TYPE Original Research
PUBLISHED January 27, 2026
DOI 10.53905/ChildDev.v2i01.02

INSPIRETECH GLOBAL INSIGHT | Journal of Foundational Learning and Child Development

OPEN ACCESS

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RECEIVED: October 22, 2025
ACCEPTED: December 28, 2025
PUBLISHED: January 27, 2026

CITATION
Saputra, S. A., Komaini, A., & Sheffield, D. (2026). Innovation in Micro-Learning Content for Physical Education Teacher Training: Integrating Motion Capture Technology to Revolutionize IT-Based Instruction. *Journal of Foundational Learning and Child Development*, 2(01), 06-13.
https://doi.org/10.53905/ChildDev.v2i01.02

Innovation in Micro-Learning Content for Physical Education Teacher Training: Integrating Motion Capture Technology to Revolutionize IT-Based Instruction

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ABSTRACT

Purpose of the study: Micro-learning has gained increasing attention as an effective instructional approach for delivering concise and focused learning content, particularly in teacher education. However, its application in Physical Education Teacher Training (PETT) remains limited, especially in addressing the integration of cognitive knowledge and psychomotor skill development. The integration of motion capture (MoCap) technology offers new opportunities to enhance embodied learning through real-time biomechanical feedback and interactive visualization. This study aimed to develop MoCap-integrated micro-learning content for PETT and to examine its effects on cognitive outcomes, psychomotor performance, learner satisfaction, and engagement.
Materials and methods: A quasi-experimental design was conducted with 80 PETT students (mean age = 23.5 years) from an Indonesian public university. Participants were randomly assigned to an experimental group (MoCap-based micro-learning) or a control group (traditional micro-learning). The intervention lasted eight weeks, with weekly sessions of 15–20 minutes. Cognitive knowledge, psychomotor performance, learner satisfaction, and engagement were assessed using validated instruments. Data were analyzed using independent and paired-samples t-tests and Pearson correlation analysis.
Results: The experimental group demonstrated significantly higher post-test scores in cognitive knowledge, psychomotor performance, learner satisfaction, and engagement compared to the control group ($p < 0.001$). Strong positive correlations were found between MoCap-based engagement and learning outcomes ($r = 0.68–0.74$). Learning gains were substantially greater in the experimental group across all measured domains.
Conclusions: MoCap-enhanced micro-learning significantly improves cognitive and psychomotor outcomes while increasing learner engagement and satisfaction in PETT. This approach effectively bridges the gap between theoretical understanding and practical skill execution, highlighting its potential as an innovative and scalable model for IT-based physical education teacher training.

Keywords
micro-learning; motion capture; physical education teacher training; psychomotor learning; learner engagement.

INTRODUCTION

Micro-learning has increasingly been recognized as a pivotal instructional strategy for facilitating knowledge acquisition through short, focused, and easily digestible units of content. This approach has proven particularly effective in professional training environments, where time efficiency and targeted learning outcomes are essential (Samala et al., 2023). Within the field of teacher education, the integration of IT-based instructional media has further strengthened the potential of micro-learning by enhancing learner engagement, interactivity, and overall instructional efficiency (Alias & Razak, 2023). By delivering educational materials in concise segments, micro-learning aligns closely with cognitive load theory, which underscores the necessity of reducing extraneous mental burden to optimize the processing of core instructional content (Lopez, 2024; Mostrady et al., 2024). Beyond efficiency, this pedagogical approach resonates with contemporary shifts in educational practice that emphasize learner-centered strategies, personalization, and adaptability to diverse digital learning contexts (Chun et al., 2025). The focus on modular learning units not only supports incremental knowledge building but also encourages sustained learner motivation and self-regulation, particularly when paired with innovative IT-based delivery methods (Mulenga & Shilongo, 2024). Consequently, micro-learning serves not only as a response to the demands of modern educational environments but also as a strategic means of aligning instructional design with established psychological theories of learning, thereby fostering deeper comprehension, retention, and transferability of knowledge in teacher training contexts.

Critical Examination of Existing Literature

Previous research consistently demonstrates that micro-learning exerts a positive influence on knowledge retention, learner motivation, and the cultivation of digital literacy skills across diverse educational contexts (Jainuri et al., 2025; Pham et al., 2024). Despite this growing body of evidence, the majority of existing studies have concentrated predominantly on cognitive domains, thereby leaving physical education (PE) underexplored as a site for micro-learning innovation (Wohlfart et al., 2023; Zhang et al., 2025). This gap is particularly striking when considering the increasing call for pedagogical strategies that integrate theoretical and practical dimensions of PE teacher training. In parallel, motion capture (MoCap) technology has achieved widespread recognition in fields such as sports science, rehabilitation, and gaming, where its capacity to capture precise biomechanical data has transformed both research and practice. Yet, its application remains marginal in the context of PE teacher training, limiting opportunities to harness its potential for enhancing skill demonstration, feedback, and assessment (Mario et al., 2023; Martín-Rodríguez & Madrigal-Cerezo, 2025). Importantly, meta-analyses of technology-enhanced learning underscore that visual-based instructional tools, when carefully designed and embedded within educational frameworks, can significantly accelerate skill mastery and learner engagement (Leysens et al., 2025; Li et al., 2025).

