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Exploring the Case-Based Learning Challenge (CBLC): a digitally mediated, inter-university simulation to enhance clinical reasoning in physiotherapy students - a quasi-experimental study

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Abstract

Background Teaching clinical reasoning and communication skills is a fundamental component of physiotherapy education. Integrating theoretical knowledge with practical application remains a core challenge, particularly in an evolving educational landscape increasingly shaped by digitalisation and inter-institutional collaboration. This study evaluates the feasibility and student-level educational impact of a national, digitally mediated, case-based simulation—the Case-Based Learning Challenge (CBLC)—designed to support clinical reasoning and decision-making in third-year physiotherapy students across multiple Italian universities.

Methods A one-group quasi-experimental design with repeated measures was adopted. The intervention consisted of a national, digitally mediated simulation, structured around the presentation and peer discussion of a complex cardiorespiratory case. Students from two universities acted as active presenters (Challenger Universities), while those from 23 additional institutions participated as guided observers (Observer Universities). University affiliation was collected only at the level of these categories (Challenger vs. Observer). The session included three phases: case presentation, peer review, and collaborative Q&A. All students completed a competence questionnaire before and immediately after the intervention, and a satisfaction survey post-intervention. Descriptive and inferential statistics were applied, including paired-sample t-tests to assess changes in competence and Cronbach's alpha to evaluate internal consistency.

Results A total of 399 students completed the baseline assessment, and 256 completed the post-intervention survey. Statistically significant improvements were observed in general clinical knowledge (mean score increase

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from 3.59 to 4.02; $p < 0.001$), and in the total competence score (from 7.05 to 7.47; $p < 0.001$). No significant change was detected in case-specific knowledge. Student satisfaction ratings were generally favourable across domains, with higher scores related to content relevance and inter-university exchange, and lower ratings associated with organisational and technical aspects. The satisfaction survey demonstrated excellent internal consistency (Cronbach's alpha = 0.913), while the competence questionnaire showed suboptimal reliability.

Conclusions The CBLC represents a feasible national digital format for delivering case-based, peer-discussion learning across multiple physiotherapy programmes and was associated with small improvements in general knowledge alongside favourable student perceptions. As outcomes were assessed at the student level and institution-specific identifiers were not collected for observer participants, these findings should be interpreted as evidence of feasibility and short-term educational impact rather than demonstrated standardisation across programmes. Future evaluations should incorporate predefined institution-level benchmarking metrics, process measures of inter-university collaboration, and delayed or performance-based assessments.

Keywords Case-based learning (CBL), Case-based learning challenge (CBLC), Clinical reasoning, Digital education, Inter-university collaboration, Physiotherapy education, Simulation-based learning

Background

Teaching clinical skills and physiotherapy clinical reasoning are a central components in the education of future physiotherapists [1]. In particular, integrating theoretical knowledge with practical application remains one of the most significant educational challenges in preparing competent, reflective healthcare professionals [2–4]. The increasing complexity of clinical needs, combined with the rapid evolution of scientific evidence, calls for innovative teaching strategies capable of bridging the gap between theory and practice, while promoting active, critical and contextualized learning [5, 6].

In this context, active learning methodologies—including peer-assisted learning, simulation-based training, structured case-based learning, and collaborative activities—have been shown to support the development of complex professional competencies in health professions education [7, 8]. In physiotherapy education, peer learning can promote reflective practice, self-efficacy, and the co-construction of knowledge [9, 10]. When supported by feedback and guided reflection, these approaches may also enhance metacognitive awareness and professional insight, thereby strengthening evidence-informed clinical reasoning, decision-making, and teamwork within authentic learning contexts [11–13].

Notably, Case-Based Learning (CBL) links theory to practice through authentic clinical cases that stimulate discussion, argumentation, and critical thinking, thereby supporting clinical reasoning, decision-making, and problem solving [14–17].

In parallel, digital technologies have increasingly been used to enhance accessibility and collaboration in health professions education, supporting inter-institutional learning by reducing geographical and organizational barriers [18–22]. Online platforms and videoconferencing can facilitate shared educational activities across campuses and enable structured, synchronous discussion around authentic clinical cases [23, 24]. When embedded within a coherent instructional design and guided facilitation, digitally mediated formats may also sustain engagement and collaborative learning processes in distributed cohorts [25, 26].

