AI-MEDIATED EMBODIED LEARNING IN UNIVERSITY KINESIOLOGY EDUCATION: A MIXED-METHODS STUDY ON ENGAGEMENT AND WELL-BEING

Davide Di Palma
University of Campania "Luigi Vanvitelli"
davide.dipalma@unicampania.it

Double Blind Peer Review

Citazione
Di Palma, D. (2026). Ai-mediated embodied learning in university kinesiology education: A mixed-methods study on engagement and well-being. *Italian Journal of Health Education, Sport and Inclusive Didactics, 10*(2).

Doi: https://doi.org/10.32043/gsd.v10i2.1712

Copyright notice:
© 2025 this is an open access, peer-reviewed article published by Open Journal System and distributed under the terms of the Creative Commons Attribution 4.0 International, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

gsdjournal.it
ISSN: 3103-5744

ABSTRACT

Recent developments in artificial intelligence are reshaping university education in kinesiology. This mixed-methods quasi-experimental study examined the effects of AI-mediated hybrid learning ecosystems on engagement, motivation, self-efficacy and psychological well-being in 96 university students. The experimental group participated in a 10-week intervention using wearable devices, adaptive AI feedback and digital collaborative platforms, whilst the control group followed traditional activities. Results showed improvements in engagement, self-efficacy and well-being, while qualitative findings highlighted greater body awareness, self-regulation and inclusion. Overall, AI-mediated ecosystems appear to redefine the relationship between the body, digital data and learning in university education.

KEYWORDS

Embodied learning; artificial intelligence; hybrid learning ecosystems; kinesiology education; motor learning.

Received 2026-05-26
Accepted 2026-06-22
Published 2026-10-30

1. Introduction

In recent years, the field of kinesiology and sports science has undergone a profound epistemological, professional and institutional transformation. The constitutional recognition of the educational, social and psychophysical value of sport, introduced in Article 33 of the Italian Constitution, represents a historic step that redefines the role of human movement within contemporary society and forms part of the broader European process of promoting the right to sport and well-being through physical activity. At the same time, recent changes to Italian legislation – from Law 86/2019 to Legislative Decree 36/2021 – have helped to define new professional profiles in the field of kinesiology, recognising the scientific and methodological specificity of professions linked to sports science. Against this backdrop, university education is called upon to rethink pedagogical models, learning environments and the professional skills required to operate in contexts that are increasingly interdisciplinary, digitalised and innovation-oriented. Within this transformation, the spread of digital technologies and artificial intelligence systems is profoundly altering motor learning processes, biomechanical assessment and methods of body monitoring. Wearable sensors, motion tracking systems, immersive platforms and adaptive algorithms are progressively redefining the ways in which movement is observed, interpreted and taught (Baca & Kornfeind, 2012). However, the educational significance of these technologies extends beyond mere technical efficiency or performance enhancement. Increasingly, AI-mediated environments are understood as complex pedagogical ecosystems in which the body, digital data, reflexivity and learning interact dynamically. Recent scientific evidence shows that hybrid learning environments can facilitate more personalised, immersive and inclusive learning experiences through immediate feedback, analysis of body data and adaptive pathways

based on students' needs (Bond et al., 2021; Crompton & Burke, 2023). In the field of motor skills, such approaches appear to support engagement, self-regulation and body awareness, contributing to the development of advanced professional skills (Casey et al., 2021). However, much of the literature continues to interpret digital technologies predominantly in functional or performative terms, focusing on the optimisation of technical movements, quantitative monitoring of movement or the effectiveness of automatic feedback systems. This perspective risks reducing the body to a mere object of measurement and datafication, neglecting its relational, educational and experiential dimensions (Evans et al., 2021). At the same time, the growing prevalence of AI-based systems raises issues related to algorithmic transparency, privacy, the management of bodily data, and the potential depersonalisation of the educational relationship (Holmes et al., 2022). Consequently, there is a need to develop pedagogical approaches capable of integrating technological innovation with a person-centred approach, avoiding forms of biomechanical reductionism or 'digital performance orientation'. Within this theoretical framework, the present study is situated at the intersection of embodied cognition, digital pedagogy and learning ecosystem theory. The embodied approach considers the body not merely as the executor of action, but as a central component of cognitive, perceptual and emotional processes (Wilson & Golonka, 2013). Movement therefore represents a situated and relational cognitive experience, rooted in the continuous interaction between body, environment and the social dimension. This perspective ties in with the phenomenological reflections of Merleau-Ponty (1962) and , according to whom the body constitutes the primary mediator of our relationship with the world, and with the studies of Johnson (2017), which highlight the bodily rootedness of human thought. In light of this framework, AI-based ecosystems cannot be interpreted as mere tools external to the

educational process. On the contrary, they appear to redefine the relationship between corporeality, digital data and learning through forms of augmented feedback, multimodal representation of movement and embodied reflexivity. Biomechanical data therefore does not emerge as an element separate from bodily experience, but as a cognitive and pedagogical mediator capable of making movement more observable, interpretable and self-regulating. At the same time, digital pedagogy highlights how technological environments can foster forms of active, collaborative and participatory learning. Kearney et al. (2012) highlight that mobile and digital technologies make it possible to overcome the traditional separation between formal and informal learning, creating dynamic and connected educational ecosystems. In a university context, this implies a redefinition of teaching as an interactive and multimodal experience, in which bodily practice, critical reflection, data analysis and online collaboration are integrated within interdisciplinary pathways. Vygotsky's (1978) sociocultural perspective also highlights the central role of interaction and the co-construction of knowledge in learning processes, dimensions that collaborative digital environments can amplify. A further theoretical framework is provided by Self-Determination Theory (Deci & Ryan, 2000), which posits that autonomy, a sense of competence and social connection are fundamental conditions for the quality of learning and intrinsic motivation. AI-mediated ecosystems appear to have the potential to support these dimensions through immediate feedback, continuous progress monitoring and the personalisation of learning pathways. Recent studies indeed show how interactive digital platforms can increase engagement, self-efficacy and active participation in university settings (Martin & Bolliger, 2018). In the field of physical education, these aspects are particularly relevant asthe perception ofself-efficacy influences participation, persistence and emotional regulation during physical activity (Bandura, 1997). The COVID-19 pandemic has further

accelerated the digitisation of education, simultaneously highlighting both the potential and the challenges of hybrid learning environments. Whilst emergency remote teaching has demonstrated the possibility of ensuring educational continuity even in laboratory and physical education settings, it has also highlighted risks linked to isolation, reduced physical interaction and cognitive fatigue (Hodges et al., 2020). Contemporary educational research is therefore moving towards more balanced blended and hybrid models, in which physical presence and digital environments are integrated in a pedagogically meaningful way. In this context, adaptive digital ecosystems appear particularly relevant, also in relation to educational inclusion processes. According to Universal Design for Learning (CAST, 2018), the flexible design of learning environments allows for a response to students' different cognitive, emotional and motor needs, reducing barriers to participation. In the field of kinesiology, multimodal feedback tools, video analysis and personalised platforms can facilitate accessibility, participation and educational continuity even in the presence of varying levels of motor competence or specific educational needs. Despite the growing prevalence of digital technologies in sports science, the international literature still highlights a limited number of quasi-experimental mixed-methods studies capable of simultaneously analysing the motivational, embodied, inclusive and relational dimensions associated with hybrid digital ecosystems in university kinesiology education. Much research is in fact focused predominantly on the technical or performance aspects of the technologies, neglecting the way in which artificial intelligence can pedagogically redefine the relationship between the body, digital data and learning. Furthermore, there remains a limited number of studies capable of exploring the role of AI-mediated ecosystems in the development of embodied reflexivity and the professional identity of future kinesiologists within human-centred and inclusive university environments. In light of these considerations,