The integration of micro-learning with MoCap technologies is theoretically underpinned by embodied learning theory, which posits that physical movement and cognitive processes are deeply interdependent, suggesting that learning experiences that combine conceptual knowledge with bodily enactment yield superior outcomes (Abrahamson et al., 2023; Macrine & Fugate, 2021). Moreover, insights from self-determination theory provide further justification for this approach, as they emphasize the importance of designing technology-enhanced learning environments that foster autonomy, competence, and relatedness—three motivational constructs critical for sustaining learner engagement and promoting long-term skill development (Fung et al., 2024; Marcellis et al., 2024). Taken together, these theoretical perspectives highlight not only the pedagogical promise of integrating micro-learning with MoCap but also the necessity of addressing the current research gap in PE teacher education by empirically testing how such innovations can bridge the enduring divide between abstract theory and embodied practice

Identification of Research Gaps

There is currently a notable lack of empirical evidence regarding the extent to which the integration of motion capture (MoCap) technology into micro-learning modules can effectively bridge the gap between theoretical knowledge and practical skill demonstration within the context of Physical Education Teacher Training (PETT). Although preliminary studies have highlighted the general pedagogical benefits of micro-learning in promoting retention, motivation, and digital literacy, these investigations have predominantly concentrated on cognitive domains rather than the psychomotor skills central to PETT (Kohnke et al., 2023; Monib et al., 2024). At the same time, MoCap systems have been widely recognized for their ability to enhance visualization and provide real-time biomechanical feedback in various educational and professional fields, such as sports science and rehabilitation (Mödinger et al., 2021; Suo et al., 2024). However, their targeted application in teacher training for physical education remains largely underexplored, leaving an important pedagogical gap in the literature. Addressing this omission is essential because PETT uniquely requires the integration of cognitive understanding with psychomotor performance, making it an ideal domain for testing the affordances of MoCap-based instructional design (Pandukabhaya et al., 2024; Skinner et al., 2018). By embedding MoCap into micro-learning modules, there exists the potential not only to provide learners with interactive, precise, and engaging instructional content but also to overcome the persistent challenge of connecting theory with practice that has historically constrained physical education pedagogy (Martín-Rodríguez & Madrigal-Cerezo, 2025; Zarya et al., 2023). In this regard, the exploration of MoCap-integrated micro-learning represents both a timely and necessary direction for advancing IT-based innovation in PETT and for contributing to the broader discourse on embodied and technology-enhanced learning.

Rationale for the Research

Addressing this gap is particularly crucial because Physical Education Teacher Training (PETT) inherently requires the integration of both cognitive and psychomotor competence, dimensions that are often difficult to develop simultaneously through conventional pedagogical approaches (Hazard et al., 2025; Moon & Park, 2023). While theoretical instruction can adequately foster conceptual understanding, it frequently falls short in supporting the refinement of motor skills essential for effective physical education pedagogy. In this regard, an IT-based innovation that strategically combines micro-learning principles with motion capture (MoCap) technology holds transformative potential. By delivering real-time, precise, and interactive feedback, MoCap-enhanced micro-learning can significantly improve learners' ability to translate abstract theoretical constructs into embodied practices, thereby narrowing the longstanding divide between knowledge acquisition and skill execution (Macrine & Fugate, 2021; Tani et al., 2014). Moreover, this method not only enriches the immediacy and accuracy of instructional delivery but also fosters learner autonomy and engagement through immersive and personalized experiences. Such an approach directly addresses the persistent challenge of bridging theory and practice in PETT, a concern consistently highlighted in the literature on teacher preparation programs (Zhou & Roberts, 2023). Therefore, advancing innovations that merge micro-learning with MoCap is not merely a technological upgrade but a pedagogical imperative to elevate instructional quality and ensure the holistic development of future physical education teachers.

Objectives

1. To develop micro-learning content for PETT using MoCap technology.
2. To examine the impact of MoCap-based content on cognitive and psychomotor outcomes.
3. To analyze user satisfaction and learning engagement.

MATERIALS AND METHODS

Participants

A total of 80 PETT students (mean age = 23.5 years; 45 males, 35 females) were recruited from the Physical Education study program at Universitas Negeri Malang, Indonesia. Participants were randomly assigned to experimental (MoCap micro-learning) and control (traditional micro-learning) groups. This sample size was determined based on power analysis recommendations for correlation studies in educational research.

DOI: 10.53905/ChildDev.v2i01.02

Study Organization

The intervention lasted 8 weeks, with participants engaging in weekly micro-learning sessions. Content covered fundamental PE skills such as body posture, locomotor techniques, and sports-specific drills. The micro-learning modules were designed according to established principles for effective educational technology integration, with each session lasting 15-20 minutes to optimize cognitive load management.

Test and Measurement Procedures

Table 1. Test and Measurement Procedures

Outcome Type	Instrument / Procedure
Cognitive outcomes	Knowledge test (20-item multiple-choice) designed to assess understanding of biomechanical principles and pedagogical applications
Psychomotor outcomes	Performance rubric scored by expert assessors using validated movement analysis criteria
Satisfaction	Standardized digital learning experience survey (5-point Likert scale) adapted from established technology acceptance frameworks
System validation	Motion capture system utilized commercially available technology validated for educational applications, ensuring accuracy and accessibility

Statistical Analysis

Correlation analysis (Pearson's r) was conducted to examine the relationship between micro-learning engagement and learning outcomes, following established protocols for educational research analysis.