Within this evolving educational context, to date, CBL studies were mainly focused on specific group of healthcare students such as those in medicine, nursing, dentistry and psychology. Few studies have addressed physiotherapy students and, to the best of our knowledge no study none have examined inter-university cohorts [27–29]. To address this gap, the present project introduces an innovative and inter-university learning initiative specifically designed for third-year physiotherapy students: the Case-Based Learning Challenge (CBLC).

The CBLC is based on the hypothesis that educational benefit of case-based learning may be furthere enhanced by encouraging interaction among students from different academic institutions. Inter-university exchange not only enriches the dialogue across varying educational approaches but also contributes to harmonizing expected competencies across different physiotherapy curricula in different institutions [30–32]. Variability in content, teaching methods and perceived preparedness among Italian university programs underscores the need for nationally coordinated educational initiatives [33, 34]. This activity aims to promote critical thinking, clinical reasoning and decision-making in physiotherapy, as well as strength skills in patient management, communication and interprofessional collaboration, as intended learning targets of the initiative.

The present study investigates the student-level educational impact of this digitally mediated, cross-institutional experience. The primary objective was to assess short-term changes in students' cardiorespiratory physiotherapy knowledge using a competence questionnaire administered before and immediately after the CBLC,

and to describe students' perceptions of the activity's relevance and educational utility through a post-intervention satisfaction survey.

A secondary objective was to evaluate the internal consistency of the competence questionnaire and the satisfaction survey. While the CBLC was conceived within a national framework aimed at fostering inter-university exchange and, in the longer term, supporting harmonised educational expectations, the present evaluation focuses on feasibility and individual-level outcomes and does not directly assess programme-level standardisation or collaborative processes.

Methods

Study design

This study employed a one-group, quasi-experimental design with repeated measures to assess the educational impact of a digitally mediated case-based learning challenge.

Given the national implementation of the CBLC as a single, synchronous inter-university educational initiative offered as a voluntary extracurricular activity, the inclusion of a parallel control or comparison group was not feasible. The intervention was delivered simultaneously across participating institutions, and neither randomisation at the individual or institutional level nor selective withholding of access was practicable within this coordinated educational framework. Accordingly, a one-group repeated-measures design was adopted as a pragmatic and methodologically appropriate approach to evaluate feasibility and short-term student-level outcomes in a real-world educational setting.

Designed for third-year physiotherapy students, the CBLC involves the structured, synchronous discussion of a clinical case with complex cardiorespiratory issues across students of multiple academic institutions.

The study is reported in accordance with the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) guidelines, to ensure methodological clarity, reproducibility, and alignment with best practices in nonrandomized educational research [35].

Participants

The study involved third-year physiotherapy students enrolled in the 2024–2025 academic year across a network of Italian universities. Two institutions—the University of Pavia and Sapienza University of Rome—were designated as active participants. Their students collaboratively developed and presented the simulation case and participated in the structured, synchronous inter-university discussion of a complex cardiorespiratory clinical scenario as part of the CBLC. This educational intervention was designed to enhance clinical reasoning, decision-making, and professional communication skills.

In addition, students from 23 other Italian universities participated as observers. This included: University of Turin, University of Trieste, Humanitas University, University of Insubria, University of Brescia, University of Eastern Piedmont "Amedeo Avogadro", University of Genoa, University of Camerino, University of Naples "Federico II", University of Modena and Reggio Emilia, University of Salerno, Vita-Salute San Raffaele University, University of Milano-Bicocca, University of Parma, University of Padua, UniCamillus – Saint Camillus International University of Health and Medical Sciences, University of Bari "Aldo Moro", University of Perugia, University of Cagliari, University of Messina, "G. d'Annunzio" University of Chieti–Pescara, Alma Mater Studiorum – University of Bologna, and University of Ferrara—attended the CBLC remotely. Although these students did not contribute to the initial case development, they engaged in the same inter-university discussion and had access to identical educational content and simulation materials. All students, regardless of institutional affiliation, completed standardized evaluation questionnaires at both baseline (T0) and post-intervention (T1), in alignment with the assessment timeline defined for the study.

