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Assessing Online Anatomy Teaching Effectiveness: Instrument Design and Validation at Ho Chi Minh City University of Physical Education and Sports

Phan Thanh Viet

Ho Chi Minh City University of Physical Education and Sports, Ho Chi Minh City, Vietnam

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ABSTRACT

Background: The institutional integration of digital learning in higher education has underscored the critical necessity of assessing domain-specific instructional effectiveness. In morphology-heavy disciplines such as Anatomy within pre-service physical education teacher education, virtual delivery poses profound pedagogical and cognitive challenges due to high intrinsic content density and the deprivation of physical tactile models.

Objectives: This study designed, operationalized, and preliminarily validated the Online Teaching Effectiveness in Anatomy Instrument (OTE-AI) to diagnose student-perceived instructional quality and cognitive bottlenecks at Ho Chi Minh City University of Physical Education and Sports (UPES).

Methods: Grounded in Cognitive Load Theory (Sweller, 2011) and international scale development standards (Boateng et al., 2018), a 15-item diagnostic instrument structured across four evaluative dimensions was developed. The instrument was empirically piloted with an exploratory sample (n = 43) drawn from a target cohort of N = 172 undergraduate pre-service physical education teachers (25.0% completion rate). Data were gathered via an institutional digital platform and analyzed using descriptive statistics, frequency distributions, and qualitative diagnostic synthesis.

Results: Findings revealed unanimous consensus regarding the fundamental curricular necessity of Anatomy (74.4% "Very Important", 25.6% "Important"), alongside substantial perceived knowledge density (86.0% rating volume as "Large" or "Very Large"). The Musculoskeletal system exhibited the highest practical utility for physical education pedagogy (60.5%), yet represented the second-largest driver of cognitive overload (20.9% recommending content reduction), following the Excretory system (30.2%). While digital classroom management and instructor facilitation were rated exceptionally high (79.1% "Very Good"), perceived learning efficacy revealed marked dispersion, with 23.2% reporting suboptimal learning gains due to cognitive fatigue and virtual delivery constraints.

Conclusions: The OTE-AI provides a valid, theory-grounded diagnostic framework capable of distinguishing technological classroom orchestration from authentic domain-specific learning efficacy. The empirical findings provide actionable justification for targeted syllabus recalibration under institutional frameworks (Decision No. 1028/QĐ-ĐHSPTDTT) and alignment with national professional teacher standards (Circular No. 20/2018/TT-BGDĐT).

KEYWORDS: Online Teaching Effectiveness, Assessment Instrument, Cognitive Load Theory, Anatomy Education, Physical Education Teacher Education, Higher Education

INTRODUCTION

The advent of Education 4.0, coupled with the profound educational disruptions precipitated by the global COVID-19 pandemic, has catalyzed an unprecedented paradigm shift toward digital transformation and distance education across higher education institutions worldwide (Gasmalla et al., 2022; Martin et al., 2021). In Vietnam, this digital transition was rapidly operationalized under the strategic directive *"Pausing school, not stopping learning"* promulgated by the Ministry of Education and Training (MOET), compelling universities to transition from emergency remote teaching toward institutionalized, sustainable distance and blended learning ecosystems (MOET, 2018). Within this evolving higher education landscape, Ho Chi Minh City University of Physical Education and Sports (UPES)—a premier specialized pedagogical institution in Southern Vietnam—systematically transitioned its academic curriculum toward digital and blended modalities commencing in the 2020–2021 academic year (Ho Chi Minh City University of Physical Education and Sports [UPES], 2025).

While digital infrastructure and learning management systems ensure instructional continuity, the paramount determinant of educational quality resides in domain-specific pedagogical effectiveness. This challenge is acutely pronounced in the delivery of foundational biomedical sciences, most notably Human Anatomy. In physical education teacher education and sports science curricula, the Anatomy course serves as an indispensable epistemological pillar. It provides the essential morphological, structural, and kinesiological knowledge required for mastering motor skills, comprehending exercise physiology, preventing athletic injuries, and conducting biomechanical movement analysis (Gasmalla et al., 2022).

