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Augmented reality as a table tennis learning medium: improving students' technical understanding and motor skills

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ABSTRACT

This study aimed to examine changes in students' technical understanding and motor skills following the implementation of an augmented reality (AR)-based table tennis learning medium. The study employed a one-group pretest–posttest design involving 30 students. Technical understanding and motor skills were assessed before and after the intervention. Data were analyzed using descriptive statistics, paired-samples t-tests, Cohen's dz, Shapiro–Wilk tests, and normalized gain. Technical understanding increased from 67.67 ± 7.03 to 80.97 ± 7.00, while motor skills improved from 65.77 ± 7.86 to 76.77 ± 6.97. Both changes were statistically significant ($p < .001$), with very large within-group effect sizes ($dz = 2.40$ and 2.02) and moderate normalized gains of 41.5% and 32.1%, respectively. AR-based table tennis learning was associated with meaningful improvements in conceptual and motor outcomes, supporting its potential as a complementary medium for university-level practical instruction.

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Introduction

The growing use of digital tools in education has changed how learning materials are delivered and experienced, providing alternatives to conventional instruction based mainly on lectures, textbooks, and static visual resources. This transformation has also influenced physical education, where effective learning requires the integration of conceptual knowledge, observation, and physical practice. Digital learning media can provide students with more accessible and contextual learning experiences, while smartphones have become widely used platforms for accessing educational content (Darko-Adjei, 2019; Festiawan et al., 2024; Kamp, 2019; Perdana et al., 2021; Puspitarini & Hanif, 2019). Technology-supported instruction, however, should remain pedagogically aligned with learning objectives and meaningful teacher–student interaction because educational effectiveness depends not only on technological resources but also on instructional and contextual factors (Bradley, 2020; Burušić et al., 2016; Ilham & Dimyati, 2021; Moraru & Cristea, 2013).

Among emerging educational technologies, augmented reality (AR) offers particular potential because it integrates digitally generated information with real-world environments, allowing learners to interact with visual representations while remaining connected to authentic learning contexts. Unlike conventional static media, AR can present three-dimensional objects, movement information, and interactive content that may facilitate the representation of concepts that are difficult to communicate verbally. Meta-analytic evidence from 134 experimental and quasi-experimental studies has demonstrated positive effects of AR on knowledge, skills, and performance outcomes (Chang et al., 2022). Similarly, evidence from higher education indicates substantial

benefits of AR-supported instruction, although its effectiveness varies according to learning outcomes and instructional characteristics (Li et al., 2025). Thus, AR should be considered not merely a technological innovation but a pedagogical medium whose effectiveness depends on how its visual and interactive features are integrated into learning activities.

The potential contribution of AR is particularly relevant to physical education and sport because motor learning requires students to connect conceptual understanding with accurate movement execution. In table tennis, students must understand and coordinate several technical components, including grip, ready position, footwork, body positioning, racket movement, ball contact, and follow-through. These components involve spatial, temporal, and sequential movement information that may be difficult to represent comprehensively through verbal explanations or static illustrations alone. AR may address this limitation by providing visual representations that allow learners to observe movement components and relate them to practical execution. Previous reviews have identified visualization, interaction, and concrete representation as important affordances of AR-based learning (Ajit et al., 2020; Alzahrani, 2020), suggesting its potential relevance for learning complex sport techniques.

From a motor-learning perspective, however, visualization alone is unlikely to produce optimal skill acquisition because motor performance develops through the interaction of observation, physical practice, feedback, and instructional guidance. Technology-supported representations may help learners construct clearer mental representations of movement, while augmented feedback can reinforce the relationship between perceived movement and actual performance. Evidence indicates that augmented feedback can facilitate gross motor and sport-specific skill learning (Moinuddin et al., 2021), while technology-mediated feedback has demonstrated potential benefits in cricket skill acquisition (Tissera et al., 2022). Recent extended-reality research has also reported improvements in psychomotor performance compared with non-XR training, although methodological heterogeneity limits definitive conclusions (Bateman et al., 2026). Accordingly, AR should complement rather than replace lecturer guidance, feedback, and repeated physical practice, particularly because pedagogical approaches and intervention characteristics influence learning outcomes (Chang et al., 2022; Gil et al., 2022).