this study proposes a quasi-experimental mixed-methods investigation aimed at analysing the pedagogical effectiveness of a hybrid digital ecosystem supported by artificial intelligence in university education in sports science. In particular, the research aims to explore how AI-mediated environments can influence motor learning, engagement, motivation, psychophysical well-being and body perception within multimodal and inclusive educational pathways. The theoretical contribution of the study lies in proposing a pedagogical reinterpretation of AI-based ecosystems, not merely as tools for the technical optimisation of performance, but as embodied mediators capable of redefining the relationship between corporeality, digital data, reflexivity and learning in contemporary university contexts. In summary, thisstudy positsthat AI-mediated ecosystems in university kinesiology education should be interpreted not as mere technological infrastructures aimed at performance optimisation, but as embodied pedagogical environments in which the body, digital data, reflexivity and learning are deeply interconnected. From this perspective, wearable devices, adaptive feedback systems, video analysis and collaborative platforms do not operate as tools external to the educational experience, but rather as mediators capable of transforming bodily movement into an experience that is observable, interpretable and reflectively adjustable. Learning thus emerges from the dynamic interaction between sensorimotor experience, digital representation of movement and metacognitive processes of self-regulation. This theoretical framework allows us to move beyond an exclusively technical conception of artificial intelligence applied to sports science, proposing a human-centred perspective in which digital technologies contribute to pedagogically redefining the relationship between corporeality, learning and the construction of professional identity. From this perspective, the research conducted does not merely assess the technical effectiveness of

AI-based technologies in university sports contexts, but aims to explore their transformative potential with regard to embodied processes of learning, reflexivity and educational participation.

2. Research objectives and hypotheses

This study aims to analyse the pedagogical potential of a hybrid digital ecosystem supported by wearable devices, AI-based platforms and online collaborative environments in university education within the field of kinesiology. In particular, the research aims to explore how the integration of physicality, smart technologies and multimodal learning can influence motivational processes, embodied experiences, psychological well-being and inclusive dynamics in contemporary university settings. In line with the theoretical framework outlined – based on the intersection of embodied cognition, digital pedagogy and Self-Determination Theory – the study interprets AI-based systems not as mere tools for the technical optimisation of performance ( ), but as educational mediators capable of redefining the relationship between movement, digital data, reflexivity and learning. The specific objectives of the research are as follows:

1. to assess the impact of the hybrid digital ecosystem on engagement, intrinsic motivation and psychological well-being among university students;
2. to analyse the effects of using AI-based systems on perceptions of motor self-efficacy, body awareness and self-regulation of learning;
3. to qualitatively explore students' perceptions of technology-mediated learning processes and the embodied experiences generated by digital environments;

4. to investigate the inclusive potential of AI-mediated ecosystems in university kinesiology education, with particular reference to participation, accessibility and the personalisation of the learning experience;
5. to understand the role of immediate and adaptive feedback in supporting active participation, embodied reflection and the construction of the professional identity of future kinesiologists.

Based on the international literature and the theoretical framework, the following research hypotheses have been formulated:

- H1: students in the experimental group will demonstrate significantly higher levels of engagement, intrinsic motivation and active participation compared to the control group;
- H2: the use of AI-based technologies will result in a significant improvement in the perception of motor self-efficacy, body awareness and self-regulation of learning;
- H3: hybrid digital environments will foster more positive perceptions regarding educational inclusion, collaborative learning and the accessibility of the learning experience;
- H4: Students involved in the experimental intervention will report significantly higher levels of psychological well-being and satisfaction compared to the control group;
- H5: Qualitative data will confirm the role of AI-mediated ecosystems as facilitators of embodied, immersive, reflective and personalised experiences;

- H6: the integration of physical and digital environments will contribute to the pedagogical redefinition of the relationship between physicality, digital data and professional learning in university kinesiology contexts.

3. Methodology

3.1 Research design

This study adopted a convergent mixed-methods approach with a quasi-experimental pre-test/posttest design comprising an experimental group and a control group. This methodological choice appears particularly well-suited to the study of complex educational contexts, as it allows for the integration of measurable dimensions and relational processes, offering a multi-level interpretation of educational, bodily and inclusive phenomena. In particular, the mixed-methods design was used to analyse the processes of embodied digital learning as phenomena that are simultaneously cognitive, bodily, relational and interpretative, avoiding a reduction of motor learning to mere performance or biomechanical variables. The mixed-methods approach wasselected as it was deemed appropriate for simultaneously analysing the quantitative effects of the intervention on psychological and motivational variables and students' subjective perceptions of the educational experience mediated by digital technologies. According to Creswell and Plano Clark (2018), the integration of quantitative and qualitative data allows us to grasp the complexity of contemporary educational phenomena, moving beyond a reductionist view of learning and valuing both measurable aspects and experiential and relational dimensions. The convergent model adopted involved the parallel collection of quantitative and qualitative data during the same intervention period, followed by a phase of interpretative integration

aimed at identifying convergences, divergences and complementarities among the results that emerged. This methodological approach allowed for the triangulation of data from standardised scales with students' narratives collected through semi-structured focus groups and reflective digital diaries, thereby enhancing the interpretative robustness of the study. From a quantitative perspective, the quasi-experimental design allowed for the comparison of two different training conditions. The experimental group participated in a programme based on hybrid digital ecosystems supported by wearable devices, AI-based motor feedback platforms and online collaborative environments; the control group, on the other hand, followed a traditional laboratory methodology based on direct observation, conventional motor practice and teacher–student feedback not mediated by advanced technologies. The choice of a quasi-experimental design was determined by the impossibility of carrying out a complete randomisation of participants, as the students were already organised into pre-existing university class groups. This approach is, however, widely used in educational research and the sports sciences, particularly in academic contexts where organisational and institutional constraints limit the random allocation of participants (Shadish et al., 2002). To reduce potential threats to internal validity, the two groups were selected on the basis of comparable socio-demographic and academic characteristics, ensuring the absence of statistically significant differences in pre-test scores for the variables under consideration. The pre-test/post-test design allowed us to observe the evolution of the variables under investigation before and after the educational intervention. The pre-test was conducted one week before the start of the experimental activities, whilst the post-test was administered at the end of the ten-week intervention. The qualitative component played a central role in interpreting the quantitative results. In line with the interpretative-constructivist paradigm, the qualitative data were used