However, delivering Anatomy courses within a virtual learning environment presents formidable pedagogical and cognitive barriers. Morphological education inherently demands intensive three-dimensional spatial orientation, multi-planar visualization, and the cognitive assimilation of extensive structural nomenclatures. Traditionally, these learning processes rely on tactile engagement with cadaveric specimens, physical plastic models, and interactive laboratory dissection. In a remote learning environment, the abrupt loss of tactile manipulation and over-reliance on static two-dimensional digital slides dramatically inflate extraneous cognitive load, overwhelming students' finite working memory capacity and impeding long-term schema acquisition (Sweller, 2011).

Despite these recognized challenges, a critical pedagogical and measurement gap persists in higher education quality assurance. Conventional Student Evaluations of Teaching (SETs) employed across universities are predominantly generic, administrative satisfaction surveys. These instruments fail to diagnose subject-specific cognitive bottlenecks, evaluate digital instructional orchestration, or assess the professional transferability of specialized biomedical content (Boateng et al., 2018; Martin et al., 2021). This diagnostic void is particularly problematic for pre-service physical education teacher training. Under Circular No. 20/2018/TT-BGDĐT on National Professional Teacher Standards (MOET, 2018), physical education graduates must master deep subject-matter pedagogical knowledge and digital instructional design to implement Vietnam's competency-based 2018 General Education Program. Furthermore, institutional curricula must maintain constructive alignment between course-level learning outcomes and institutional accreditation frameworks established under Decision No. 1028/QĐ-ĐHSPTDTT (Cohen et al., 2007; UPES, 2025). Without a validated, domain-specific diagnostic instrument, curriculum recalibration and pedagogical innovation remain grounded in anecdotal assumptions rather than robust empirical evidence.

To address this pressing methodological and institutional gap, the present investigation was conducted to develop, operationalize, and preliminarily validate a specialized diagnostic scale: *the Online Teaching Effectiveness in Anatomy Instrument (OTE-AI)*. Grounded in Cognitive Load Theory (CLT) (Sweller, 2011) and international scale development standards (Boateng et al., 2018), the OTE-AI is structured across four interrelated dimensions: Curricular Importance and Cognitive Knowledge Load, Interdisciplinary Connectivity, Online Instructional Organization, and Perceived Learning Efficacy. Specifically, this study addresses three primary research objectives:

(1) To design and operationalize a theory-grounded diagnostic instrument capable of capturing the multidimensional facets of online Anatomy instruction;

(2) To conduct an empirical pilot administration of the OTE-AI among pre-service physical education teachers at UPES to identify specific cognitive bottlenecks and curricular preferences; and

(3) To propose evidence-based pedagogical strategies and targeted syllabus recalibrations under Decision No. 1028/QĐ-ĐHSPTDTT to enhance biomedical digital instruction in physical education higher education.

THEORETICAL FRAMEWORK AND CONCEPTUAL DIMENSIONS

1. Cognitive Load Theory in Online Anatomy Pedagogy

The conceptual architecture of the OTE-AI is fundamentally anchored in CLT, as formalized by Sweller (2011). Rooted in human cognitive architecture, CLT posits that working memory is strictly limited in capacity and duration when processing novel information, whereas long-term memory stores expansive, highly organized cognitive schemas. In instructional settings, the total cognitive architecture comprises three distinct, additive load dimensions:

(1) *Intrinsic Cognitive Load:* The inherent mental effort required to process academic content, primarily dictated by its degree of “element interactivity.” In Anatomy courses, intrinsic load is exceptionally high because anatomical structures cannot be mastered in isolation; comprehending a single biomechanical movement necessitates the simultaneous mental integration of multiple elements, including osseous landmarks, articular axes, muscular origin-insertion dynamics, and neuromuscular innervation (Gasmalla et al., 2022; Sweller, 2011).

(2) *Extraneous Cognitive Load:* The non-essential mental burden generated by suboptimal instructional formats, ambiguous user interfaces, or split-attention effects. In virtual distance-learning environments, the deprivation of tactile cadaveric models and over-reliance on poorly sequenced two-dimensional digital slides inflate extraneous load, depleting working memory bandwidth that is vital for meaningful learning.

(3) *Germane Cognitive Load:* The constructive working-memory capacity devoted to schema construction, schema automation, and the integration of novel anatomical knowledge into long-term functional memory networks.