Evidence concerning immersive and augmented technologies in physical education continues to develop. Pérez-Muñoz et al. (2024) identified motor and health-related competencies among important outcomes associated with AR, virtual reality, and mixed-reality applications in physical education, while Azzahra et al. (2025) reported potential benefits of AR for motor educability in football learning. Nevertheless, the available literature remains dominated by general educational contexts, systematic reviews, and applications outside table tennis. Moreover, technology-supported motor learning is influenced by instructional design, scaffolding, opportunities for practice, and the amount of information presented to learners (Zhang et al., 2022). Excessive visual information may also affect cognitive processing; therefore, AR environments should prioritize essential movement information and avoid unnecessary complexity, particularly given evidence that the effects of AR on cognitive load vary according to design and implementation (Zhu et al., 2026).

Despite the growing evidence supporting AR in education and physical education, empirical research specifically examining AR-supported table tennis learning at the university level remains limited. More importantly, few studies have simultaneously investigated technical understanding as a cognitive outcome and motor skills as a psychomotor outcome, leaving uncertainty regarding whether AR-supported instruction can contribute to these interconnected dimensions of table tennis learning. Addressing this gap is important because conceptual understanding does not necessarily translate directly into proficient movement execution, and both dimensions are essential in practical sport instruction. Therefore, this study aimed to examine changes in students' technical understanding and motor skills following the implementation of an AR-based table tennis learning medium. Given the one-group pretest–posttest design, the study evaluates within-group changes following the intervention rather than establishing definitive causal superiority of AR over conventional instruction.

Method

This study employed a Research and Development (R&D) approach to develop an augmented reality (AR)-based learning medium for table tennis using the Luther–Sutopo Multimedia Development Life Cycle (MDLC). The development comprised six stages: concept, design, material collection, assembly, testing, and distribution. The concept stage identified learning needs and essential table tennis techniques, while the design stage established the content structure, AR Book layout, and interaction flow. Relevant instructional materials, images, and visual objects were then collected and integrated into the AR Book. The testing stage involved expert validation and user trials, followed by final preparation of the product for instructional use.

Product quality was evaluated by subject matter, instructional design, and technology experts using validation sheets with a five-point rating scale covering content suitability, instructional design, technological quality, visual appearance, program quality, and content presentation. Small- and large-group trials were subsequently conducted to examine user acceptance and practicality. Preliminary learning outcomes were evaluated with 30 students using a one-group pretest–posttest design. Students completed assessments of technical understanding and motor skills before and after using the AR-based learning medium. Because no control group was included, the evaluation focused on within-group changes following the intervention rather than establishing a causal advantage of AR over conventional instruction.

Expert-validation and user-trial scores were converted into feasibility percentages. Technical understanding and motor-skill outcomes were summarized using means and standard deviations, while the normality of change scores was examined using the Shapiro–Wilk test. Pretest and posttest scores were compared using paired-samples t-tests at a significance level of $p < .05$. Cohen's dz was calculated to quantify the magnitude of within-group change, and normalized gain (N-gain) was used to determine relative improvement. The combined interpretation of statistical significance, effect size, and normalized gain provided complementary evidence regarding changes in students' technical understanding and motor skills following implementation of the AR-based table tennis learning medium.

Results and Discussions

Validation results indicate that the AR Book learning media received positive assessments from experts. Subject matter expert validation yielded an average score of 92.3%, indicating that the aspects of content, accuracy, and material suitability fell into the "very good" category. Instructional design validation achieved an average score of 91.1%, while technology expert validation averaged 89.9%. Based on these three results, the overall average validation score for the media reached 91.1%, placing it in the "very good" category.