Although students from Challenger and Observer Universities differed in their level of active involvement during the preparatory phase, both groups were exposed to the same educational content, clinical case, peer discussion, and moderated Question-and-Answer (Q&A) Session. For this reason and given the study's primary focus on feasibility and student-level educational impact rather than role-specific effects, participants were analysed within a single cohort.

This approach is consistent with the pragmatic evaluation of large-scale educational interventions, where varying degrees of engagement are inherent to instructional design.

Eligibility criteria

Eligible participants were third-year physiotherapy students formally enrolled at one of the Italian universities. Adequate proficiency in the Italian language was required to ensure effective comprehension of the educational materials and meaningful participation in the simulation-based learning and evaluations.

Recruitment strategy

Recruitment was coordinated by the administrative offices of the participating physiotherapy programmes, which circulated an invitation via official university channels (including email). Participation was voluntary and required completion of a digital informed consent form. To ensure confidentiality, communications and data handling were managed by the administrative offices, and

both administrative staff and the research team were blinded to participants' identities.

Study setting and data collection

The CBLC intervention and all associated data collection were conducted entirely online. GoogleForm® was used both for synchronous participation and for asynchronous completion of evaluation surveys. GoogleForm® was chosen for its compliance with the European General Data Protection Regulation (GDPR), ensuring that data collection adhered to EU Regulation 2016/679 on data protection. Each participant generated a pseudonymized identification code by combining the first two letters of the mother's name, the first letter of the father's name, and the his/her birthdate.

For evaluation purposes, university affiliation was collected in categorical form: students indicated whether they belonged to one of the two Challenger Universities (Sapienza University of Rome or the University of Pavia) or to the aggregated category 'Observer Universities', which included all other participating institutions. Because institution-specific identifiers were not collected for observer students, analyses stratified by individual observer universities and between-institution comparisons across participating programmes were not feasible. Consequently, participation rates could not be compared across individual observer institutions. Enrollment and completion were monitored only at the aggregate level (Challenger vs. Observer Universities), in line with the categorical data collection strategy adopted to preserve anonymity and facilitate large-scale participation.

Baseline equivalence between Challenger and Observer groups in terms of prior exposure, competence level, or educational background was not formally assessed. The competence questionnaire administered at T0 was used to characterise the overall cohort rather than to perform subgroup comparisons, which were not predefined objectives of the study and were limited by the aggregated recording of observer participants. As such, the present analyses focus on within-group pre–post changes at the cohort level.

This coding system enabled secure linkage of individual responses between T0 and T1 while maintaining anonymity. The post-intervention questionnaire (T1) was administered immediately after completion of the CBLC session using the same digital platform and access procedure.

All data were stored on GDPR-compliant servers.

Ethical considerations

The study adhered to the principles of the Declaration of Helsinki and the European General Data Protection Regulation (GDPR) [36, 37]. Ethical approval was obtained from the Ethics Committee for Transdisciplinary Research of Sapienza University of Rome (Approval No. CERT_195E1A36C08). Prior to participation, students were provided with detailed information about the study's objectives, data management and protection procedures, including their right to access, rectify, and delete their personal data. Data were collected exclusively in pseudonymized form, securely managed and stored, and inaccessible to the research team. All results are reported in aggregate form, ensuring anonymity and confidentiality.

Procedures

Pre-implementation phase

The Pre-Implementation Phase of the CBLC represented a foundational step aimed at ensuring the systematic planning, development, and organization of the educational intervention. This stage was characterized by a series of structured activities, including institutional coordination, the development and structuring of the clinical case, and the creation of evaluation instruments. All components were aligned with the principles of Active Learning and Evidence-Based Practice (EBP), ensuring consistency with the Core Competencies of Physical Therapists in Italy.

Institutional coordination and project endorsement The CBLC was initiated within the framework of the Italian Permanent Conference of Health Professions Degree Courses, under the education commission. This commission is responsible for setting educational standards and promoting innovative learning methodologies.

During the 2022–2025 mandate, the directive emphasized the enhancement of active learning strategies to improve clinical reasoning, decision-making, and communication skills among physiotherapy students. Within this framework, the CBLC was conceptualized as a pilot project that bridges theoretical knowledge with practical application through inter-university collaborative simulations.