Within online biomedical education, effective digital pedagogy seeks to eliminate extraneous load while scaffolding high intrinsic load, thereby maximizing germane cognitive resources. In physical education teacher education, pre-service teachers must develop durable mental schemas that translate static morphological structures into dynamic sports kinesiology and pedagogical demonstrations (Martin et al., 2021; MOET, 2018). Consequently, evaluating digital instructional quality cannot rely on generic satisfaction surveys. The OTE-AI operationalizes CLT principles by systematically diagnosing student perceptions across specific load dimensions: quantifying perceived knowledge density and module-specific overload (intrinsic load), assessing virtual instructional delivery and instructor facilitation (extraneous load), and evaluating interdisciplinary applicability and perceived learning efficacy (germane schema acquisition).

2. Multidimensional Operationalization of the Instrument

To operationalize the multidimensional construct of online teaching effectiveness in morphological biomedical sciences, the design of the OTE-AI synthesized scale development protocols established by Boateng et al. (2018), constructive alignment principles (Cohen et al., 2007), and validated online course design metrics (Martin et al., 2021). Rather than treating instructional quality as a unidimensional satisfaction metric, the OTE-AI decomposes digital pedagogical effectiveness into four interconnected, theory-grounded evaluative domains encompassing 15 structured items:

Corresponding Author: Phan Thanh Viet

- **Domain 1: Curricular Importance and Cognitive Knowledge Load (Items 1, 2, 7, 8):** Grounded in the intrinsic cognitive load dimension of CLT (Sweller, 2011), this domain diagnoses student perceptions regarding the fundamental curricular necessity of Anatomy courses within physical education. It systematically quantifies perceived knowledge density and identifies specific anatomical organ modules that generate cognitive overload or require content restructuring, thereby providing empirical baselines for institutional syllabus recalibration.
- **Domain 2: Interdisciplinary Connectivity and Practical Applicability (Items 3, 4, 5, 6):** Drawing upon constructive alignment and professional teacher competency frameworks (MOET, 2018), this domain measures the horizontal integration of anatomical concepts with subsequent sports biomedical disciplines (e.g., sports physiology, sports biomechanics, and sports medicine) and their vertical transferability into practical athletic coaching and physical education pedagogy. It isolates learner thematic interest and functional utility across specific anatomical systems.
- **Domain 3: Online Instructional Organization and Instructor Facilitation (Items 9, 10, 11):** Reflecting the extraneous cognitive load dimension (Martin et al., 2021; Sweller, 2011), this domain evaluates the pedagogical orchestration of virtual learning environments. It assesses the reasonableness of online assessment tasks, the structural quality of virtual classroom management, and the immediacy, responsiveness, and academic facilitation provided by the instructor during digital sessions.
- **Domain 4: Perceived Learning Efficacy and Overall Course Quality (Items 12, 13, 14, 15):** Serving as the evaluative criterion for germane schema acquisition, this domain captures self-reported learning mastery achieved in the virtual environment, global satisfaction with online course quality, demographic identifiers, and open-ended qualitative diagnostic feedback to guide continuous, data-informed curriculum refinement under institutional frameworks (Decision No. 1028/QĐ-ĐHSPTDTT; UPES, 2025).

Together, these four domains establish a robust diagnostic matrix that enables researchers and academic administrators to triangulate technological delivery success with genuine pedagogical and biomedical learning outcomes.

METHODOLOGY

1. Research Design and Scale Development Procedure

This study employed a sequential instrument design and descriptive pilot survey design (Boateng et al., 2018; Cohen et al., 2007). The development process adhered to standard measurement stages:

(1) *Item Generation and Domain Delineation:* Initial items were generated based on course learning outcomes (CLOs) specified in the Physical Education curriculum syllabus (UPES, 2025) and literature-grounded online instructional criteria (Martin et al., 2021).

(2) *Content Validation:* The draft items were subjected to expert review by faculty members from the Department of Biomedicine and educational measurement specialists to establish face and content validity.

(3) *Digitization and Pilot Field Testing:* The refined instrument was digitized via Google Forms and deployed in a real-world online learning environment.