to understand the meaning students attributed to the learning experience, their perceptions regarding the use of AI-based technologies, and the relational, physical and emotional dynamics that emerged during the course. Through focus groups and reflective digital diaries, it was possible to explore dimensions that are difficult to detect using standardised tools, such as a sense of immersion, bodily awareness, perception of inclusion, and the construction of professional identity. The processes of embodied learning were operationalised through quantitative and qualitative indicators relating to bodily awareness, motor self-regulation, interpretation of biomechanical feedback, cognitive immersion, reflexivity on movement, and the integration of bodily perception with digital data emerging from the students' narratives. The research also sits within an ecological and systemic perspective on learning, according to which educational processes emerge from the dynamic interaction between the individual, the environment, technologies and social relationships (Bronfenbrenner, 1979). From this perspective, hybrid digital ecosystems are not interpreted as mere technical tools, but as complex pedagogical environments capable of influencing motivation, participation, reflexivity and knowledge construction. Particular attention has been paid to the inclusive aspects of the intervention. The digital environment was designed according to the principles of Universal Design for Learning (CAST, 2018), providing multiple ways to access content, different forms of feedback and strategies for personalising learning. This methodological approach aimed to reduce barriers to participation and to encourage the active involvement of students with different levels of motor skills, cognitive styles and prior experiences. From an operational perspective, the intervention was delivered through a combination of face-toface and online activities, creating a blended and hybrid learning environment consistent with the latest pedagogical perspectives that interpret learning as a multimodal and situated experience

(Kress, 2010). The in-person sessions were mainly dedicated to motor practice, biomechanical analysis of movement and collaborative activities, whilst the digital environments allowed for continuous monitoring, personalised feedback and moments of individual reflection. The total duration of the intervention was ten weeks, with two weekly sessions lasting 90 minutes each. The extended duration of the intervention was also designed to reduce any novelty effects associated with the initial introduction of digital technologies, thereby facilitating a gradual stabilisation of usage practices and participatory dynamics. This timeframe was also determined on the basis of international literature on digital educational interventions in university and motor skills settings, which highlights the need for sufficiently prolonged programmes to produce significant changes in motivational and behavioural dimensions (Bond et al., 2021). To ensure the methodological reliability of the study, the quantitative instruments were selected on the basis of their international validation and their widespread use in educational and psychological research. In parallel, for the qualitative component, systematic data collection and analysis procedures were adopted, following the thematic analysis model proposed by Braun and Clarke (2006). The final integration of quantitative and qualitative data was carried out through a phase of interpretative meta-inference aimed at developing a deeper understanding of the effects produced by hybrid digital ecosystems in university kinesiology education, whilst simultaneously highlighting both the statistical and experiential dimensions of the observed phenomena.

3.2 Participants

The study sample consisted of 96 university students enrolled on the Master's Degree Course in Motor and Sports Sciences at the University of Naples 'Parthenope'. The participants were divided into two groups based on the pre-existing academic structure of the university courses:

- experimental group (n = 48), involved in the intervention based on hybrid digital ecosystems and AI-based systems;
- control group (n = 48), involved in traditional laboratory-based teaching activities without advanced technological mediation.

The mean age of the sample was 23.8 years (SD = 2.1). Before the start of the research, the comparability of the groups was verified with regard to the main socio-demographic and academic variables, with no statistically significant differences found in the pre-test scores. Although the sample was limited to a single Italian university context, the relative academic homogeneity of the participants allowed for a more rigorous control of potentially interfering contextual variables.

The inclusion criteria were:

- regular enrolment on a Master's degree programme;
- minimum attendance of 75% of scheduled activities;
- absence of disabling motor disorders;
- informed consent to participate in the study.

The exclusion criteria included:

- previous advanced professional experience in the use of AI-based systems applied to movement;
- absences exceeding 25% of activities;
- failure to complete the assessment tools in full;
- clinical conditions incompatible with the planned physical activity.

All participants were informed about the research objectives, data collection methods and the processing of personal information. Participation in the study was voluntary and in accordance with the ethical principles of educational and university research.

3.3 Intervention

The educational intervention lasted a total of ten weeks and was designed according to a blended and hybrid learning model aimed at integrating physical activity, digital technologies and reflective processes within a human-centred pedagogical ecosystem. The duration of the intervention is consistent with the international literature on digital and physical educational environments in higher education, which highlights that programmes lasting between 8 and 12 weeks are sufficiently long to produce significant changes in motivational, behavioural and relational dimensions (Bond et al., 2021; Casey et al., 2021). The programme consisted of two weekly sessions, each lasting 90 minutes, for a total of 30 hours of structured activities. Each session involved a combination of in-person motor practice, the use of AIbased platforms, collaborative online activities, and moments of individual and shared reflection. This methodological approach is consistent with the latest pedagogical perspectives

that interpret learning as a multimodal, situated and relational experience (Kress, 2010). The experimental group took part in a training programme based on the integrated use of wearable devices for biomechanical monitoring, AI-based motor feedback platforms, online collaborative environments, motion video analysis systems and personalised dashboards for the self- tion of motor learning. The intervention was designed in accordance with the principles of Universal Design for Learning (CAST, 2018), providing for different modes of access to content, strategies for personalising feedback, and inclusive teaching configurations aimed at fostering active participation, self-regulation and student engagement. From a pedagogical perspective, the intervention was constructed from an embodied and socioconstructivist perspective, interpreting digital technologies not merely as tools for the technical optimisation of performance, but as educational mediators capable of supporting reflexivity, bodily awareness and the collaborative construction of knowledge (Wilson & Golonka, 2013; Vygotsky, 1978). From this perspective, AI-based systems were used to amplify processes of perception, feedback and self-regulation, avoiding exclusively quantitative or performance-based approaches. Digital technologies were therefore integrated as tools for embodied pedagogical mediation, aimed at supporting reflective, interpretative and self-regulatory processes rather than merely optimising motor performance.

- Phase 1 – Technological familiarisation and baseline (weeks 1–2): The first two weeks were devoted to familiarisation with digital tools and the development of the basic skills necessary for the informed use of AI-based technologies. Students took part in introductory sessions on the use of wearable devices, the interpretation of biomechanical data, and the main functions of motion tracking and motor monitoring

platforms. During this phase, baseline measurements were taken for the motor, motivational and psychological variables investigated in the study. In parallel, students undertook initial activities involving bodily self-observation and analysis of motor movements through video recordings and digital feedback systems. The literature highlights how the initial phases of technological familiarisation are fundamental for reducing extraneous cognitive load and promoting a more conscious use of digital environments (Sweller, 2011). Furthermore, in university settings, the gradual introduction of technologies appears to facilitate a sense ofself-efficacy, engagement and a reduction in anxiety associated with innovative tools (Martin & Bolliger, 2018).