The project was officially launched in October 2024, with an online presentation to all Italian physiotherapy degree programs. A simulation calendar for 2025 was shared, and invitations were extended to all universities, resulting in the participation of 25 institutions, categorized as:

- Challenger Universities (*Sapienza University of Rome* and *University of Pavia*): responsible for developing and presenting the clinical case.
- Observer Universities: attended the simulation as interactive observers, participating primarily in the Q&A session.

Development and structuring of the clinical case The clinical case was developed by a multidisciplinary expert panel convened by the Permanent Conference, including senior physiotherapists and cardiopulmonary rehabilitation clinicians all with extensive didactic experience with physiotherapy students. The objective was to create a realistic and multifaceted clinical scenario that would challenge students' clinical reasoning and decision-making abilities.

The case was designed to be:

- Complex, simulating a realistic cardiorespiratory scenario;
- Multifactorial, incorporating medical history, subjective/objective assessments, comorbidities, and psychosocial factors;
- Educational, aimed at challenging students' clinical reasoning, prioritization, and evidence integration.

After validation via multiple expert reviews, the finalized case was distributed one month before the event to the Challenger Universities. The case was distributed one month in advance to support self-directed preparation, critical appraisal of evidence, and autonomous clinical reasoning, in line with the expected competencies of final-year physiotherapy students. This instructional choice should be considered when interpreting pre–post changes in questionnaire performance, as it limits attribution of observed effects to the live simulation session alone.

Their students were tasked with independently preparing a structured PowerPoint presentation, which included:

- Clinical assessment and physiotherapeutic evaluation;
- Physiotherapy diagnosis and prognosis;
- Evidence-based rehabilitation goals and treatment plan;
- Management of complications and follow-up strategies;
- Students were explicitly required to integrate current scientific literature into their treatment proposals, emphasizing evidence-based practice.

Creation of evaluation instruments To evaluate learning outcomes systematically, an expert panel—including educators, clinical specialists, and members of the Italian Association of Physiotherapists (AIFI)—developed two instruments:

- The Competence Questionnaire, designed to assess students' application of clinical knowledge in realistic scenarios.
- The Satisfaction Survey, aimed at capturing students' perceptions of the educational experience, their engagement during the CBLC, and its perceived impact on their clinical skills.

These tools were designed to ensure alignment with the CBLC's pedagogical objectives.

Transition to implementation

With the completion of all preparatory activities—including institutional alignment, case development, and evaluation tool design—the study was positioned for smooth implementation.

To promote consistency across participating universities, standardized written instructions were circulated to all programme coordinators prior to the event, covering the session agenda, timing, access procedures, participant roles, and the administration of the baseline (T0) and immediate post-intervention (T1) questionnaires. As the CBLC was delivered as a single, centrally hosted synchronous session, all students were exposed to the same sequence of activities (Case Presentation, Peer Review, and Collaborative Q&A) under uniform procedural conditions.

Implementation phase

The CBLC was conducted as a synchronous, inter-university educational simulation using the Webex Cisco® platform. This platform supported real-time participation by up to 1,000 students and enabled interaction among students from various institutions.

The CBLC was structured as a single-session event lasting approximately two hours, divided into three phases: (i) Case Presentation, (ii) Peer Review, (iii) Collaborative Q&A. Secure access links were distributed via institutional email. Across all participating institutions, the CBLC was delivered outside scheduled curricular teaching hours as an additional voluntary learning activity. Students prepared independently and were not monitored or coached by faculty during the preparatory period, fostering autonomy and self-directed learning.

Case presentation The first phase of the CBLC involved the structured presentation of the clinical case by the Challenger Universities. One month before the event, both universities received the same complex cardiorespiratory clinical case, designed to replicate a real-world scenario with multifaceted rehabilitation challenges (Fig. 1).