2. Participants and Pilot Context

The pilot investigation was conducted at the Faculty of Fundamental and Biomedical Sciences, UPES, across the 2024–2025 and 2025–2026 academic years within the online learning framework. The total target cohort comprised N = 172 undergraduate students enrolled across formal cohorts. A pilot sample of n = 43 full-time undergraduate students completed the digitized evaluation form in its entirety. While the sample size serves exploratory pilot diagnostic purposes (Cohen et al., 2007), it yielded robust preliminary insights into the distributional characteristics and practical functioning of the survey items.

3. Structure of the OTE-AI

The final digitized instrument comprises 15 items categorized into Likert-scale single-choice items, multi-response thematic checklists, open-ended qualitative prompts, and demographic markers (see Table 1).

Table 1: Structural Matrix and Item Specifications of the Online Teaching Effectiveness in Anatomy Instrument (OTE-AI)

Item No.	Evaluative Dimension	Prompt / Content Focus	Measurement Scale / Response Categories
Item 1	Domain 1: Curricular Value	Perceived importance of Anatomy in the PE curriculum	5-point Likert: *Very important, Important, Moderate, Unimportant, Unnecessary*
Item 2	Domain 1: Cognitive Load	Perceived magnitude of knowledge density	5-point Likert: *Very large, Large, Medium, Small, Very small*
Item 3	Domain 2: Interdisciplinary Link	Connectivity with sports biomedical cluster	5-point Likert: *Highly rigorous & scientific, Rigorous & scientific, Poorly connected, Disconnected, No connection*
Item 4	Domain 2: Practical Transfer	Horizontal connection to practical sports courses	5-point Likert: *Applicable to all, Applicable to most, Applicable to some, Inapplicable to most, Inapplicable to all*
Item 5	Domain 2: Thematic Interest	Specific anatomical topic of highest interest	Categorical (7 systemic modules: *Musculoskeletal, Nervous, Cardiovascular, Respiratory, Digestive, Excretory, Metabolism*)

Item 6	Domain 2: Thematic Application	Specific anatomical topic with highest practical utility	Categorical (7 systemic modules: *Musculoskeletal, Nervous, Cardiovascular, Respiratory, Digestive, Excretory, Metabolism*)
Item 7	Domain 1: Workload Reduction	Anatomical topic requiring workload/content reduction	Categorical (7 systemic modules: *Musculoskeletal, Nervous, Cardiovascular, Respiratory, Digestive, Excretory, Metabolism*)
Item 8	Domain 1: Workload Increase	Anatomical topic requiring increased content depth	Categorical (7 systemic modules: *Musculoskeletal, Nervous, Cardiovascular, Respiratory, Digestive, Excretory, Metabolism*)
Item 9	Domain 3: Assessment Design	Reasonableness of online testing and assessment tasks	5-point Likert: *Highly reasonable, Reasonable, Neutral, Unreasonable, Completely unreasonable*
Item 10	Domain 3: Class Organization	Quality of virtual classroom management and workflow	5-point Likert: *Very good, Good, Average, Poor, Very poor*
Item 11	Domain 3: Instructor Facilitation	Quality of instructor academic support and responsiveness	5-point Likert: *Very good, Good, Average, Poor, Very poor*
Item 12	Domain 4: Learning Efficacy	Perceived learning efficacy achieved in virtual setting	5-point Likert: *Very high, High, Moderate, Low, Very low*
Item 13	Domain 4: Overall Quality	Overall perceived quality of the online Anatomy course	5-point Likert: *Very high, High, Moderate, Low, Very low*
Item 14	Domain 4: Qualitative Feedback	Open-ended recommendations for pedagogical enhancement	Qualitative text input
Item 15	Demographics	Academic cohort identification and institutional email	Categorical / Text input

RESULTS

1. Domain 1: Curricular Importance and Cognitive Knowledge Load

Analysis of pilot responses demonstrated high perceptual consensus regarding the critical importance of Anatomy course within the physical education degree program. As detailed in Table 2, 74.4% (n = 32) of respondents evaluated the course as "Very Important," while the remaining 25.6% (n = 11) rated it as "Important." No students rated the discipline as moderate, unimportant, or unnecessary.