These results demonstrate that the developed product meets the criteria for content suitability, instructional design, and technology. The use of visual objects and AR technology offers a more interactive alternative for presenting material compared to methods relying solely on text and static images. The small-group trial yielded an average score of 91.27% (categorized as "very good"), while the large-group trial achieved an average score of 90.67% (also categorized as "very good"). rial results indicate that the media is well-received by users and demonstrates a high level of practicality. The digital nature of the media allows students to access materials with greater flexibility and actively explore the learning content.

Table 1. Data on students' technical understanding following the intervention

Variable	Pretest Mean ± SD	Posttest Mean ± SD	Mean Difference	t(29)	p	Cohen's dz	N-gain
Technical understanding	67.67 ± 7.03	80.97 ± 7.00	13.30	13.15	< .001	2.40	41.5%

The mean technical understanding score increased from 67.67 at pretest to 80.97 at posttest, representing an average increase of 13.30 points.The paired-samples t-test showed a statistically significant difference between pretest and posttest scores, $t(29) = 13.15$, $p < .001$. The Cohen's dz value of 2.40 indicates a very large within-group effect. The mean N-gain was 0.415 or 41.5%, which is conventionally interpreted as a moderate level of normalized improvement. The Shapiro–Wilk test for the change scores showed that the distribution did not significantly deviate from normality, $W = .971$, $p = .558$.

Table 2. Data on students' motor skills following the intervention.

Variable	Pretest Mean ± SD	Posttest Mean ± SD	Mean Difference	t(29)	p	Cohen's dz	N-gain
Motor skills	65.77 ± 7.86	76.77 ± 6.97	11.00	11.06	< .001	2.02	32.1%

The mean motor skill score increased from 65.77 to 76.77, with an average increase of 11.00 points.The paired-samples t-test indicated a statistically significant difference, $t(29) = 11.06$, $p < .001$. The Cohen's dz of 2.02 indicates a very large within-group effect. The mean N-gain was 0.321 or 32.1%, categorized as moderate. The Shapiro–Wilk test also indicated that the motor skill change scores were normally distributed, $W = .948$, $p = .150$.

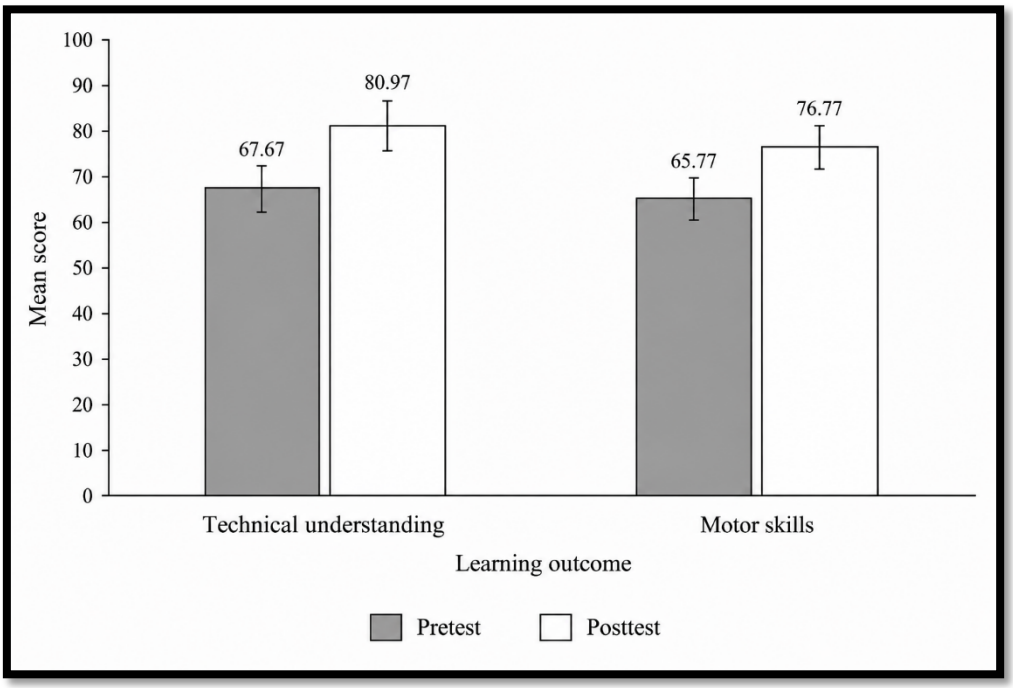


Figure 1. Comparison of Pretest and Posttest Scores for Technical Understanding and Motor Skills