Students were required to independently analyze the clinical case and develop a structured PowerPoint presentation encompassing key components of clinical reasoning. The presentation included:

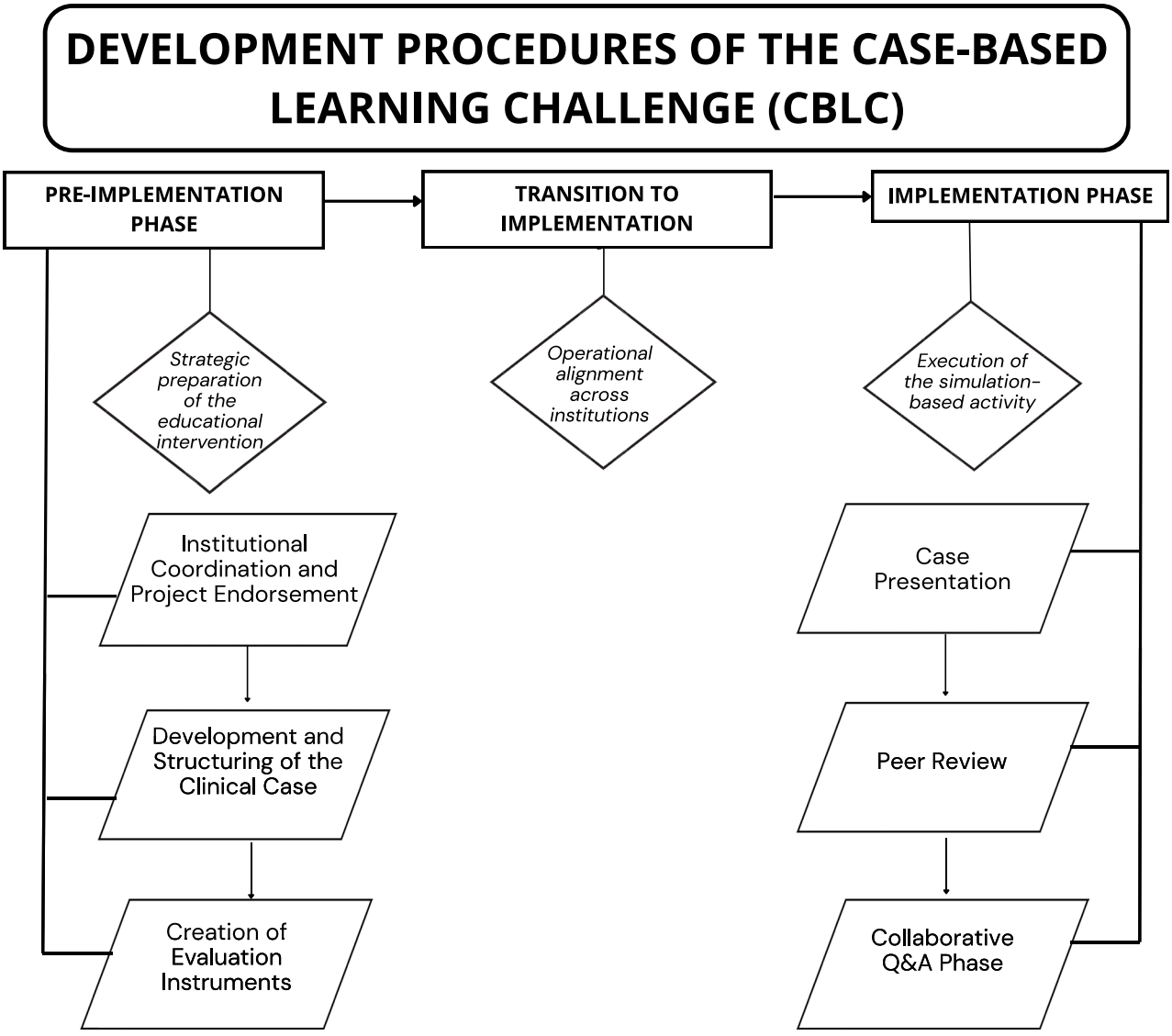

Fig. 1 Development procedure for the CBLC

- A complete clinical assessment reflecting both subjective and objective findings.
- A physiotherapeutic evaluation focused on respiratory function, comorbidities, and functional impairments.
- The identification of a physiotherapy diagnosis and prognosis, aligned with patient-specific needs.
- The definition of rehabilitation objectives, structured around functional recovery and quality of life improvement.
- An evidence-based treatment plan integrating current scientific literature and best practices.
- Strategies for managing potential complications and follow-up protocols for monitoring patient progress.

The preparation of the presentation was entirely autonomous, reinforcing critical thinking, problem-solving, and independent decision-making. This choice was intentional, aiming to foster self-management skills and clinical reasoning without external guidance, simulating real-world decision-making processes. During the simulation event, each university designated two representatives to present their clinical reasoning and proposed interventions. The presentations were delivered consecutively, with each group allocated 30 min to outline their approach, structured as a formal lecture. Interactive discussion during the presentation was not expected; all questions and critiques were reserved for the subsequent phases.