Conversely, data regarding knowledge density confirmed the presence of substantial intrinsic cognitive load. A combined 86.0% of respondents classified the anatomical knowledge load as either "Very Large" (48.8%, n = 21) or "Large" (37.2%, n = 16), while only 14.0% (n = 6) perceived it as "Medium." When asked to identify specific modules requiring workload reduction (Item 7), the Excretory system was most frequently identified (30.2%, n = 13), followed closely by the Musculoskeletal system (20.9%, n = 9), Nervous system (14.0%, n = 6), Digestive system (14.0%, n = 6), and Energy Metabolism (14.0%, n = 6).

Table 2: Descriptive Summary of Student Pilot Responses across Core Evaluative Domains (n = 43)

Survey Item / Dimension	Evaluative Category	Frequency (n)	Percentage (%)
Item 1: Curricular Importance	Very important	32	74.4%
	Important	11	25.6%
	Moderate	0	0.0%
	Unimportant	0	0.0%
	Unnecessary	0	0.0%
Item 2: Cognitive Knowledge Load	Very large	21	48.8%
	Large	16	37.2%
	Medium	6	14.0%
	Small	0	0.0%
	Very small	0	0.0%
Item 6: Highest Practical Utility	Musculoskeletal system	26	60.5%
	Nervous and Neuromuscular system	4	9.3%
	Cardiovascular and Blood system	4	9.3%
	Respiratory system	4	9.3%
	Energy Metabolism and Nutrition	4	9.3%
	Digestive system	1	2.3%
	Excretory system	0	0.0%
Item 7: Content Requiring Reduction	Excretory system	13	30.2%
	Musculoskeletal system	9	20.9%
	Nervous and Neuromuscular system	6	14.0%
	Digestive system	6	14.0%

	Energy Metabolism	6	14.0%
	Cardiovascular system	4	9.3%
	Respiratory system	2	4.7%
Item 10: Virtual Class Organization	Very good	34	79.1%
	Good	8	18.6%
	Average	1	2.3%
	Poor	0	0.0%
	Very poor	0	0.0%
Item 12: Perceived Learning Efficacy	Very high	4	9.3%
	High	21	48.8%
	Moderate	8	18.6%
	Low	5	11.6%
	Very low	5	11.6%
Item 13: Overall Course Quality	Very high	15	34.9%
	High	25	58.1%
	Moderate	3	7.0%
	Low	0	0.0%
	Very low	0	0.0%

2. Domain 2: Thematic Interest and Practical Applicability

In terms of pedagogical relevance to physical education and sports science, Item 6 demonstrated distinct differentiation among organ systems. The Musculoskeletal system was overwhelmingly perceived as having the highest practical utility by 60.5% (n = 26) of students. Nervous, Cardiovascular, Respiratory, and Metabolic systems each garnered 9.3% (n = 4) of responses, whereas the Digestive (2.3%) and Excretory (0.0%) systems were perceived as having minimal direct practical application to physical education instruction.

Interest distribution (Item 5) aligned with utility: students expressed the highest learning engagement with the Musculoskeletal system (74.4%, n = 32) and Energy Metabolism (44.2%, n = 19), while internal visceral systems received lower interest ratings (Digestive: 25.6%, Excretory: 23.3%).

3. Domain 3: Virtual Class Management and Instructional Facilitation

Student evaluations of instructional organization in the virtual environment were remarkably positive. For Item 10, 79.1% ($n = 34$) rated virtual classroom management as “Very Good,” 18.6% (n = 8) as “Good,” and only 2.3% (n = 1) as “Average.” No negative ratings (“Poor” or “Very Poor”) were recorded. This indicates that instructional workflow, digital attendance tracking, and platform administration successfully transitioned from emergency coping mechanisms to stabilized pedagogical delivery.

4. Domain 4: Learning Efficacy, Overall Quality, and Diagnostic Feedback

As illustrated in Table 2, global perceptions of course quality (Item 13) were overwhelmingly favorable: 34.9% (n = 15) rated it “Very High,” 58.1% (n = 25) rated it “High,” and 7.0% (n = 3) rated it “Moderate,” with zero negative responses.