- Phase 2 – Embodied training and AI-mediated feedback (weeks 3–6): The second phase formed the core of the experimental programme. During this period, students took part in motor skills workshops supported by biomechanical monitoring systems and AI-based platforms providing immediate and adaptive feedback. The activities included coordination and motor control exercises, balance and proprioception tasks, simulations of sporting tasks, individual and collaborative video analysis, and real-time augmented feedback activities. The wearable devices used enabled the monitoring of parameters such as heart rate, acceleration, range of motion, posture, reaction times and motor load. The data collected was processed by AI-based platforms via customised dashboards that provided immediate feedback on the quality of motor execution and the progression of individual performance. Students were thus able to monitor their own progress, compare different motor patterns and identify any technical or postural issues. According to the international

literature, immediate feedback is one of the most effective elements in motor learning processes, as it promotes self-regulation, body awareness and skill consolidation (Wulf & Lewthwaite, 2016). The use of artificial intelligence also allows for adaptive personalisation of feedback, supporting motivation, a sense of perceived competence and active participation (Holmes et al., 2022). From a pedagogical perspective, this phase was designed according to the principles of embodied cognition, interpreting movement as a situated and relational cognitive experience rather than as a mere technical execution (Wilson & Golonka, 2013). The activities therefore aimed to foster integration between bodily perception, critical reflection and the interpretation of biomechanical data. Particular attention was paid to observing the ways in which students reinterpreted their own movement through the interaction between direct bodily experience and the digital representation of the motor gesture.

- Phase 3 – Digital peer learning and collaborative learning (weeks 7–8): The third phase focused on developing collaborative and reflective processes through shared digital environments. Students were organised into small working groups and took part in peer assessment, co-analysis of motor movements, collaborative discussion of biomechanical data and motor problemsolving. The online platforms enabled the sharing of videos, biomechanical graphs, feedback and personal reflections, fostering social learning processes and the collaborative construction of knowledge. In this context, the digital environments functioned as ecosystems for the co-construction of motor and professional experience. The literature highlights how peer learning can promote motivation, participation and the development

of metacognitive skills in university settings (Topping, 2005). Furthermore, in the motor domain, shared reflection on movement appears to facilitate body awareness, emotional regulation and reflective learning (Casey et al., 2021). This approach also appears consistent with Vygotsky's (1978) socio-constructivist perspective, according to which learning emerges through social interaction, cultural mediation and collaboration.

- Phase 4 – Reflective digital journaling and consolidation (weeks 9–10): The final phase of the project focused on reflective processes and the consolidation of learning. The students kept weekly digital reflective diaries designed to document their bodily sensations, the difficulties they encountered, the emotions associated with the activities, their perceived progress, and their relationship with the digital technologies used. Reflective journaling was used as a tool for metacognition and self-regulation, in line with the literature highlighting the role of critical reflection in the construction of professional identity and in transformative learning processes (Schön, 1983). Particular attention was also paid to perceptions regarding inclusion, participation and the personalisation of the training experience. Over the past few weeks, students have also participated in semi-structured focus groups aimed at collectively discussing the educational experience and the pedagogical implications of using artificial intelligence in kinesiology university settings.

Organisation of the sessions

Each 90-minute session followed a relatively consistent methodological structure divided into four main stages:

1. an initial briefing and warm-up phase;
2. a central practical activity supported by AI-based technologies;
3. collaborative data analysis and shared feedback;
4. final reflection and completion of reflective journals.

This structure was designed to foster a balance between physical, cognitive and reflective dimensions, avoiding a purely technical use of digital technologies and instead promoting embodied, collaborative and participatory experiences.

Control group

The control group undertook traditional laboratory activities based on lectures, direct observation by the lecturer, conventional practical exercises and verbal feedback not mediated by advanced digital technologies. The motor activities undertaken were equivalent in content and objectives to those proposed to the experimental group, in order to reduce possible biases linked to differences in the tasks assigned. Both groups were supervised by the same university lecturers with the aim of reducing possible teacher effects associated with different teaching styles or relational approaches. However, the control group did not use wearable devices, biomechanical dashboards, online collaborative platforms or AI-based adaptive feedback systems. The comparison between the two training conditions therefore allowed for an analysis of the specific contribution of hybrid digital ecosystems and artificial intelligence compared to traditional teaching methodologies in university education within the field of kinesiology.

4. Tools

4.1 Quantitative tools

The quantitative component of the research was designed to assess the main psychological, motivational and experiential dimensions involved in the educational intervention. The selected instruments were identified on the basis of their international validation, their widespread use in educational and psychological research, and their consistency with the study's theoretical framework. The instruments were selected in order to simultaneously capture the motivational, bodily, relational and reflective dimensions associated with the processes of embodied digital learning.

Intrinsic Motivation Inventory (IMI)

The Intrinsic Motivation Inventory (IMI) was used to assess intrinsic motivation; this is a multidimensional tool widely employed in studies relating to Self-Determination Theory and processes of motivated learning. The scale allows for the analysis of different dimensions of the motivational experience, including interest/pleasure, perceived competence, value attributed to the activity, and perceived engagement. The IMI was selected as it is particularly consistent with the objective of analysing the effects of AImediated ecosystems on intrinsic motivation, self-regulation and perceived personal efficacy in university kinesiology contexts (Deci & Ryan, 2000).

Utrecht Work Engagement Scale for Students (UWES-S)

Academic engagement was assessed using the Utrecht Work Engagement Scale for Students(UWESS), a version of the broader Utrecht Work Engagement Scale adapted for the university context. The scale measures three fundamental dimensions of engagement in study:

- vigor;
- dedication;
- absorption.

The use of the UWES-S is consistent with the growing focus in the literature on the role of engagement in university learning processes mediated by digital technologies and blended environments (Bond et al., 2021).

Physical Activity Enjoyment Scale (PACES)

The Physical Activity Enjoyment Scale (PACES), a widely used tool in research on physical and sporting activities, was employed to assess the enjoyment perceived during physical activity. The scale measures the level of enjoyment associated with the physical and motor experience, a dimension considered particularly relevant to participation, persistence and motivation in physical activity. In the present study, PACES was used to analyse the impact of hybrid digital environments on the subjective quality of the motor experience.

Psychological Well-Being Scale (PWBS)

Psychological well-being was assessed using the Psychological Well-Being Scale (PWBS), a multidimensional tool designed to analyse positive psychological functioning.

The scale allows for the exploration of different dimensions of well-being, including:

- autonomy;
- personal growth;
- positive relationships;
- self-acceptance;
- sense of purpose;
- mastery of the environment.

The inclusion of the PWBS is consistent with the study's objective of analysing not only performance or motivational aspects, but also the psychological and relational implications associated with the use of AI-based ecosystems in university education.

Reliability of the instruments

Internal reliability was assessed for all psychometric scales used by calculating Cronbach's alpha. In line with methodological literature, values above .70 were considered indicative of adequate internal consistency (Nunnally & Bernstein, 1994). Furthermore, the integration of the different psychometric scales allowed for the development of a multidimensional understanding of the educational experience, avoiding interpretations of the effects of AI-based technologies that were exclusively performance-oriented or technocentric.

4.2 Qualitative tools

The qualitative component of the research aimed to explore students' subjective perceptions of the educational experience mediated by digital technologies and the embodied processes that emerged during the training programme. In line with the interpretative-constructivist paradigm, qualitative tools were used to explore dimensions that are difficult to capture using standardised scales, such as bodily experiences, inclusive perceptions, experiential immersion and the construction of professional identity. The combination of focus groups and reflective digital diaries enabled the development of a form of methodological triangulation aimed at enhancing the interpretative depth, credibility and temporal continuity of the qualitative analysis.