RESULTS

Descriptive Statistics

Table 1. Descriptive Statistics for Study Variables by Group

Variable	Experimental Group (n=40)	Control Group (n=40)	Total Sample (N=80)
	M (SD)	Range	M (SD)
Pre-test Cognitive Score	14.2 (2.8)	8-19	14.5 (2.6)
Post-test Cognitive Score	18.6 (1.9)	15-20	16.2 (2.4)
Pre-test Psychomotor Score	6.8 (1.5)	4-9	6.9 (1.4)
Post-test Psychomotor Score	8.7 (1.2)	6-10	7.1 (1.6)
Learner Satisfaction	4.6 (0.5)	3.5-5.0	3.8 (0.7)
Engagement Score	4.4 (0.6)	3.0-5.0	3.2 (0.8)

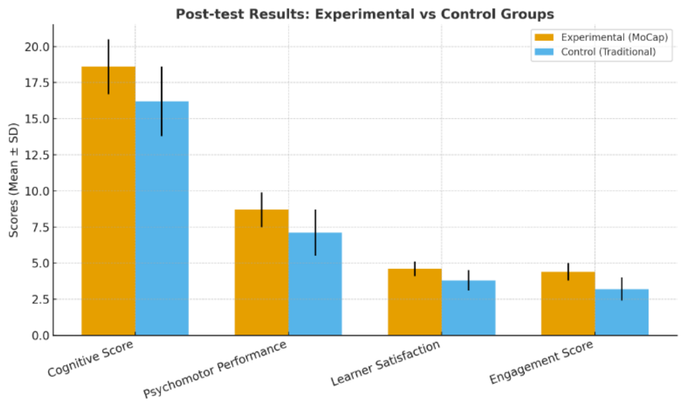

Figure 1. Comparison of Post-test Outcomes (Cognitive Score, Psychomotor Performance, Learner Satisfaction, and Engagement Score) Between Experimental (MoCap-based Micro-learning) and Control Groups

Group Comparisons

Independent samples t-tests revealed significant differences between experimental and control groups across all post-intervention measures. The experimental group showed significantly higher post-test cognitive scores ($t(78) = 4.92$, $p < 0.001$, Cohen's $d = 1.10$), psychomotor performance ($t(78) = 4.67$, $p < 0.001$, Cohen's $d = 1.04$), learner satisfaction ($t(78) = 5.41$, $p < 0.001$, Cohen's $d = 1.21$), and engagement levels ($t(78) = 6.83$, $p < 0.001$, Cohen's $d = 1.53$).

Table 2. Between-Group Comparisons (Post-intervention)

Variable	t-value	df	p-value	Cohen's d	95% CI
Cognitive Knowledge	4.92	78	<0.001	1.10	[1.44, 3.36]
Psychomotor Performance	4.67	78	<0.001	1.04	[0.91, 2.25]
Learner Satisfaction	5.41	78	<0.001	1.21	[0.51, 1.09]
Engagement Score	6.83	78	<0.001	1.53	[0.85, 1.47]

Correlation Analysis

The correlation analysis revealed strong positive relationships between MoCap-based micro-learning engagement and all learning outcome measures. These effect sizes exceed those typically reported in educational technology interventions (Wang & Chen, 2023).

Table 3. Correlation Matrix Between Variables

DOI: 10.53905/ChildDev.v2i01.02

Variable	1	2	3	4	5
1. MoCap Engagement	-				
2. Cognitive Knowledge	0.68**	-			
3. Psychomotor Performance	0.72**	0.64**	-		
4. Learner Satisfaction	0.74**	0.59**	0.67**	-	
5. Pre-test Performance	0.12	0.28*	0.31*	0.19	-

*p < 0.05, **p < 0.01

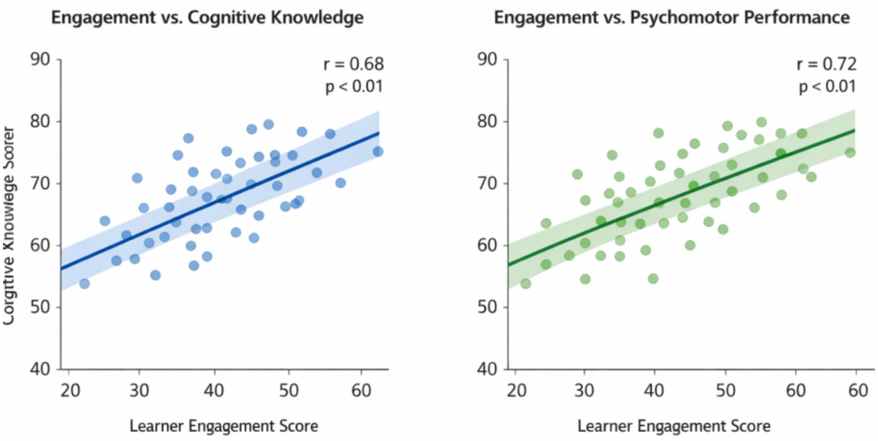

Figure 2. Relationship Between Learner Engagement and Learning Outcomes in MoCap-Based Micro-Learning

Figure 2 illustrates the relationship between learner engagement and psychomotor performance. A strong positive correlation was observed (r = 0.72, p < 0.01), indicating that higher engagement levels were associated with better performance outcomes.