Peer review The second phase of the CBLC focused on collaborative evaluation through a Peer Review Process. During this stage, students from the university that did not present first assumed the role of peer reviewers. Their primary responsibility was to critically evaluate the intervention plans presented by their counterparts, focusing on the coherence of the clinical reasoning, the appropriateness of the proposed treatments, and their alignment with current evidence-based practices.

Peer reviewers intervened autonomously, driven by their own reflections, doubts, or critical analyses of the presentations. This open format encouraged spontaneous and genuine interaction among participants. Notably, the process was not guided by predefined checklists or rubrics, allowing for a natural emergence of methodological and clinical differences between universities. All feedback was verbal, but presenters were required to document the comments received for future reference and reflection.

The peer review process was moderated by a faculty member, specifically selected for their expertise in physiotherapy and clinical research methodology. The moderation was focused exclusively on maintaining adherence to the educational objectives of the CBLC, ensuring that discussions remained respectful, structured, and oriented towards constructive critique. The moderator's role was crucial in guiding the dialogue, prompting reflective questions, and maintaining a structured flow of critique without deviating from the core objectives of the simulation.

The peer review process was designed to stimulate reflective thinking and analytical skills, encouraging students to compare different clinical reasoning approaches and discuss the rationale behind specific therapeutic decisions. It also allowed participants to identify gaps in reasoning and explore alternative evidence-based solutions, contributing to a deeper understanding of clinical practice.

Collaborative Q&A phase The final phase of the CBLC consisted of the Collaborative Question-and-Answer (Q&A) Session, which aimed to foster interactive learning and collective critical reflection. During this stage, observer students from the participating universities were invited to actively engage with the presenters, posing questions, seeking clarifications, and sharing their perspectives on the clinical reasoning and intervention strategies proposed.

The Q&A session was designed to broaden the educational experience by incorporating diverse viewpoints from students across multiple academic settings. Questions posed during this phase were entirely spontaneous, with no predefined structure or guidelines, allowing for a natural and open exchange of perspectives that reflected the authentic curiosities and insights of the participants. The discussions were moderated by a faculty member who guided the dialogue, ensuring that it remained focused on evidence-based clinical reasoning and physiotherapeutic decision-making. This phase encouraged an open exchange of ideas, promoting critical thinking and reinforcing the application of theoretical knowledge to practical scenarios.

The Collaborative Q&A Phase concluded the simulation event, allowing participants to consolidate their understanding, clarify uncertainties, and reflect on the proposed interventions with direct peer interaction and expert facilitation.

The session was delivered using institutionally available digital infrastructure (Webex Cisco® and GoogleForm®) routinely adopted for educational activities; therefore, no additional direct financial costs were incurred by participating universities.

A graphic summary of the procedural steps described in this section is presented in Fig. 1.

Outcome measures

The educational intervention was evaluated using two complementary instruments designed to capture students' short-term performance on applied clinical reasoning tasks and their perceptions of the learning experience.

Competence questionnaire

The Competence Questionnaire was a purpose-built, single-best-answer multiple-choice tool developed for the CBLC to assess students' short-term performance on applied clinical reasoning and decision-making tasks in cardiorespiratory physiotherapy. The questionnaire was not a previously validated instrument and was not intended to measure global clinical competence or workplace performance.

Item development was undertaken by an expert panel of physiotherapy educators and clinicians with experience in cardiorespiratory rehabilitation and academic teaching. Items were designed to reflect realistic, evidence-informed decision points aligned with the CBLC learning objectives. The questionnaire comprised 10 items organised into two sections: a *General Section* (common cardiorespiratory scenarios) and a *Case-Specific Section* (decision points related to the CBLC case). All items used a four-option, single-best-answer format.

The questionnaire was administered at two time points: baseline (T0) immediately before the CBLC session and post-intervention (T1) immediately after completion of the session, using the same GoogleForm® access procedure via a QR code. Identity verification followed institutional procedures (in-person for Challenger Universities and online for Observer Universities). To ensure

controlled access, the form was available only via QR code, and technical support was provided during administration. A self-generated pseudonymised code enabled secure linkage of T0 and T1 responses while preserving anonymity, supported by the platform timestamp for data tracking.