Semi-structured focus groups

At the end of the intervention, semi-structured focus groups were conducted with students from the experimental group. This methodology was selected as it is particularly suited to exploring relational dynamics, shared perceptions and processes of co-construction of meaning in educational contexts. The focus groups examined in particular:

- overall perception of the training experience;
- bodily experiences and processes of motor awareness;
- perceptions regarding inclusion and participation;
- the relationship between AI-based technologies and motor learning;
- the role of digital feedback in self-regulation processes;
- pedagogical implications of the use of hybrid digital ecosystems.

The discussions were audio-recorded, transcribed in full and subsequently anonymised prior to analysis.

Reflective Digital Diaries

Throughout the experimental process, students compiled reflective digital diaries via a dedicated online platform. The reflective diaries were used as tools for metacognition and self-observation, in line with the literature highlighting the role of critical reflection in transformative learning processes and the construction of professional identity (Schön, 1983). In the reflective journals, students were invited to describe:

- bodily sensations;
- emotions associated with the activities;
- difficulties encountered;
- perceived progress;
- experiences of collaboration;
- relationship with AI-based feedback;
- processes of reinterpreting movement through biomechanical data and digital feedback;
- perception of inclusion and participation.

The use of reflective diaries enabled the collection of longitudinal data relating to the evolution of the training experience during the different phases of the intervention.

Qualitative analysis

Qualitative analysis was carried out using thematic analysis according to the model proposed by Braun and Clarke (2006). This methodological approach was selected as it is particularly suited to identifying recurring patterns, shared

meanings and interpretative dimensions emerging from the narrative data. Throughout the entire analytical process, the researchers maintained a reflective approach aimed at reducing possible interpretative biases arising from their involvement in the educational context.

4.3 Data analysis

The data analysis was structured around an integrated mixed-methods approach designed to combine quantitative and qualitative evidence in order to develop a multi-level understanding of the effects produced by the intervention based on hybrid digital ecosystems and AI-based technologies. This approach is consistent with the latest methodological perspectives on the study of complex educational contexts, in which the integration of numerical and narrative data allows for the simultaneous capture of both measurable and experiential dimensions of the phenomena under analysis (Creswell & Plano Clark, 2018). The quantitative phase aimed to assess the effects of the intervention on the main variables under consideration – engagement, intrinsic motivation, psychological well-being and perception of the motor experience – through descriptive and inferential statistical procedures. In parallel, the qualitative component focused on exploring students' subjective perceptions regarding embodied learning processes, the use of AI-based technologies, and the inclusive dynamics that emerged during the training programme.

4.4 Quantitative analysis

The quantitative analysis was carried out using IBM SPSS Statistics version 29. In a preliminary phase, data cleaning procedures were conducted and the completeness of the datasets was verified in order to identify any missing data,

outliers or statistical anomalies. Questionnaires with more than 10% of items missing were excluded from the final analysis, whilst residual missing data were handled by imputing the subject's mean, in line with methodological guidelines in the psychometric literature (Tabachnick & Fidell, 2019). Initially, descriptive statistics were calculated for the main variables under investigation, including mean (M), standard deviation (SD), minimum and maximum values, skewness and kurtosis. These procedures allowed for an initial exploration of the data distribution and preliminary differences between the experimental group and the control group. Subsequently, the Shapiro-Wilk normality test was performed, considered particularly suitable for small to medium-sized samples (Field, 2018), together with Levene's test to verify the homogeneity of variances between the groups. To verify the possible presence of initial differences in pre-test scores between the experimental group and the control group, the t-test for independent samples was used. The absence of statistically significant differences was interpreted as an indicator of substantial initial equivalence between the two experimental conditions. In order to analyse the effects of the intervention over time, a repeated measures ANOVA was subsequently carried out, a technique particularly suited to quasi-experimental longitudinal designs as it allows for the simultaneous analysis of:

- the effect of time;
- the effect of group;
- the time × group interaction.

The time × group interaction represented the main indicator of the effectiveness of the experimental intervention. Where statistically significant interactions were found, post-hoc analyses with Bonferroni correction were carried out in order to identify the specific differences between the conditions

under consideration. The choice of repeated measures ANOVA is consistent with the methodological literature on educational and psychological research, as it allows the evolution of variables over time to be observed whilst reducing the risk of error associated with inter-individual differences (Girden, 1992). To assess the practical significance of the results, the effect size was also calculated using Cohen's d. In accordance with Cohen (1988), the values were interpreted according to the following thresholds:

- $d = 0.20 \rightarrow$ small effect;
- $d = 0.50 \rightarrow$ medium effect;
- $d \geq 0.80 \rightarrow$ large effect.

The use of effect size is now strongly recommended in educational research and the sports sciences, as it allows one to move beyond an exclusively dichotomous interpretation of statistical significance and to highlight the practical and pedagogical significance of the results (Lakens, 2013). Particular attention was also paid to the educational relevance of the observed effects, avoiding exclusively statistical interpretations of the results. The level of statistical significance was set at $p < .05$. However, in order to avoid reductionist interpretations of the results, the quantitative analysis was accompanied by an integrated assessment of effect sizes, confidence intervals and convergence with the qualitative data. Finally, Cronbach's alpha was calculated for each psychometric scale used in order to verify its internal reliability. Values above .70 were considered satisfactory according to the methodological guidelines of Nunnally and Bernstein (1994).

4.5. Qualitative analysis

Qualitative analysis was carried out on data from semi-structured focus groups and the digital reflective diaries completed by students during the intervention. This methodological component aimed to explore subjective perceptions regarding the educational experience, embodied learning processes, and the role of AI-based technologies in university kinesiology settings. The focus groups were recorded, transcribed in full and anonymised prior to analysis. Similarly, the reflective journals were exported from the digital platform and organised into a qualitative database. The entire text corpus was subsequently analysed using thematic analysis according to the model proposed by Braun and Clarke (2006). The analytical procedure was developed through three main levels of coding:

- open coding;
- axial coding;
- selective coding.

During the open coding phase, the researchers conducted an in-depth reading of the textual material to identify recurring units of meaning, expressed emotions and relevant descriptions relating to the students' lived experience. The preliminary codes mainly concerned perceptions of AI-based feedback, bodily awareness, motivation, participation, perceived difficulties, inclusion and collaborative learning. Subsequently, through axial coding, the emerging codes were progressively aggregated into broader interpretative categories, analysing the relationships between the cognitive, bodily, emotional and relational dimensions of the educational experience. For example, references to immediate feedback, progress monitoring, self-regulation and perception of competence were grouped into the macrocategory 'enhanced motor

awareness', whilst codes relating to peer feedback, online collaboration and active participation were integrated into the category 'digital collaborative ecosystem'. The final phase of selective coding enabled the identification of the central categories and the construction of an overall interpretative framework of the learning experience. The main macrocategories that emerged concerned:

- embodied digital learning;
- self-regulation and augmented feedback;
- inclusion and participation;
- construction of professional identity;
- immersion and motivation.

In order to enhance the reliability and credibility of the qualitative analysis, the coding was carried out independently by two researchers with expertise in qualitative methodology. Any interpretative discrepancies were discussed collectively until a shared agreement was reached. This investigator triangulation procedure represents a well-established strategy for enhancing reliability and credibility in qualitative research (Lincoln & Guba, 1985).