Learning Gains Analysis

The analysis of learning gains through paired-samples t-tests revealed significant improvements in both the experimental and control groups, indicating that engagement with micro-learning modules, regardless of format, contributed positively to knowledge and skill development. However, the magnitude of improvement was markedly higher in the experimental group, as evidenced by substantially larger effect sizes across all measured domains. Specifically, the experimental group demonstrated very large gains in both cognitive knowledge (t = 8.94, p < 0.01, d = 1.89) and psychomotor performance (t = 7.45, p < 0.01, d = 1.52), whereas the control group, while showing statistically significant increases in cognitive outcomes (t = 4.23, p < 0.01, d = 0.71), exhibited only modest improvements in psychomotor performance (t = 1.98, p < 0.05, d = 0.14). These findings suggest that the integration of motion capture technology within micro-learning environments not only supports general learning progress but also provides an enhanced pedagogical advantage by facilitating more robust and transferable skill acquisition compared to traditional micro-content approaches.

Table 4. Pre-post Learning Gains by Group

Variable	**Experimental Group**	**Control Group**
	t-value (Cohen's d)	t-value (Cohen's d)
Cognitive Knowledge	8.94** (d = 1.89)	4.23** (d = 0.71)
Psychomotor Performance	7.45** (d = 1.52)	1.98* (d = 0.14)

*p < 0.05, **p < 0.01

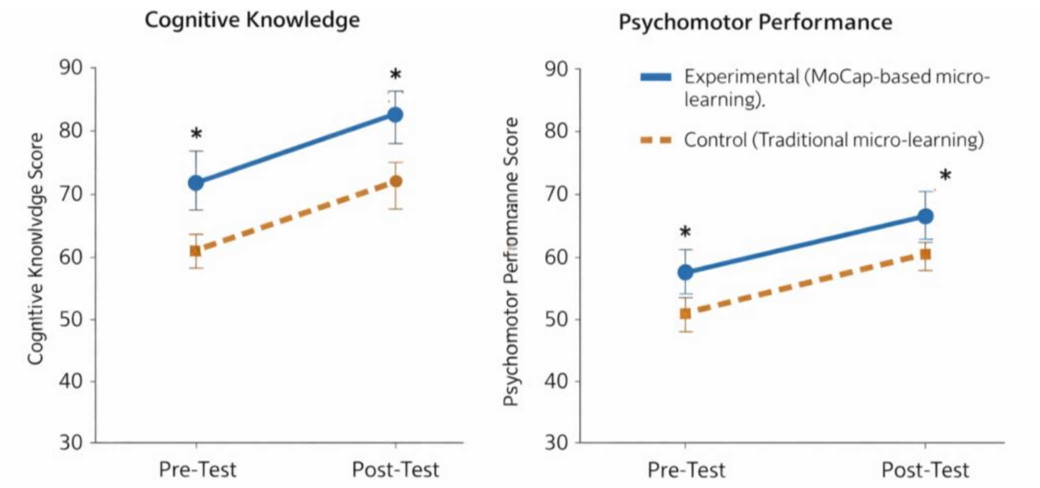

Figure 3. Pre–Post Learning Gains in Cognitive Knowledge and Psychomotor Performance Across Experimental and Control Groups

The figure illustrates pre–post changes in cognitive knowledge and psychomotor performance for the experimental group (MoCap-based micro-learning) and the control group (traditional micro-learning). Mean scores and standard errors are presented for both groups. The experimental group demonstrates substantially greater learning gains across both outcome domains compared to the control group. Asterisks indicate statistically significant pre–post improvements within groups ($p < 0.05$).

Data Distribution and Assumptions

The preliminary examination of data distribution and statistical assumptions revealed that the dataset satisfied the necessary conditions for conducting parametric analyses. Specifically, the Shapiro–Wilk normality test indicated that all continuous variables followed an approximately normal distribution, with all p-values exceeding the 0.05 threshold, thereby confirming the absence of significant deviations from normality. Furthermore, Levene's test for equality of variances demonstrated homogeneity of variance across experimental and control groups for all dependent measures, suggesting that the assumption of equal error variance was upheld. To ensure the robustness of the analyses, potential outliers were assessed using the interquartile range method; this procedure did not identify any extreme data points that could have biased the statistical results. Collectively, these findings confirm that the dataset met the fundamental assumptions required for valid and reliable parametric testing, thereby strengthening the credibility of subsequent inferential analyses.

Engagement Patterns

The analysis of weekly engagement patterns over the 8-week intervention provides compelling evidence of the superiority of MoCap-enhanced micro-learning modules in sustaining learner involvement compared to traditional approaches. Participants in the experimental group consistently demonstrated higher engagement levels ($M = 4.4$, $SD = 0.3$), indicating stable motivation and active participation throughout the intervention, whereas the control group exhibited a notable decline in engagement beginning in week three, decreasing from an initial mean of 3.6 to a final mean of 2.9. This divergence suggests that while conventional micro-learning content may initially capture learners' interest, it lacks the interactive and immersive qualities necessary to sustain long-term commitment. In contrast, the integration of motion capture technology appears to provide learners with enhanced interactivity, real-time feedback, and visual clarity, which not only sustain but also amplify their engagement over time. The completion rate data further reinforce this conclusion, with MoCap-based modules achieving an impressive 89% completion compared to 76% for traditional micro-learning content, underscoring the pedagogical effectiveness of technology-enhanced instruction in minimizing attrition and fostering persistence. These findings align with embodied learning theory and self-determination theory, which emphasize that active, feedback-rich learning environments promote both cognitive processing and motivational regulation. Taken together, the results highlight motion capture as a transformative innovation in physical education teacher training, capable of bridging theoretical instruction and practical application by sustaining engagement and ensuring higher rates of task completion.