However, Item 12 captured meaningful polarization regarding actual perceived learning efficacy. While 58.1% reported positive efficacy (48.8% High, 9.3% Very High), a notable 23.2% reported suboptimal outcomes (11.6% Low, 11.6% Very Low), alongside 18.6% reporting Moderate efficacy. Qualitative feedback from Item 14 revealed that disparities in individual digital device capabilities, home bandwidth instability, and the visual limitations of 2D screen sharing for complex 3D anatomical structures were primary contributing factors to reduced learning efficacy among the lower quartile.

DISCUSSION

1. Psychometric and Pedagogical Utility of the OTE-AI

The empirical results confirm that the designed OTE-AI functions effectively as a multidimensional diagnostic instrument. Rather than acting as a generic student satisfaction questionnaire, the instrument successfully differentiated between perceived organizational quality (which was uniformly high) and perceived learning efficacy (which revealed clear disparities). This bifurcation reflects the theoretical tenets of Sweller (2011) and Martin et al. (2021): smooth technological orchestration (low extraneous management load) does not automatically eliminate intrinsic learning bottlenecks in structurally dense disciplines like Anatomy.

The empirical pilot findings confirm that the designed OTE-AI functions effectively as a multidimensional diagnostic instrument rather than a superficial course satisfaction survey. A critical psychometric strength of the instrument lies in its diagnostic granularity, successfully capturing a pronounced pedagogical bifurcation: while ratings for online instructional organization and technological management were uniformly high (79.1% rating it as “Very Good”), perceived learning efficacy revealed marked dispersion, with 23.2% reporting low or very low learning outcomes. This dichotomy empirically validates the core theoretical tenets articulated by Sweller (2011) and Martin et al. (2021). Flawless technological orchestration, structured digital workflows, and responsive instructor facilitation effectively minimize extraneous cognitive load; however, they cannot automatically eliminate the dense intrinsic cognitive bottlenecks inherent in morphological disciplines.

Anatomy course requires intense spatial-visual processing, structural orientation, and the rapid memorization of complex Latin-derived nomenclatures. In a remote learning environment, the absence of tactile engagement with physical cadaveric specimens or plastic anatomical models exacerbates cognitive processing demands (Gasmalla et al., 2022). Consequently, when digital lectures rely predominantly on two-dimensional slides or passive screen sharing, working memory capacity becomes overwhelmed by intrinsic content complexity, even if extraneous organizational hurdles are well managed. By detecting this precise divergence, the OTE-AI proves its construct sensitivity and diagnostic capability, distinguishing administrative delivery success from genuine conceptual schema acquisition.

Furthermore, the instrument's ability to differentiate utility and workload across specific anatomical organ systems provides actionable data for evidence-based curriculum reform. In pre-service physical education teacher training, curricular content must balance scientific rigor with professional application (Boateng et al., 2018; MOET, 2018). The high utility attributed to the musculoskeletal system (60.5%) contrasted with the perceived redundancy of visceral systems demonstrates that the OTE-AI effectively captures learner needs. Thus, the instrument serves not only as an evaluative metric for digital teaching quality but also as an empirical mechanism to guide targeted syllabus restructuring under institutional frameworks (Decision No. 1028/QĐ-ĐHSPTDTT).

2. Managing Cognitive Load in Morphological Online Instruction

The empirical finding that 86.0% of participants perceived the anatomical knowledge load as either large or very large strongly corroborates contemporary international literature regarding the pedagogical complexities of morphological education (Gasmalla et al., 2022). Anatomy course inherently imposes an exceptionally high intrinsic cognitive load due to the vast volume of structural nomenclature, intricate multi-planar spatial relationships, and systemic physiological interactions. In a conventional face-to-face laboratory, this intrinsic complexity is mitigated through multi-sensory tactile engagement with physical plastic models, anatomical specimens, and peer palpation. When shifted to a virtual distance-learning environment, the abrupt deprivation of tactile manipulation, coupled with the cognitive constraints of two-dimensional screen rendering, dramatically inflates extraneous cognitive load, thereby consuming finite working memory resources that should otherwise be allocated to deep conceptual schema construction (Sweller, 2011).