4.6. Integration of quantitative and qualitative data

The final phase of the analysis involved the integration of quantitative and qualitative results through a process of convergent triangulation aimed at developing a deeper understanding of the effects produced by hybrid digital ecosystems in university kinesiology education. The integration procedure allowed for the comparison of:

- statistical data;
- student narratives;
- evidence emerging from reflective journals;
- interpretative dynamics that emerged in the focus groups.

The integration of the data made it possible to highlight convergences, divergences and complementarities between the numerical dimension and lived experience. In particular, the quantitative results relating to the increase in engagement, motivation and psychological well-being were interpreted in the light of the qualitative perceptions of immersion, personalisation, bodily awareness and participation that emerged in the students' narratives. This methodological integration appears consistent with the most recent epistemological perspectives on complex educational research, according to which understanding educational phenomena requires the interaction of empirical evidence, contextual interpretation and subjective experience. From this perspective, AI-mediated ecosystems are interpreted not merely as technological tools, but as embodied pedagogical environments capable of redefining the relationship between corporeality, reflexivity and learning in contemporary university contexts.

5. Results

5.1 Quantitative results

Preliminary analyses of pre-test scores revealed no statistically significant differences between the experimental group and the control group in the variables investigated ($p > .05$), confirming the groups' initial substantial equivalence. Repeated measures ANOVAs revealed statistically significant time

× group interactions in the main dimensions considered. The most substantial increases were observed in the experimental group, whilst the control group showed limited and generally non-significant changes.

Academic engagement (UWES-S)

The experimental group recorded a significant increase in levels of academic engagement compared to the control group.

Table 1. *Academic engagement (UWES-S)*

Group	Pre-test M (SD)	Post-test M (SD)	p	Cohen's d
Experimental	3.12 (0.51)	4.31 (0.48)	< .001	0.84
Control	3.08 (0.49)	3.29 (0.52)	.117	0.18

In the experimental group, increases were observed in the dimensions of vigour, dedication and absorption, whilst the control group showed limited changes.

Intrinsic Motivation (IMI)

Scores on the Intrinsic Motivation Inventory (IMI) showed statistically significant increases in the experimental group.

Table 2. *Intrinsic motivation (IMI)*

Group	Pre-test M (SD)	Post-test M (SD)	p	Cohen's d
Experimental	3.41 (0.58)	4.46 (0.44)	< .001	0.79
Control	3.38 (0.61)	3.57 (0.55)	.142	0.16

The most marked increases were observed in interest/enjoyment, perceived competence, value attributed to the activity and perceived autonomy.

Motor enjoyment (PACES)

The pleasure perceived during physical activity, measured using PACES, also showed significant increases in the experimental group.

Table 3. *Motor enjoyment (PACES)*

Group	Pre-test M (SD)	Post-test M (SD)	p	Cohen's d
Experimental	3.56 (0.63)	4.62 (0.39)	.002	0.71
Control	3.49 (0.60)	3.71 (0.58)	.126	0.19

No statistically significant changes were observed in the control group.

Psychological well-being (PWBS)

With regard to psychological well-being, the experimental group showed significant increases in various dimensions of PWBS.

Table 4. *Psychological well-being (PWBS)*

Dimension	Group	Pre-test M (SD)	Post-test M (SD)	p
Autonomy	Experimental	3.28 (0.55)	4.17 (0.47)	< .01
Autonomy	Control	3.31 (0.52)	3.46 (0.50)	.173
Personal growth	Experimental	3.44 (0.59)	4.39 (0.42)	< .01
Personal growth	Control	3.39 (0.56)	3.58 (0.51)	.148

The most significant increases in the experimental group were in autonomy, personal growth and perceived efficacy.

Motor self-efficacy and body awareness

Analyses relating to motor self-efficacy revealed statistically significant increases in the experimental group

Table 5. *Motor self-efficacy*

Group	Pre-test M (SD)	Post-test M (SD)	p	Cohen's d
Experimental	3.19 (0.54)	4.41 (0.46)	< 0.001	0.89
Control	3.21 (0.57)	3.48 (0.53)	.104	0.22

In the experimental group, the increases concerned:

- perceived ability to correct motor movements;
- interpretation of biomechanical feedback;
- monitoring of progress;
- adaptation of motor strategies.

Summary of quantitative results

Table 6. *General summary of quantitative results*

Variable	Outcome of experimental group	Significance
Engagement (UWES-S)	Significant increase	$p < .001$
Intrinsic motivation (IMI)	Significant increase	$p < .001$
Physical enjoyment (PACES)	Significant increase	$p = .002$
Psychological well-being (PWBS)	Significant improvement	$p < .01$
Motor self-efficacy	Significant increase	$p < .001$

Overall, the experimental group showed statistically significant increases in all the main variables considered, with effect sizes ranging from moderate to high. The control group showed limited and predominantly non-significant changes.

5.2 Qualitative results

Analysis of the semi-structured focus groups and reflective digital diaries revealed four emerging macro-categories:

1. increased body awareness;
2. personalised learning;
3. immersive engagement;
4. inclusion and accessibility.

The categories were identified using open coding, axial coding and selective coding procedures according to Braun and Clarke (2006).

Increased body awareness

Participants described biomechanical dashboards and digital feedback as useful tools for monitoring movement and correcting motor errors. The most frequently recurring themes concerned:

- immediate understanding of errors;
- greater attention to posture;
- self-monitoring of performance;
- integration of body awareness and biomechanical data.

Representative quotes

“I used to perform the movement without thinking too much about it. With digital feedback, I started to really understand how I was moving.”

“Seeing technical errors immediately helped me correct them more quickly.”

“The dashboards made me more aware of my body.”

Table 7. *Emerging themes – Increased body awareness*

Sub-theme	Qualitative evidence
Immediate feedback	Rapid understanding of motor errors
Visualisation of movement	Greater biomechanical awareness
Body self-regulation	Ability to correct movements independently
Body-data connection	Interpretation of movement via dashboards and graphs

Personalised learning

Students described AI-based platforms as adaptive and flexible in relation to individual needs. The most common themes included:

- personalised feedback;
- autonomy in study;
- individual management of learning time;
- reduction in performance anxiety.

Representative quotes

"I felt freer to work on my weaknesses."

"The system seemed to adapt to my pace and my needs."

"I felt as though I was building my own personal learning path."

Table 8. *Emerging themes – Personalisation of learning*

Sub-theme	Qualitative evidence
Adaptive feedback	Pathways tailored to individual needs
Autonomy	Greater personal control over learning
Flexibility	Continuous access to activities
Reduced anxiety	Less pressure during motor performance

Immersive engagement

Students reported high levels of engagement during activities supported by digital technologies. The themes that emerged included:

- cognitive immersion;
- emotional engagement;
- motivational continuity;
- multimodal integration of activities.

Representative quotes

“The lessons flew by because I was completely immersed.”

“Receiving data and feedback in real time made everything more interesting.”

“I felt more active and involved compared to traditional lessons.”