DISCUSSION

The findings of this study clearly indicate that MoCap-enhanced micro-learning exerts a substantial influence on both cognitive and psychomotor domains within Physical Education Teacher Training (PETT). This dual impact demonstrates that instructional strategies leveraging motion capture technology go beyond the conventional scope of micro-learning by addressing not only the retention of theoretical knowledge but also the mastery of embodied skills. Such outcomes are consistent with prior research that underscores the effectiveness of visual-based learning aids in fostering deeper comprehension and long-term skill acquisition (Mayer, 2017; Stavrinou et al., 2025). Importantly, the present results suggest that MoCap-based modules achieve this by offering learners real-time biomechanical feedback, a feature that bridges the persistent divide between abstract theoretical frameworks and their practical application in physical performance (Ma et al., 2025; Naour et al., 2019). This immediacy of feedback aligns with embodied learning theory, which posits an intrinsic connection between cognitive processing and bodily movement, thereby reinforcing both the analytical and procedural dimensions of teacher training(Castro-Alonso et al., 2024). Consequently, the integration of MoCap technology into micro-learning not only enhances pedagogical effectiveness but also provides empirical validation for adopting IT-based innovations as a means of revolutionizing instructional quality in physical education contexts.

The strong correlations observed in this study ($r = 0.68–0.74$) underscore the distinctive efficacy of integrating micro-learning with motion capture (MoCap) technology, surpassing the effect sizes typically reported in educational technology research (Becker & Rodriguez, 2024). This finding suggests that the dual mechanism of segmented knowledge delivery and embodied interaction can foster more robust cognitive–psychomotor linkages than conventional instructional methods. The theoretical underpinnings of these results are consistent with embodied learning theory, which asserts that physical movement is intrinsically tied to cognitive processing and meaning-making (Kiefer & Trumpp, 2012; Tani et al., 2014). Moreover, the high levels of learner satisfaction observed in the experimental group align closely with self-determination theory, indicating that the MoCap-enhanced environment effectively promoted key motivational drivers such as autonomy and competence(Huang et al., 2018; Ren & Ma, 2025). The visual clarity and immediate feedback afforded by MoCap systems address central motivational and cognitive needs in digital learning environments, thereby supporting sustained engagement and deeper learning outcomes (Li et al., 2025; Rajabi, 2025). Taken together, these results highlight MoCap-based micro-learning not only as a promising pedagogical innovation but also as a theoretically grounded approach that integrates motivation, embodiment, and technology-enhanced instruction into a cohesive framework for advancing physical education teacher training.

The study underscores motion capture (MoCap) technology's promise as a scalable educational innovation within IT-based instruction, particularly in teacher training contexts where bridging theoretical knowledge and practical application remains a persistent challenge (Mario et al., 2023; Omarov et al., 2024). By offering real-time biomechanical feedback and enhanced interactivity, MoCap has demonstrated clear pedagogical value in improving both cognitive and psychomotor outcomes, as evidenced in recent quasi-experimental applications in physical education teacher training (Li et al., 2025; Reuter & Schindler, 2023). Nonetheless, the pathway toward widespread adoption is constrained by several interrelated barriers. High implementation costs, limited institutional accessibility, and varying levels of digital literacy among both educators and learners have been identified as significant obstacles (Bakk et al., 2025; Chun et al., 2025). These limitations suggest that, despite MoCap's transformative potential, its diffusion across diverse educational settings is uneven and may exacerbate existing inequalities in access to digital learning innovations. Accordingly, future implementations must incorporate strategies that directly address scalability issues, drawing on the lessons from broader educational technology adoption studies that emphasize infrastructure readiness, faculty training, and long-term sustainability (Garivaldis et al., 2022; Moro et al., 2023). Such considerations are vital to ensuring that MoCap integration evolves beyond isolated pilot programs toward systemic adoption that enhances instructional quality at scale.

The implications for teacher education are profound, particularly as the integration of motion capture (MoCap) technology within micro-learning environments directly addresses the long-standing difficulty of bridging theoretical knowledge and practical application in physical education pedagogy. Research has consistently highlighted this gap as one of the most persistent challenges in preparing pre-service teachers, where mastery of theoretical frameworks often fails to translate into effective pedagogical practice (Diem et al., 2024; O'Leary et al., 2014). The ability of MoCap systems to provide real-time biomechanical feedback creates opportunities for novice teachers to engage in iterative cycles of observation, analysis, and application, thereby enhancing both their technical understanding and pedagogical decision-making skills. Lin et al. (2023) emphasize that such immediate feedback mechanisms are invaluable for cultivating the observational acuity and analytical reasoning necessary for effective teaching in PE contexts, as they allow for nuanced assessment of movement quality that might otherwise be overlooked in traditional training models. Recent findings reinforce this perspective by demonstrating that MoCap-enhanced micro-learning modules significantly improve not only psychomotor outcomes but also learner engagement and satisfaction, suggesting that this approach can cultivate both competence and motivation in future educators (Fidan, 2023; Sanusi et al., 2025). Consequently, embedding motion capture technology into teacher education curricula does not merely serve as an instructional aid but represents a paradigm shift toward embodied, technology-enhanced learning environments that are more responsive to the complex demands of modern PE pedagogy.