Satisfaction survey

The Satisfaction Survey was developed to assess students' perceptions of the educational experience, their engagement during the CBLC, and the perceived relevance and utility of the activity for future clinical practice.

Item development was undertaken by the same expert panel involved in the design of the educational intervention and competence questionnaire, comprising physiotherapy educators and clinicians with experience in cardiorespiratory rehabilitation and academic teaching. Survey items were generated through iterative discussion and consensus, with the aim of ensuring content relevance, clarity, and alignment with the pedagogical objectives of the CBLC.

The final instrument consisted of 12 items organised into four conceptual domains: general organisation of the event, clarity and quality of presentations, relevance and utility of the topics discussed, and perceived educational value of inter-university comparison. Responses were recorded using a 5-point Likert scale (1 = not at all satisfactory; 5 = highly satisfactory).

In addition, three open-ended questions were included to allow participants to provide qualitative feedback on strengths, areas for improvement, and perceived learning outcomes. No formal pilot testing was conducted prior to implementation, as the survey was intended as a formative evaluation tool within a single national educational initiative.

The Satisfaction Survey was administered once, immediately after completion of the CBLC session (T1), using the same digital access procedures adopted for the competence questionnaire. This instrument was designed to complement performance-based outcomes by capturing feasibility, acceptability, and perceived educational value rather than objective learning effectiveness.

An English-language version of the CBLC Questionnaire has been provided as supplementary material [see Additional file 1]. This file includes the instructions for pseudonymized data collection, the full Competence Questionnaire and the Satisfaction Survey.

Sample size

A priori sample size estimation was performed in accordance with the study's predefined objectives. For the primary objective—to detect changes in students' competencies as measured by the Competence Questionnaire—a sample size calculation was conducted using a paired-sample t-test model. Assuming a two-tailed hypothesis (H_1: $\mu_1 \neq \mu_2$), a small effect size (Cohen's $d = 0.2$), a significance level of $\alpha = 0.05$, and a statistical power of 80%, a minimum of 199 participants was required to detect significant within-group differences. The assumption of a small effect size was considered appropriate given the advanced training level of third-year physiotherapy students, for whom core cardiorespiratory knowledge and clinical reasoning skills are largely established at baseline, thus constraining the magnitude of short-term detectable change.

For the secondary objective—to evaluate the psychometric properties of the Competence Questionnaire and the Satisfaction Survey, with particular focus on internal consistency—a separate sample size calculation was conducted using Bonett's formula for Cronbach's alpha [38]. Assuming an expected alpha of 0.80, a maximum allowable error of ± 0.05, a 95% confidence level, and 90% power, a minimum of 169 participants was deemed necessary.

Both sample size estimations were conducted using R statistical software (version 4.3.1).

Statistical analysis

All analyses were conducted using IBM SPSS® Statistics version 28.0. Statistical significance was set at $p < 0.05$ for all two-tailed tests, in accordance with the a priori sample size estimations defined for both the primary and secondary objectives.

Descriptive analysis

Descriptive statistics were first used to characterize the study sample. Frequencies and percentages were reported to distinguish between students from Challenger Universities (Sapienza University of Rome and University of Pavia) and those from Observer Universities. This categorisation reflected the structure of data collection, as observer participants were recorded as a single aggregated group. Accordingly, descriptive statistics by individual observer universities and between-institution comparative analyses were not conducted.

For the Competence Questionnaire, item-level frequencies and percentages of correct and incorrect answers were calculated, along with mean and standard deviation values for each of the two subscales ("General Section" and "Case-Specific Section") and for the overall score.

Similarly, the Satisfaction Survey, administered only at post-intervention (T1), was analyzed by reporting means, standard deviations, and response distributions for each item on the 5-point Likert scale. Although the survey included three open-ended questions for qualitative feedback, no formal content analysis was conducted, in line with the primary objectives of the present study.

Inferential analysis

To assess the effectiveness of the educational intervention, within-group comparisons were conducted using pre- and post-intervention scores (T0 vs. T1) from the Competence Questionnaire. Analyses were performed on the overall score (sum of all 10 items) and separately for the two subscales.