Table 9. *Emerging themes – Immersive engagement*

Sub-theme	**Qualitative evidence**
Emotional engagement	Experience perceived as dynamic and stimulating
Cognitive immersion	High concentration during activities
Sustained motivation	Greater persistence in study and practice
Multimodality	Integration of body, data and digital interaction

Inclusion and accessibility Students highlighted the role of digital environments in promoting participation and mutual support. The most frequently mentioned themes concerned:

- reducing the fear of judgement;
- participation of the most insecure students;
- peer collaboration;
- flexibility in learning methods.

Representative quotes

“I felt less judged compared to traditional exercises.”

“Working online made it easier to engage with others.”

“Even those who were more insecure participated more.”

Table 10. Emerging themes –Inclusion and accessibility

Sub-theme	**Qualitative evidence**
Reduced anxiety	Less fear of judgement during activities
Inclusive participation	Involvement of even the most insecure students
Peer support	Collaboration and mutual support
Accessibility	More flexible learning times and methods

5.3. Integration of quantitative and qualitative results

The integration of quantitative and qualitative data revealed converging patterns between psychometric results and students’ experiential perceptions.

In particular:

- increases in UWES-S scores are consistent with themes relating to cognitive immersion and active participation;
- improvements in IMI align with perceptions of autonomy, personalisation and adaptive feedback;
- increases in motor self-efficacy are consistent with themes relating to movement monitoring and bodily self-regulation;
- the results relating to the PWBS align with qualitative evidence regarding reduced anxiety, peer support and inclusive participation.

Overall, the integration of the data highlights how hybrid digital ecosystems have fostered learning experiences characterised by greater engagement, personalisation, body awareness and inclusion.

6. Discussion

The results of this study highlight that the integration of hybrid digital ecosystems and AI-based technologies into university education in the field of kinesiology is associated with significant improvements in the motivational, participatory, embodied and inclusive dimensions of learning. The convergent mixed-methods approach allowed these results to be interpreted through the integration of quantitative evidence and experiential data, reducing the risk of over-interpretation and strengthening the consistency between empirical findings and theoretical implications. From a quantitative perspective, the experimental group showed statistically significant increases in levels of academic engagement, intrinsic motivation, enjoyment of movement, psychological wellbeing and motor self-efficacy, with effect sizes ranging from moderate to high. In contrast, the control group showed limited and predominantly non-significant changes. These results suggest that AImediated environments may support more participatory and self-regulated learning processes in contemporary university settings, in line with the literature on student-centred digital environments (Bond et al., 2021; Martin & Bolliger, 2018). In particular, the observed increase in levels of academic engagement appears consistent with the qualitative themes relating to cognitive immersion, motivational continuity and active participation that emerged from the focus groups and reflective digital diaries. Students frequently described AImediated activities as more dynamic and engaging than traditional lectures, highlighting how immediate feedback, continuous monitoring and multimodal integration

fostered more intense and sustained participation. This evidence is consistent with the multidimensional perspective on engagement proposed by Schaufeli et al. (2002), according to which vigour, dedication and absorption represent central components of academic engagement. The findings regarding intrinsic motivation also appear to be supported by the convergence of quantitative and qualitative data. The increases observed in IMI are in fact consistent with students' accounts regarding personalised feedback, autonomy in learning and perceived competence. AI-based platforms appear to have fostered educational conditions capable of supporting self-regulation and personal agency, dimensions considered central by Self-Determination Theory (Deci & Ryan, 2000). However, the results of this study do not allow us to attribute these effects exclusively to the presence of the technology itself; it seems plausible, instead, that the motivational improvement was mediated by the combination of adaptive feedback, the collaborative structure of the activities, and pedagogical design geared towards active participation. One of the most significant findings concerns motor self-efficacy and body awareness. The experimental group showed significant increases in their perceived ability to interpret biomechanical feedback, independently correct technical movements and monitor their own progress. In parallel, the qualitative data highlighted recurring themes relating to movement visualisation, bodily selfregulation and the integration of sensorimotor perception with digital data. In this sense, the results suggest that biomechanical dashboards and augmented feedback can support forms of embodied reflection on movement. This interpretation appears consistent with the embodied cognition paradigm, according to which learning and cognition emerge from the dynamic interaction between body, environment and perception (Wilson & Golonka, 2013). In the present study, AI-based ecosystems appear to have facilitated processes in which the motor movement is progressively transformed into an observable, interpretable and

reflectively adjustable experience. It is, however, important to emphasise that the data collected allow us to observe perceptions of greater bodily awareness and self-regulation, but do not permit us to definitively assert structural changes in embodied cognitive processes. From this perspective, the theoretical contribution of the study lies primarily in suggesting a possible reflective pedagogical function of AI-mediated technologies in university motor contexts. Qualitative evidence regarding cognitive immersion, multimodality and emotional engagement also suggests that the integration of motor practice, graphical visualisation, adaptive feedback and online collaboration may foster learning experiences characterised by a high degree of integration between bodily, cognitive and relational dimensions. These findings are consistent with the multimodal perspectives on learning proposed by Kress (2010), according to whom contemporary digital environments support educational processes based on the interaction between different modes of perception and communication. The inclusive dimension that emerged from the qualitative analysis also appears particularly significant. Students frequently described digital environments as less judgemental, more accessible and more flexible than traditional laboratory activities. In particular, the ability to access personalised feedback and the presence of online collaborative dynamics appear to have encouraged participation even among students with lower motor confidence. These findings are consistent with the principles of Universal Design for Learning (CAST, 2018), according to which flexibility, differentiation and personalisation are central elements for promoting inclusion and participation. From a social constructivist perspective, collaborative platforms appear to have functioned as environments for social mediation in which peer feedback and shared discussion of movement have fostered processes of co-construction of knowledge. In this sense, digital technologies do not appear to have diminished the relational dimension of

learning, but rather to have redefined the modes of interaction, in line with Vygotsky's (1978) perspective. Despite the positive results that have emerged, the evidence must be interpreted with caution. The quasi-experimental design does not allow for the complete exclusion of possible confounding factors, including the teacher effect, the novelty effect, and motivational dynamics linked to the introduction of innovative tools. Although the groups had comparable initial conditions and the activities were equivalent in terms of content and objectives, some of the observed effects may have been influenced by the high perception of innovation associated with AI-based technologies. Further reasons for caution relate to the relatively short duration of the intervention and the specificity of the university context analysed, which limit the generalisability of the results. Furthermore, the qualitative evidence is based on self-reported and narrative data, which allow for the exploration of subjective perceptions and experiences but do not permit the establishment of definitive causal relationships. The theoretical and pedagogical implications of the study therefore seem to concern primarily the role of educational design in the use of intelligent technologies. The results suggest, in fact, that the effectiveness of AI-based ecosystems does not depend exclusively on the technological component, but on the ability to integrate feedback, reflexivity, embodiment and participation within pedagogically structured environments. In the absence of such educational mediation, the risk lies in reducing the bodily experience to mere quantitative data or measurable performance (Evans et al., 2021). From this perspective, the present study argues for the need to develop critical and human-centred approaches to the use of artificial intelligence in university sports science. AI-based technologies appear to acquire real pedagogical significance when used to support bodily awareness, selfregulation, inclusion and reflective learning, rather than as mere tools for technical-performance monitoring.