Figure 1 illustrates the changes in students' technical understanding and motor skills following the implementation of the AR-based table tennis learning medium. Technical understanding increased from 67.67 ± 7.03 at pretest to 80.97 ± 7.00 at posttest, representing a mean difference of 13.30 points. Motor skills similarly increased from 65.77 ± 7.86 to 76.77 ± 6.97, with a mean difference of 11.00 points. Paired-samples t-tests confirmed significant pretest–posttest differences for both technical understanding, $t(29) = 13.15$, $p < .001$, and motor skills, $t(29) = 11.06$, $p < .001$. These results demonstrate consistent within-group improvements in both learning outcomes following the AR-based intervention.

The present study demonstrated significant improvements in students' technical understanding and motor skills following the implementation of the AR-based table tennis learning medium. Technical understanding increased by 13.30 points, whereas motor skills increased by 11.00 points, indicating improvement across both cognitive and psychomotor learning outcomes. These findings are consistent with meta-analytic evidence showing that AR-supported instruction can enhance knowledge, skills, and performance (Chang et al., 2022). Similar evidence from higher education has also demonstrated positive effects of AR across different learning outcomes, although the magnitude of these effects varies according to instructional context and implementation characteristics (Li et al., 2025). The present findings therefore extend the existing literature by showing that AR-supported learning may be relevant not only for conceptual learning but also for practical skill development in table tennis.

The greater improvement in technical understanding than in motor skills may reflect differences between acquiring movement-related knowledge and developing proficient movement execution. AR enables movement information to be presented through interactive visual representations that may help students identify technical components such as body positioning, racket movement, ball contact, and follow-through. Such representations can provide more concrete information than verbal explanations or static illustrations and may facilitate the formation of clearer mental representations of movement. Visualization, interaction, and concrete representation have been identified as important affordances of AR-supported education (Ajit et al., 2020; Alzahrani, 2020). Nevertheless, because visualization and mental representation were not directly assessed in this study, their contribution should be interpreted as a plausible mechanism rather than a demonstrated causal pathway (AS & Wasan, 2024; Ma et al., 2024; Xie et al., 2025).

Motor-skill development requires more than conceptual recognition of correct movement because learners must progressively coordinate perception, movement execution, practice, and corrective feedback. AR-based representations may provide an additional reference that students can use to understand the intended movement pattern before translating that information into physical performance. This interpretation is consistent with evidence that augmented feedback can facilitate gross motor and sport-specific skill acquisition (Moinuddin et al., 2021) and that technology-mediated feedback can contribute to sport-skill learning (Tissera et al., 2022). Extended-reality training has similarly shown potential for improving psychomotor performance, although

methodological heterogeneity across studies limits definitive conclusions regarding its superiority over conventional approaches (Bateman et al., 2026). The smaller gain in motor skills observed in this study may therefore indicate that psychomotor improvement requires longer and more intensive physical practice than conceptual understanding (Feng et al., 2025; Ilham et al., n.d.; Jiménez Orozco et al., 2022; Safari et al., 2025).

The magnitude of improvement also requires careful statistical interpretation. Cohen's dz values of 2.40 for technical understanding and 2.02 for motor skills indicate very large standardized within-group changes, whereas N-gain values of 41.5% and 32.1%, respectively, indicate moderate improvement relative to the maximum attainable scores. These findings are not contradictory because the two indices represent different dimensions of change. Cohen's dz reflects the magnitude of the mean change relative to the variability of individual change scores, whereas N-gain represents the proportion of potential improvement achieved from baseline. Thus, the results suggest that changes were substantial and relatively consistent within the group, while considerable potential for further improvement remained. This distinction is important because very large effect sizes should not be interpreted as evidence that students had achieved optimal technical or motor proficiency (Annisa et al., 2026; Apriyanto et al., 2026; Pane et al., 2025; Yu & Soachalerm, 2024).