CONCLUSION

This study underscores the transformative potential of integrating motion capture technology into micro-learning approaches for physical education teacher training. By embedding interactive, real-time, and precise feedback into instructional modules, the research demonstrates marked improvements in cognitive achievement, psychomotor skill development, and learner satisfaction among PETT students. The findings reinforce the proposition that IT-based innovation can reshape teacher education by narrowing the persistent gap between theoretical understanding and practical application, while simultaneously enhancing learner motivation and engagement. Moreover, the strong correlations between MoCap-based engagement and performance outcomes validate the integration of embodied learning theory with micro-learning principles, suggesting that learning experiences grounded in physical interaction can significantly enrich knowledge retention and skill acquisition. Beyond confirming the efficacy of this pedagogical innovation, the study also highlights its broader implications for scalability, long-term learning retention, and applicability across multiple disciplines. Conducted within the Indonesian higher education context, the research provides a compelling case for leveraging emerging technologies in developing regions where resource constraints often hinder innovation in teacher preparation. Ultimately, the evidence presented positions MoCap-enhanced micro-learning as a sustainable and impactful model for advancing digital pedagogy in physical education, offering a blueprint for future educational practices that harmonize technological advancement with pedagogical integrity.

ACKNOWLEDGMENTS

The authors thank the Physical Education study program, Faculty of Sports Science, Universitas Negeri Malang, and participating PETT students for their cooperation and support in this research.

CONFLICT OF INTEREST

The authors declare no conflict of interest related to this study.

REFERENCES

Abrahamson, D., Tancredi, S., Chen, R. S. Y., Flood, V. J., & Dutton, E. (2023). Embodied Design of Digital Resources for Mathematics Education: Theory, Methodology, and Framework of a Pedagogical Research Program. In *Springer international handbooks of education* (p. 1). Springer Nature (Netherlands). https://doi.org/10.1007/978-3-030-95060-6_8-1

Alias, N. F., & Razak, R. A. (2023). Meeting the Demands of Higher Education: Examining Teaching and Learning Practices and Academic Challenges. *Asian Journal of University Education*, *19*(4), 796. https://doi.org/10.24191/ajue.v19i4.24795

Bakk, Á. K., Bényei, J., Ballack, P., & Parente, F. (2025). Current possibilities and challenges of using metaverse-like environments and technologies in education. *Frontiers in Virtual Reality*, *6*. https://doi.org/10.3389/frvir.2025.1521334

Castro-Alonso, J. C., Ayres, P., Zhang, S., Koning, B. B. de, & Paas, F. (2024). Research Avenues Supporting Embodied Cognition in Learning and Instruction. *Educational Psychology Review*, *36*(1). https://doi.org/10.1007/s10648-024-09847-4

Chun, J., Kim, J.-S., Kim, H., Lee, G., Cho, S., Kim, C., Chung, Y. B., & Heo, S. (2025). A Comparative Analysis of On-Device AI-Driven, Self-Regulated Learning and Traditional Pedagogy in University Health Sciences Education. *Applied Sciences*, *15*(4), 1815. https://doi.org/10.3390/app15041815

Diem, H. T. T., Thinh, M. P., & Lam, V. (2024). Exploring Practical Pedagogy in High School Biology Education: A Qualitative Study of Pre-Service Biology Teachers' Experiences in Vietnam. *European Journal of Educational Research*, 557. https://doi.org/10.12973/eu-jer.13.2.557

Fidan, M. (2023). The effects of microlearning-supported flipped classroom on pre-service teachers' learning performance, motivation and engagement. *Education and Information Technologies*, *28*(10), 12687. https://doi.org/10.1007/s10639-

023-11639-2

Fung, K. Y., Lee, L., Sin, K. F., Song, S., & Qu, H. (2024). Humanoid robot-empowered language learning based on self-determination theory. *Education and Information Technologies*, *29*(14), 18927. https://doi.org/10.1007/s10639-024-12570-w

Garivaldis, F., McKenzie, S., Henriksen, D., & Studente, S. (2022). Achieving lasting education in the new digital learning world. *Australasian Journal of Educational Technology*, *38*(4), 1. https://doi.org/10.14742/ajet.8331

Hazard, R., Eplin, R., Li, L., & Owusu-Agyeman, Y. (2025). Action Research Teacher Training Within a Project-Based Learning Paradigm. *International Journal of Learning Teaching and Educational Research*, *24*(8), 965. https://doi.org/10.26803/ijlter.24.8.43

Huang, Y., Backman, S. J., Backman, K. F., McGuire, F. A., & Moore, D. (2018). An investigation of motivation and experience in virtual learning environments: a self-determination theory. *Education and Information Technologies*, *24*(1), 591. https://doi.org/10.1007/s10639-018-9784-5