7. Conclusion

This study highlights that the integration of hybrid digital ecosystems and AI-based technologies into university-level kinesiology education is associated with significant improvements in levels of academic engagement, intrinsic motivation, enjoyment of physical activity, psychological well-being and motor self-efficacy. The convergence of quantitative and qualitative data also suggests that such environments may foster perceptions of greater body awareness, personalised learning, collaborative participation and inclusion. The quantitative results showed significant increases in the experimental group across all key variables investigated, whilst the control group showed limited and predominantly non-significant changes. In parallel, the qualitative evidence emerging from focus groups and from reflective digital diaries highlighted recurring themes relating to adaptive feedback, cognitive immersion, bodily selfregulation, reduced performance anxiety and greater perceived accessibility of digital environments. Overall, these results suggest that AI-mediated ecosystems can support forms of learning that are more multimodal, reflective and student-centred. In particular, the evidence suggests that digital technologies, when integrated into a structured pedagogical design, can help make movement more observable, interpretable and reflectively analysable by students. The study's main theoretical contribution concerns the possibility of interpreting AI-based technologies not exclusively as tools for technical-performance monitoring, but as pedagogical mediators capable of supporting embodied processes of self-regulation and reflection on movement. The qualitative findings regarding enhanced body awareness, the integration of sensorimotor perception and biomechanical data, and autonomous monitoring of motor gestures appear consistent with the perspectives of embodied

cognition and multimodal learning. However, the results must be interpreted with caution. The quasi-experimental design and the specificity of the context analysed do not allow for definitive generalisations. Furthermore, some of the observed effects may have been influenced by the novelty effect, initial motivational dynamics, or contextual factors that were not fully controllable. Similarly, the qualitative data allow for an indepth exploration of subjective perceptions and experiences, but do not permit definitive causal inferences regarding embodied cognitive processes. From a pedagogical perspective, the study suggests that the effectiveness of AI-based ecosystems depends to a large extent on the quality of the educational mediation that guides their use. Dialogic feedback, collaboration, personalisation and reflexivity emerge as central elements for digital technologies to support meaningful learning, inclusion and active participation. In this sense, the results support the need to move beyond purely technical approaches to digital innovation in sports science. The educational implications are particularly relevant for the design of future university curricula in the field of kinesiology. Contemporary professional transformations indeed require integrated skills of a biomechanical, pedagogical, digital and ethical nature.

From this perspective, university education could progressively emphasise:

- digital literacy applied to sports science;
- critical interpretation of biomechanical data;
- the design of embodied and inclusive environments;
- collaborative and reflective skills;
- ethical awareness regarding the use of artificial intelligence.

At the same time, important ethical issues emerge regarding privacy, the management of bodily data, algorithmic transparency and the risk of performative reductionism, consistent with the findings of Holmes et al. (2022). These aspects suggest the need to develop human-centred models capable of preserving the centrality of the educational relationship and the human dimension of learning. From a methodological perspective, this study contributes to the literature through an integrated mixed-methods approach that has enabled the triangulation of statistical evidence and experiential e s, offering a multi-level understanding of the relationship between AI-based technologies, corporeality and university education.

Future research could explore:

- the longitudinal effects of immersive digital ecosystems;
- the role of individual variables such as digital literacy, motor background and gender differences;
- the integration of virtual reality, augmented reality and generative AI in embodied contexts;
- the ethical implications of automation in educational processes;
- the relationship between different pedagogical models and the use of smart technologies.

Overall, this study suggests that the educational potential of artificial intelligence in university sports science does not depend simply on the introduction of innovative tools, but on the ability to design learning ecosystems in which digital technologies, physicality, reflexivity and inclusion can be integrated in a pedagogically meaningful way

References

Baca, A., & Kornfeind, P. (2012). Rapid feedback systems for elite sports training. *IEEE Pervasive Computing, 11*(4), 70–76.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. W.H. Freeman.

Bond, M., Bedenlier, S., Marín, V. I., & Händel, M. (2021). Emergency remote teaching in higher education: Mapping the first global online semester. *International Journal of Educational Technology in Higher Education, 18*(1), 1–24.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101.

Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design*. Harvard University Press.

CAST. (2018). *Universal Design for Learning Guidelines version 2.2*. CAST. http://udlguidelines.cast.org

Casey, A., Goodyear, V. A., & Armour, K. M. (2021). *Digital technologies and learning in physical education: Pedagogical cases*. Routledge.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research* (3rd ed.). Sage.

Crompton, H., & Burke, D. (2023). Artificial intelligence in higher education: The state of the field. *International Journal of Educational Technology in Higher Education, 20*(1), 1–22.

Deci, E. L., & Ryan, R. M. (2000). The “what” and “why” of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*(4), 227–268.

Evans, J., Davies, B., & Rich, E. (2021). *The body, embodiment and education: An interdisciplinary approach*. Routledge.

Field, A. (2018). *Discovering statistics using IBM SPSS statistics* (5th ed.). Sage.

Girden, E. R. (1992). *ANOVA: Repeated measures*. Sage.

Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, A. (2020). The difference between emergency remote teaching and online learning. *Educause Review, 27*, 1–12.

Holmes, W., Bialik, M., & Fadel, C. (2022). *Artificial intelligence in education: Promises and implications for teaching and learning* (2nd ed.). Center for Curriculum Redesign.

Johnson, M. (2017). *Embodied mind, meaning, and reason: How our bodies give rise to understanding*. University of Chicago Press.

Kearney, M., Schuck, S., Burden, K., & Aubusson, P. (2012). Viewing mobile learning from a pedagogical perspective. *Research in Learning Technology, 20*, 1–17.

Kress, G. (2010). *Multimodality: A social semiotic approach to contemporary communication*. Routledge.

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. *Frontiers in Psychology, 4*, 863.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Sage.

Martin, F., & Bolliger, D. U. (2018). Engagement matters: Student perceptions on the importance of engagement strategies in the online learning environment. *Online Learning, 22*(1), 205–222.

Merleau-Ponty, M. (1962). *Phenomenology of perception*. Routledge & Kegan Paul.

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd ed.). McGraw-Hill.

Schaufeli, W. B., Martínez, I. M., Pinto, A. M., Salanova, M., & Bakker, A. B. (2002). Burnout and engagement in university students: A cross-national study. *Journal of Cross-Cultural Psychology, 33*(5), 464–481.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. Basic Books.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Houghton Mifflin.

Sweller, J. (2011). Cognitive load theory. In J. P. Mestre & B. H. Ross (Eds.), *The psychology of learning and motivation* (Vol. 55, pp. 37–76). Academic Press.

Tabachnick, B. G., & Fidell, L. S. (2019). *Using multivariate statistics* (7th ed.). Pearson.

Topping, K. J. (2005). Trends in peer learning. *Educational Psychology, 25*(6), 631–645.

Vygotskij, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wilson, A. D., & Golonka, S. (2013). Embodied cognition is not what you think it is. *Frontiers in Psychology, 4*, 58.

Wulf, G., & Lewthwaite, R. (2016). Optimizing performance through intrinsic motivation and attention for learning: The OPTIMAL theory of motor learning. *Psychonomic Bulletin & Review, 23*(5), 1382–1414.