From a pedagogical perspective, the moderate normalized gains indicate that AR should function as a complementary learning resource rather than replace direct instruction and physical practice. Effective table tennis learning requires students to repeatedly apply technical information, receive corrective feedback, and refine movement execution under lecturer supervision. The effectiveness of AR-supported instruction is influenced by pedagogical design, scaffolding, and opportunities for practice, emphasizing the importance of integrating technology into a structured learning process (Zhang et al., 2022). Cognitive load should also be considered when designing AR content because additional visual information may facilitate learning when it highlights essential movement cues but may interfere with processing when the display becomes unnecessarily complex. Evidence indicates that AR may reduce cognitive load, although its effects vary according to design and implementation characteristics (Zhu et al., 2026). Accordingly, AR content should prioritize essential technical information while maintaining sufficient opportunities for authentic physical practice (Faruk et al., 2025; Gumilar et al., 2024; Raibowo et al., 2023; Škopek et al., 2024).

Several methodological considerations limit the interpretation of these findings. The one-group pretest–posttest design does not permit the observed improvements to be attributed exclusively to the AR-based learning medium because repeated testing, physical practice, lecturer involvement, maturation, or other learning experiences may have contributed to the changes. Furthermore, visualization processes, augmented feedback, cognitive load, and individual components of table tennis performance were not directly measured, preventing confirmation of the mechanisms proposed to explain the findings. Future studies should employ controlled experimental designs with larger samples, clearly defined intervention durations, and delayed retention tests to determine whether AR-supported improvements persist and whether they exceed those achieved through conventional instruction (Adi et al., 2024; Liu et al., 2024; Wulandari et al., 2026). Examining specific table tennis techniques and potential cognitive and motor-learning mechanisms would also provide stronger evidence regarding how AR contributes to practical sport learning.

Conclusions

The implementation of the AR-based table tennis learning medium was associated with significant improvements in students' technical understanding and motor skills, indicating its potential to support both cognitive and psychomotor learning outcomes. The improvement was more pronounced in technical understanding than in motor skills, suggesting that AR may provide stronger initial support for understanding movement concepts, while motor skill development requires sustained physical practice and feedback. These findings support the use of AR as a complementary medium for table tennis instruction rather than a replacement for direct practice and lecturer guidance. However, because the study employed a one-group pretest–posttest design, the observed improvements cannot be attributed exclusively to AR. Further controlled studies are needed to determine its comparative effectiveness and the persistence of learning outcomes over time.

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References

Adi, I. P. P., Dartini, N. P. D. S., & Spyanawati, L. P. (2024). Android-based digital teaching materials in table tennis learning. Jurnal Ilmiah Pendidikan Dan Pembelajaran, 8(3), 614–620.

Ajit, G., Lucas, T., & Kanyan, R. (2020). A Systematic Review of Augmented Reality in STEM Education. 20(2). Alzahrani, N. M. (2020). Augmented Reality : A Systematic Review of Its Benefits and Challenges in E-learning Contexts. Azzahra, A., Sumpena, A., & Mudjianto, S. (2025). The Effect of Augmented Reality (AR) on Students '

Annisa, N., Harefa, N. A. J., Ramadhan, A., & Simamora, D. (2026). Adaptive Equipment-Based Learning to Improve Backhand Stroke Skill Acquisition in Secondary School Table Tennis. Joska: Jurnal Isori Kampar, 3(02).

Apriyanto, R., Da'i, M., Yudhantara, F., Ramdhani, N., & Jazali, M. K. (2026). The Effect Of Microcontroller Technology Training On Improving Table Tennis Skills. COMPETITOR: Jurnal Pendidikan Kepelatihan Olahraga, 18(1), 1045–1055.

AS, J., & Wasan, A. (2024). Effectiveness of Virtual Reality-Based Forehand Smash Training Model for Table Tennis Athletes Performance. Pakistan Journal of Life & Social Sciences, 22(2).