Within this theoretical lens, the empirical data revealed a critical "curricular paradox": the Musculoskeletal system was simultaneously recognized as possessing the highest practical utility (60.5%) and identified as the second most demanding module in need of content reduction (20.9%). This apparent contradiction underscores a fundamental pedagogical misalignment in conventional instructional delivery. Pre-service physical education teachers inherently value musculoskeletal knowledge because it directly underpins motor skill pedagogy, athletic coaching, and exercise prescription. However, traditional didactic teaching often emphasizes passive, rote memorization of exhaustive topographical details (e.g., precise bony landmarks, isolated muscle origins, and insertions) rather than dynamic biomechanical functions. When delivered online without interactive visual aids, this descriptive overload overwhelms learners.

Consequently, instructional designers and lecturers cannot simply truncate musculoskeletal content, as this would compromise foundational scientific competence required by national teacher standards (MOET, 2018). Instead, digital pedagogy must be strategically re-engineered to optimize cognitive load distribution (Martin et al., 2021; Sweller, 2011). Faculty should integrate interactive 3D virtual dissection platforms, asynchronous micro-learning video modules adhering to the segmenting principle, and explicit sports-movement video analyses. By transforming static anatomical descriptions into dynamic, functional kinesiological models, digital instruction effectively minimizes extraneous interface load, scaffolds intrinsic complexity, and maximizes germane cognitive load—fostering durable schema acquisition without sacrificing scientific rigor.

3. Alignment with National Teacher Standards and Curriculum Updating

In the Vietnamese higher education landscape, undergraduate physical education programs operate under a dual mandate: equipping graduates with robust biomedical scientific foundations while preparing them for professional K–12 teaching roles governed by the National Professional Teacher Standards under Circular No. 20/2018/TT-BGDĐT (MOET, 2018). Specifically, Standard 2 of this regulatory framework mandates that pre-service educators demonstrate deep subject-matter knowledge, innovative pedagogical design, and advanced digital instructional competencies to fulfill the competency-based demands of Vietnam's 2018 General Education Program. The diagnostic data gathered via the OTE-AI provide critical empirical justification for operationalizing constructive curricular alignment between university course syllabi and national professional benchmarks (Cohen et al., 2007; HUPES, 2025).

A critical finding emerging from this study is the extreme perceptual divergence across anatomical organ systems. While musculoskeletal kinesiology was overwhelmingly recognized as vital for physical educators (60.5% utility), visceral systems exhibited marginal professional applicability: the digestive system accounted for only 2.3% of perceived utility, while the excretory system recorded 0.0% utility and attracted the highest demand for content reduction (30.2%). In conventional medical curricula, exhaustive coverage of visceral morphology is essential; however, in a pre-service physical education curriculum, an excessive instructional emphasis on descriptive visceral histology and topographical anatomy represents a curricular misalignment. This exhaustive descriptive content consumes precious instructional time while inducing unnecessary cognitive fatigue (Sweller, 2011).

Consequently, the institutional undergraduate curriculum syllabus promulgated under Decision No. 1028/QĐ-ĐHSPTDTT must undergo evidence-informed structural recalibration (UPES, 2025). Rather than maintaining uniform credit distribution across all organ systems, academic departments should streamline didactic lecture hours devoted to non-movement visceral anatomy. These credit hours should be strategically reallocated toward applied functional kinesiology, exercise neuro-motor mechanisms, injury prevention biomechanics, and sport-specific anthropometry. Furthermore, delivering this restructured syllabus through validated digital instructional platforms (Martin et al., 2021) directly models digital pedagogical competencies for pre-service teachers. By bridging theoretical anatomy with physical training practice and digital delivery, UPES can ensure that future physical educators possess both the specialized biomedical mastery and the digital innovation capacity required by modern educational standards.

4. Limitations and Directions for Future Validation

Notwithstanding the substantive theoretical and empirical contributions of this study, several methodological limitations must be acknowledged.

First, the preliminary validation of the OTE-AI was executed using an exploratory pilot sample of n = 43 undergraduate students drawn from a total target cohort of N = 172 enrolled across formal physical education courses at UPES (representing a 25.0% pilot completion rate). While this pilot sample size proved functionally adequate for initial item screening, face validity verification, and diagnostic curriculum feedback (Cohen et al., 2007), the sample size precluded the execution of advanced multivariate psychometric testing, such as Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), or Structural Equation Modeling (SEM) (Boateng et al., 2018). Consequently, the statistical generalizability of the findings across the entire institutional cohort and to broader higher education settings remains to be empirically established.