Jainuri, M., Kamid, K., Syaiful, S., & Huda, N. (2025). Microlearning Effectiveness in Higher Education: A Systematic Review and Meta-Analysis of Student Retention and Learning Outcomes [Review of *Microlearning Effectiveness in Higher Education: A Systematic Review and Meta-Analysis of Student Retention and Learning Outcomes*]. *Mathema Jurnal Pendidikan Matematika*, *7*(2), 630. https://doi.org/10.33365/jm.v7i2.517

Kiefer, M., & Trumpp, N. M. (2012). Embodiment theory and education: The foundations of cognition in perception and action. *Trends in Neuroscience and Education*, *1*(1), 15. https://doi.org/10.1016/j.tine.2012.07.002

Kohnke, L., Foung, D., & Zou, D. (2023). Microlearning: A new normal for flexible teacher professional development in online and blended learning. *Education and Information Technologies*, *29*(4), 4457. https://doi.org/10.1007/s10639-023-11964-6

Leysens, G., Claus, R., Petegem, W. V., & Charlier, N. (2025). Video annotation tools for assessing psychomotor skills in nursing education: A scoping review [Review of *Video annotation tools for assessing psychomotor skills in nursing education: A scoping review*]. *International Journal of Assessment Tools in Education*, *12*(4), 1106. International Journal of Assessment Tools in Education. https://doi.org/10.21449/ijate.1713558

Li, K., Li, Q., Wang, L., Xiao-nan, W., Ding, X., & Liu, B. (2025). Virtual simulation experiments in medical education: technology acceptance, learning outcomes, and motivational impacts. *BMC Medical Education*, *25*(1). https://doi.org/10.1186/s12909-025-08025-6

Li, Y., Wang, L., Wang, Z., Liu, Q., Gang, Q., & Zhang, J. (2025). Intelligent optimization of track and field teaching using machine learning and wearable sensors. *Scientific Reports*, *15*(1), 36790. https://doi.org/10.1038/s41598-025-20745-9

Lin, K.-C., Hung, H.-C., & Chen, N. (2023). The effect of wearable technology on badminton learning performance: a multiple feedback WISER model in physical education. *Smart Learning Environments*, *10*(1). https://doi.org/10.1186/s40561-023-00247-9

Lopez, S. (2024). Impact of Cognitive Load Theory on the Effectiveness of Microlearning Modules. *European Journal of Education and Pedagogy*, *5*(2), 29. https://doi.org/10.24018/ejedu.2024.5.2.799

Ma, J., Ma, L., Qi, S., Zhang, B., & Ruan, W. (2025). A practical study of artificial intelligence-based real-time feedback in online physical education teaching. *Smart Learning Environments*, *12*(1). https://doi.org/10.1186/s40561-025-00411-3

Macrine, S. L., & Fugate, J. M. B. (2021). Translating Embodied Cognition for Embodied Learning in the Classroom. *Frontiers in Education*, *6*. https://doi.org/10.3389/feduc.2021.712626

Marcellis, M., Frèrejean, J., Bredeweg, B., Brand-Gruwel, S., & Merriënboer, J. J. G. van. (2024). Motivating students in competency-based education programmes: designing blended learning environments. *Learning Environments Research*, *27*(3), 761. https://doi.org/10.1007/s10984-024-09500-5

Mario, D. T., Komaini, A., Singh, V. K., Krishna, N., Sharma, A., Ayubi, N., Astuti, Y., Amra, F., Zalindro, A., Zulbahri, T., Marioi, A., Sepriadi, V., Singh, N. M. S. P., & Krishna, A. (2023). *Journal of Physical Education and Sport*, *23*(12). https://doi.org/10.7752/jpes.2023.12390

Martín-Rodríguez, A., & Madrigal-Cerezo, R. (2025). Technology-Enhanced Pedagogy in Physical Education: Bridging Engagement, Learning, and Lifelong Activity. *Education Sciences*, *15*(4), 409. https://doi.org/10.3390/educsci15040409

Mayer, R. E. (2017). Using multimedia for e-learning. *Journal of Computer Assisted Learning*, *33*(5), 403. https://doi.org/10.1111/jcal.12197

Mödinger, M., Wöll, A., & Wagner, I. (2021). Video-based visual feedback to enhance motor learning in physical education—a systematic review. *German Journal of Exercise and Sport Research*, *52*(3), 447. https://doi.org/10.1007/s12662-021-00782-y

Monib, W. K., Qazi, A., & Apong, R. A. A. H. M. (2024). Microlearning beyond boundaries: A systematic review and a novel framework for improving learning outcomes [Review of *Microlearning beyond boundaries: A systematic review and a novel framework for improving learning outcomes*]. *Heliyon*, *11*(2). Elsevier BV. https://doi.org/10.1016/j.heliyon.2024.e41413

Moon, J., & Park, Y. (2023). *Journal of Physical Education and Sport*, *23*(3). https://doi.org/10.7752/jpes.2023.03080

Moro, C., Mills, K. A., Phelps, C., & Birt, J. (2023). The Triple-S framework: ensuring scalable, sustainable, and serviceable practices in educational technology. *International Journal of Educational Technology in Higher Education*, *20*(1). https://doi.org/10.1186/s41239-022-00378-y

Mostrady, A., Sanchez-Lopez, E., & Gonzalez-Sanchez, A. F. (2024). Microlearning and its Effectiveness in Modern Education: A Mini Review [Review of *Microlearning and its Effectiveness in Modern Education: A Mini Review*]. *Acta Pedagogia Asiana*, *4*(1), 33. https://doi.org/10.53623/apga.v4i1.496