Bateman, S. P., Harris, D. J., Buckingham, G., Wilson, M., & Vine, S. J. (2026). The effectiveness of extended reality training programmes for improving psychomotor skill performance : A systematic review and meta-analysis. In Educational Research Review (Vol. 52, Issue July). Elsevier Ltd. https://doi.org/10.1016/j.edurev.2026.100824

Bradley, V. M. (2020). Learning Management System (LMS) Use with Online Instruction. International Journal of Technology in Education, 4(1), 68. https://doi.org/10.46328/ijte.36

Burušić, J., Babarović, T., & Velić, M. Š. (2016). School effectiveness and educational management: Towards a South-Eastern Europe research and public policy agenda. School Effectiveness and Educational Management: Towards a South-Eastern Europe Research and Public Policy Agenda, May, 1–159. https://doi.org/10.1007/978-3-319-29880-1

Chang, H., Binali, T., Liang, J., Chiou, G., Cheng, K., Lee, S. W., & Tsai, C. (2022). Ten years of augmented reality in education: A meta-analysis of (quasi-) experimental studies to investigate the impact. Computers & Education, 191(August), 104641. https://doi.org/10.1016/j.compedu.2022.104641

Darko-Adjei, N. (2019). The use and effect of smartphones in students' learning activities: Evidence from the University of Ghana, Legon. Library Philosophy and Practice, 2019.

Faruk, M., Ali, M., Susilana, R., Dewi, L., Alias, N., Mahardika, I. M. S. U., Syafi'i, I., Huda, M. S., Wahyudi, A. R., & Andriana, L. M. (2025). The interventions of physical education by using augmented reality based mobile learning can significantly improve gross motor skills in elementary school students. Retos, 64, 201–210.

Feng, D., Cossich, V. R. A., Abdelrasoul, E., Campelo, A. M., & Katz, L. (2025). The impact of video performance technology and peer-to-peer learning on table tennis skill acquisition in elementary students. Frontiers in Sports and Active Living, 7, 1653334.

Festiawan, R., Sumanto, E., Febriani, A. R., Permadi, A. A., Arifin, Z., Utomo, A. W., Nugroho, W. A., & Pratama, K. W. (2024). The Hybrid Learning System With Project Based Learning: Can It Increase Creative Thinking Skill and Learning Motivation in Physical Education Learning? Retos, 56, 1009–1015. https://doi.org/10.47197/retos.v56.105047

Gil, S., Singh, U., Gutierrez, J., & Marks, S. (2022). Pedagogical design in education using augmented reality : A systematic review. 2013.

Gumilar, A., Negara, J. D. K., Nuryadi, N., Firmansyah, H., Mudjihartono, M., Hambali, B., & Purnomo, E. (2024). Development of digital-based return board table tennis learning media. Jurnal Patriot, 6(1), 13–20.

Ilham, A., Datau, S., & Ikhsan, H. (n.d.). Development of learning media introduction to table tennis sports equipment based on augmented reality. Journal Of Sport Education (JOPE), 7(1), 49–60.

Ilham, I., & Dimyati, D. (2021). The Effect of Visualization, Relaxation, and Self-efficacy on the Performance of Men Speed World Record Athletes Category. International Journal of Human Movement and Sports Sciences, 9(1), 48–55. https://doi.org/10.13189/saj.2021.090107

Jiménez Orozco, H. L., Álvarez Araque, W. O., & Sarmiento Fautoque, D. Y. (2022). Augmented Reality As A Teaching Strategy To Strengthen The Technical Fundamentals Of Volleyball. Journal of Language & Linguistics Studies, 18(4), 492.

Kamp, A. (2019). Science & Technology Education for 21 St Century Europe. Cesaer, December. https://doi.org/10.5281/zenodo.3582544

Li, G., Luo, H., Chen, D., Wang, P., Yin, X., & Zhang, J. (2025). Augmented Reality in Higher Education : A Systematic Review and Meta-Analysis of the Literature from 2000 to 2023.

Liu, S., Wu, C., Xiao, S., Liu, Y., & Song, Y. (2024). Optimizing young tennis players' development: Exploring the impact of emerging technologies on training effectiveness and technical skills acquisition. Plos One, 19(8), e0307882.