Second, the investigation relied exclusively on cross-sectional, self-reported student evaluations administered via digital forms. Although student feedback provides vital diagnostic insights into learner experience and perceived cognitive load, self-reported measures remain susceptible to subjective response biases, including social desirability and temporary fluctuations in digital engagement. Furthermore, while the instrument effectively captured self-perceived learning efficacy, it did not directly correlate these perceptions with objective, performance-based learning outcomes.

To advance the psychometric maturity and institutional utility of the OTE-AI, future research trajectories should pursue three methodological enhancements:

(1) Empirical data collection should be expanded to encompass the full institutional cohort (N = 172) and scaled across multi-institutional, nationwide cohorts (target N ≥ 300–500) to conduct comprehensive construct validation as recommended by Boateng et al. (2018). This will enable EFA to establish latent factor structures, CFA to confirm structural model fit, and Item Response Theory modeling to determine individual item discrimination and difficulty parameters.

(2) Longitudinal research designs should be employed to establish test-retest reliability across sequential academic semesters.

(3) Future investigations must establish criterion-related validity by correlating OTE-AI dimensional scores with objective academic metrics, including standardized anatomy theoretical examination scores, practical anatomical landmark palpation assessments, and functional kinesiological movement analysis competencies.

CONCLUSION

This study successfully designed, operationalized, and preliminarily validated the OTE-AI to evaluate online instruction within the specialized context of pre-service physical education teacher training at UPES. Grounded in CLT and international standards for educational scale development, the 15-item instrument demonstrated high diagnostic sensitivity across four core dimensions: curricular relevance and cognitive load, interdisciplinary connectivity, virtual instructional delivery and instructor facilitation, and perceived learning efficacy. The empirical pilot findings provided robust evidence that while pre-service physical education teachers universally recognize the foundational importance and high functional utility of musculoskeletal anatomy, virtual delivery presents considerable intrinsic cognitive load that requires pedagogical and structural optimization. Importantly, the instrument successfully differentiated smooth technological classroom management from authentic domain-specific learning efficacy, establishing itself as a rigorous diagnostic tool for continuous quality assurance in biomedical and sports science distance education.

RECOMMENDATIONS

Based on the empirical evidence and diagnostic insights generated by the OTE-AI, the following strategic recommendations are proposed across three distinct levels:

1. **Curricular Restructuring and Alignment with National Standards:** The undergraduate Anatomy course syllabus under Decision No. 1028/QĐ-ĐHSPTDTT should undergo targeted recalibration. Academic workload associated with descriptive, non-applied visceral anatomy (specifically the excretory and digestive systems) should be streamlined. Concurrently, instructional credit hours should be strategically reallocated toward musculoskeletal anatomy, functional kinesiology, neuromuscular control, and applied sports biomechanics. This structural revision directly supports pre-service physical education teachers in acquiring core subject-matter competence mandated by the National Professional Teacher Standards under Circular No. 20/2018/TT-BGDĐT.
2. **Digital Pedagogical Innovations and Cognitive Load Management:** To optimize online learning efficacy in morphological disciplines, academic departments should transition from passive slide presentations to active digital learning ecosystems. Grounded in CLT, instructors should integrate interactive 3D anatomy visualization platforms, virtual dissection software, and asynchronous micro-lectures. These multi-sensory digital instructional tools effectively minimize extraneous cognitive load while facilitating spatial-anatomical comprehension and germane schema construction.
3. **Institutional Scaling and Future Psychometric Expansion:** UPES and comparable physical education and sports science institutions should institutionalize the OTE-AI framework across other foundational biomedical courses (e.g., sports physiology, sports biomechanics, and sports medicine) and practical sports coaching disciplines to establish a data-informed quality enhancement system. Methodologically, future research should expand participant recruitment across multi-institutional cohorts to perform advanced psychometric validation—including Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and Item Response Theory—thereby establishing a fully standardized national assessment scale for digital higher education.

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