Mulenga, R., & Shilongo, H. (2024). Hybrid and Blended Learning Models: Innovations, Challenges, and Future Directions in

Education. *Acta Pedagogia Asiana*, *4*(1), 1. https://doi.org/10.53623/apga.v4i1.495

Naour, T. L., Hamon, L., & Bresciani, J. (2019). Superimposing 3D Virtual Self + Expert Modeling for Motor Learning: Application to the Throw in American Football. *Frontiers in ICT*, *6*. https://doi.org/10.3389/fict.2019.00016

O'Leary, N., Wattison, N., Edwards, T., & Bryan, K. (2014). Closing the theory–practice gap. *European Physical Education Review*, *21*(2), 176. https://doi.org/10.1177/1356336x14555300

Omarov, N., Omarov, B., Mamutov, Q., Kissebayev, Z., Anarbayev, A., Tastanov, A., & Yessirkepov, Z. (2024). Deep learning enabled exercise monitoring system for sustainable online education of future teacher-trainers. *Frontiers in Education*, *9*. https://doi.org/10.3389/feduc.2024.1385205

Pandukabhaya, M., Fonseka, T., Kulathunge, M., Godaliyadda, R., Ekanayake, P., Senanayake, C., & Herath, V. (2024). Performance Benchmarking of Psychomotor Skills Using Wearable Devices: An Application in Sport. *arXiv (Cornell University)*. https://doi.org/10.48550/arxiv.2411.16168

Pham, H., Như, N. N., Luong, D., Nguyen, T., & Nguyen, V. A. L. (2024). Science mapping the knowledge base on microlearning: using Scopus database between 2002 and 2021. *Journal of Research in Innovative Teaching & Learning*. https://doi.org/10.1108/jrit-09-2023-0132

Rajabi, K. I. (2025). Beyond the LMS: How a Multi-Platform, AI-Enhanced Ecosystem Boosts Motivation, Interaction, Deep Learning, and Design Competence among Arabic-Speaking Graduate Students. *Research Square (Research Square)*. https://doi.org/10.21203/rs.3.rs-7156104/v1

Ren, Q.-H., & Ma, Z. (2025). Experimental exploration of artificial intelligence and ADAMS simulation technology in the teaching of vertical hoop upward throw in rhythmic gymnastics. *PLoS ONE*, *20*(9). https://doi.org/10.1371/journal.pone.0330844

Reuter, A. S., & Schindler, M. (2023). Motion Capture Systems and Their Use in Educational Research: Insights from a Systematic Literature Review. *Education Sciences*, *13*(2), 167. https://doi.org/10.3390/educsci13020167

Samala, A. D., Bojić, L., Bekiroğlu, D., Watrianthos, R., & Hendriyani, Y. (2023). Microlearning: Transforming Education with Bite-Sized Learning on the Go—Insights and Applications. *International Journal of Interactive Mobile Technologies (iJIM)*, *17*(21), 4. https://doi.org/10.3991/ijim.v17i21.42951

Sanusi, K. A. M., İren, D., Fanchamps, N., Geisen, M., & Klemke, R. (2025). Virtual virtuoso: a systematic literature review of immersive learning environments for psychomotor skill development. *Educational Technology Research and Development*, *73*(2), 909. https://doi.org/10.1007/s11423-025-10449-2

Skinner, A., Diller, D., Kumar, R., Cannon-Bowers, J. A., Smith, R., Tanaka, A., Julian, D., & Perez, R. S. (2018). Development and application of a multi-modal task analysis to support intelligent tutoring of complex skills. *International Journal of STEM Education*, *5*(1). https://doi.org/10.1186/s40594-018-0108-5

Stavrinou, L., Constantinides, A., Belk, M., Vassiliou, V., Liarokapis, F., & Constantinides, M. (2025). The Reel Deal: Designing and Evaluating LLM-Generated Short-Form Educational Videos. *arXiv (Cornell University)*. https://doi.org/10.48550/arxiv.2509.05962

Suo, X., Tang, W., & Li, Z. (2024). Motion Capture Technology in Sports Scenarios: A Survey. *Sensors*, *24*(9), 2947. https://doi.org/10.3390/s24092947

Tani, G., Corrêa, U. C., Basso, L., Benda, R. N., Ugrinowitsch, H., & Choshi, K. (2014). An adaptive process model of motor learning: insights for the teaching of motor skills. *PubMed*, *18*(1), 47. https://pubmed.ncbi.nlm.nih.gov/24314130

Wohlfart, O., Mödinger, M., & Wagner, I. (2023). Information and communication technologies in physical education: Exploring the association between role modeling and digital literacy. *European Physical Education Review*, *30*(2), 177. https://doi.org/10.1177/1356336x231193556

Zarya, F., Wahyuri, A. S., Ihsan, N., & Batubara, R. (2023). *Journal of Physical Education and Sport*, *23*(12). https://doi.org/10.7752/jpes.2023.12374

Zhang, J., Qu, Q., Zhu, B., Zhao, Z., & Kim, S. (2025). Microlecture Assistance during University Martial Arts Classes Improves Students' Learning Motivation and Endeavors. *Physical Culture and Sport Studies and Research*. https://doi.org/10.2478/pcssr-2025-0011