and post-lab reflection. For teacher trainees and professional development programs, the results underscore the importance of strengthening competencies in responsive, student-centered teaching, including digital microlearning curation, technology-mediated feedback, and practicum scaffolding strategies that explicitly promote meaningful and mindful learning. For government and education authorities, the evidence supports prioritizing policy guidance, minimum service standards, and targeted investment in infrastructure, including reliable internet, device access, laboratory facilities, and safety resources, to scale integrated microlearning and practicum models across schools and regions.

7. Limitations and Directions for Future Research

There is a need to expand the conceptual model by exploring potential mediating and moderating variables that may enrich the understanding of the relationships among microlearning, teacher teaching style, practical-based learning, learning satisfaction, and deep learning. While the present study demonstrates that instructional variables exert significant direct effects, albeit with varying magnitudes, future research should examine the role of psychological factors such as intrinsic motivation, self-regulated learning, curiosity, and cognitive engagement, which may strengthen or weaken these relationships. Longitudinal research is also recommended to capture the dynamic evolution of learning behaviors over time, thereby providing insight into how satisfying learning experiences and practical activities shape sustained patterns of deep learning.

Furthermore, future studies should broaden the research context by incorporating different educational levels, subject areas, and digital learning environments, including adaptive technologies, AI-based learning systems, and simulation-based instruction. Such extensions will not only deepen theoretical understanding but also offer practical contributions to the development of more effective, personalized, and long-term deep-learning–oriented instructional designs.

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