Ma, D., Hu, X., Shi, J., Patel, M., Jain, R., Liu, Z., Zhu, Z., & Ramani, K. (2024). avattar: Table tennis stroke training with embodied and detached visualization in augmented reality. Proceedings of the 37th Annual ACM Symposium on User Interface Software and Technology, 1–16.

Moinuddin, A., Goel, A., & Sethi, Y. (2021). The Role of Augmented Feedback on Motor Learning : A Systematic Review. 13(11). https://doi.org/10.7759/cureus.19695

Moraru, M., & Cristea, G. (2013). Self-knowledge and Professional Development-sustainable Educational Condition of a Relationship. Procedia - Social and Behavioral Sciences, 89, 94–97. https://doi.org/10.1016/j.sbspro.2013.08.816

Motor Educabil- ity in Football Learning. Journal of Physical Education , Health and Sport, 12(2), 374–381.

Pane, B. S., Chairad, M., & Dewi, R. (2025). The effect of augmented reality as learning media on table tennis learning interest. JTP-Jurnal Teknologi Pendidikan, 27(1), 35–44.

Perdana, G. S., Widiyanto, & Ilham. (2021). Development of an android-based application as an information system for sports venues and sport community. International Journal of Human Movement and Sports Sciences, 9(6), 1131–1139. https://doi.org/10.13189/saj.2021.090608

Pérez-Muñoz, S., Calle, R. C., Campo, P. T. M., & Rodríguez-Cayetano, A. (2024). A Systematic Review of the Use and Effect of Virtual Reality , Augmented Reality and Mixed Reality in Physical Education.

Puspitarini, Y. D., & Hanif, M. (2019). Using Learning Media to Increase Learning Motivation in Elementary School. Anatolian Journal of Education, 4(2), 53–60. https://doi.org/10.29333/aje.2019.426a

Raibowo, S., Sugihartono, T., Permadi, A., & Pujianto, D. (2023). Mobile Learning to Improve Student Learning Outcomes in Tennis. Indonesian Journal of Physical Education and Sport Science, 3(2), 166–173.

Safari, I., Supriyadi, T., & Susilawati, D. (2025). Holistic Pedagogical Model for Table Tennis: Integrating Regulations, Multimedia, and Sportsmanship. International Journal of Human Movement and Sports Sciences, 13(3), 636–646.

Škopek, M., Heidler, J., Balkó, Š., Vojtíková, L., & Ulrichová, R. (2024). Evaluation of the influence of training in an immersive virtual reality environment on sports skills in table tennis. Baltic Journal of Health and Physical Activity, 16(3), 5.

Tissera, K., Orth, D., Huynh, M., & Benson, A. C. (2022). The impact of augmented feedback (and technology) on learning and teaching cricket skill : A systematic review with meta-analysis. 1–18. https://doi.org/10.1371/journal.pone.0279121

Wulandari, N., As, J., Anggraeni, E., Septyani, N., & Fadjri, M. (2026). Beyond the visual: the lived experience of sensorimotor dissonance in virtual reality table tennis training. Jurnal Konseling Dan Pendidikan, 14(1), 788–799.

Xie, D., Chen, B., Li, H., & Huang, Q. (2025). Enhancing table tennis performance and physical fitness through digital technology: a quasi-experimental study based on the TPACK framework. Frontiers in Sports and Active Living, 7, 1595455.

Yu, M., & Soachalerm, A. (2024). A construction of virtual reality technology teaching model to improve table tennis skills for university students. International Journal of Sociologies and Anthropologies Science Reviews, 4(5), 123–132.

Zhang, J., Li, G., Huang, Q., Feng, Q., & Luo, H. (2022). Augmented Reality in K – 12 Education : A Systematic Review and Meta-Analysis of the Literature from 2000 to 2020.

Zhu, X., Peng, K., Yu, S., & Wang, G. (2026). Can augmented reality technology reduce learners ' cognitive load ? A meta - analysis.