Because three pre-specified scale-level comparisons were performed (General Section, Case-Specific Section, and Total score), a Bonferroni-adjusted significance threshold ($\alpha = 0.05/3 = 0.0167$) was additionally applied as a sensitivity analysis; this did not change the interpretation of the results. Normality of score distributions was assessed using the Shapiro–Wilk test. When normality was confirmed, paired-sample t-tests were applied. For non-normally distributed data, the Wilcoxon signed-rank test was used as a non-parametric alternative. Item-level responses were recorded in binary format (1 = correct, 0 = incorrect) to allow for inferential comparison.

Psychometric properties

As part of the secondary aim, internal consistency of both the Competence Questionnaire and the Satisfaction Survey was assessed using Cronbach's alpha. Values ≥ 0.70 were considered acceptable, with ≥ 0.80 indicating good reliability. Additionally, corrected item-total correlations and "alpha if item deleted" values were examined to explore each instrument's internal coherence.

Results

Participant characteristics

Out of 500 eligible third-year physiotherapy students from 25 Italian universities, 399 (79.8%) completed the baseline assessment (T0). At post-intervention (T1), 256 students (64.2% of those assessed at baseline) completed the follow-up questionnaire, corresponding to a non-completion rate of 35.8% between timepoints. As reasons for non-completion were not systematically recorded in this large-scale online educational event, attrition is likely to reflect pragmatic constraints (e.g., time limitations, early departure, or connectivity issues) rather than protocol-driven exclusion. Non-completion differed by role category, with a higher rate among Challenger students (17/39; 43.6%) than among Observer students (123/360; 34.2%). However, because reasons for non-completion were not collected and the number of Challenger students was small, these differences should be interpreted descriptively.

Table 1 Distribution of participants by university group at each assessment time point (T0 and T1)

Baseline (T0)	
Challenger Universities, n (%)	
Sapienza University of Rome	14 (3.5%)
University of Pavia	25 (6.3%)
Observer Universities, n (%)	360 (90.2%)
Total (*n*)	399
Follow-up (T1)	
Challenger Universities, n (%)	
Sapienza University of Rome	6 (2.3%)
University of Pavia	16 (6.3%)
Observer Universities, n (%)	237 (92.6%)
Total (n)	256

As shown in Table 1, participants at T0 included 14 students (3.5%) from Sapienza University of Rome and 25 (6.3%) from the University of Pavia, collectively designated as Challenger Universities. The remaining 360 students (90.2%) were from Observer Universities. At T1, the sample consisted of 6 students (2.3%) from Sapienza, 16 (6.3%) from Pavia, and 237 (92.6%) from Observer Universities.

Observer participants were analysed as a single aggregated group, consistent with the categorical collection of university affiliation. Pre–post analyses were conducted on students with paired responses across T0 and T1. Because reasons for non-completion were not collected a priori, attrition-related selection bias cannot be excluded.

The flow of participants through the stages of recruitment, baseline assessment, follow-up, and inclusion in the analyses is summarised in Fig. 2.

Descriptive results

Competence questionnaire

Analysis of item-level performance on the Competence Questionnaire revealed variable accuracy across items and subscales. As presented in Table 2, at baseline (T0), correct response rates ranged from 40.6% (Item 8, Case-Specific Section) to 96.5% (Item 6, Case-Specific Section). Following the CBLC intervention (T1), modest improvements were observed in several items, most notably Item 10 (from 59.6% to 67.6%) and Item 3 (from 50.1% to 54.7%). Accuracy remained high for Items 6 and 7 across both time points, while Items 8 and 9 consistently exhibited lower performance. Notably, performance remained stable on Item 8 (40.6% at both timepoints), suggesting persistent difficulty with this domain.

Subscale-level analysis demonstrated that it mean accuracy improvements in both the General Section and the Case-Specific Section, with particularly evident gains in items directly related to evidence-based exercise prescription and clinical outcome interpretation.

Satisfaction survey

Post-intervention student satisfaction (T1) was assessed using a 12-item survey rated on a 5-point Likert scale. The highest mean scores were reported for Item 3 (Relevance and Utility of Topics Discussed; 4.14 ± 0.748) and Item 4 (Effectiveness of Inter-University Comparison;

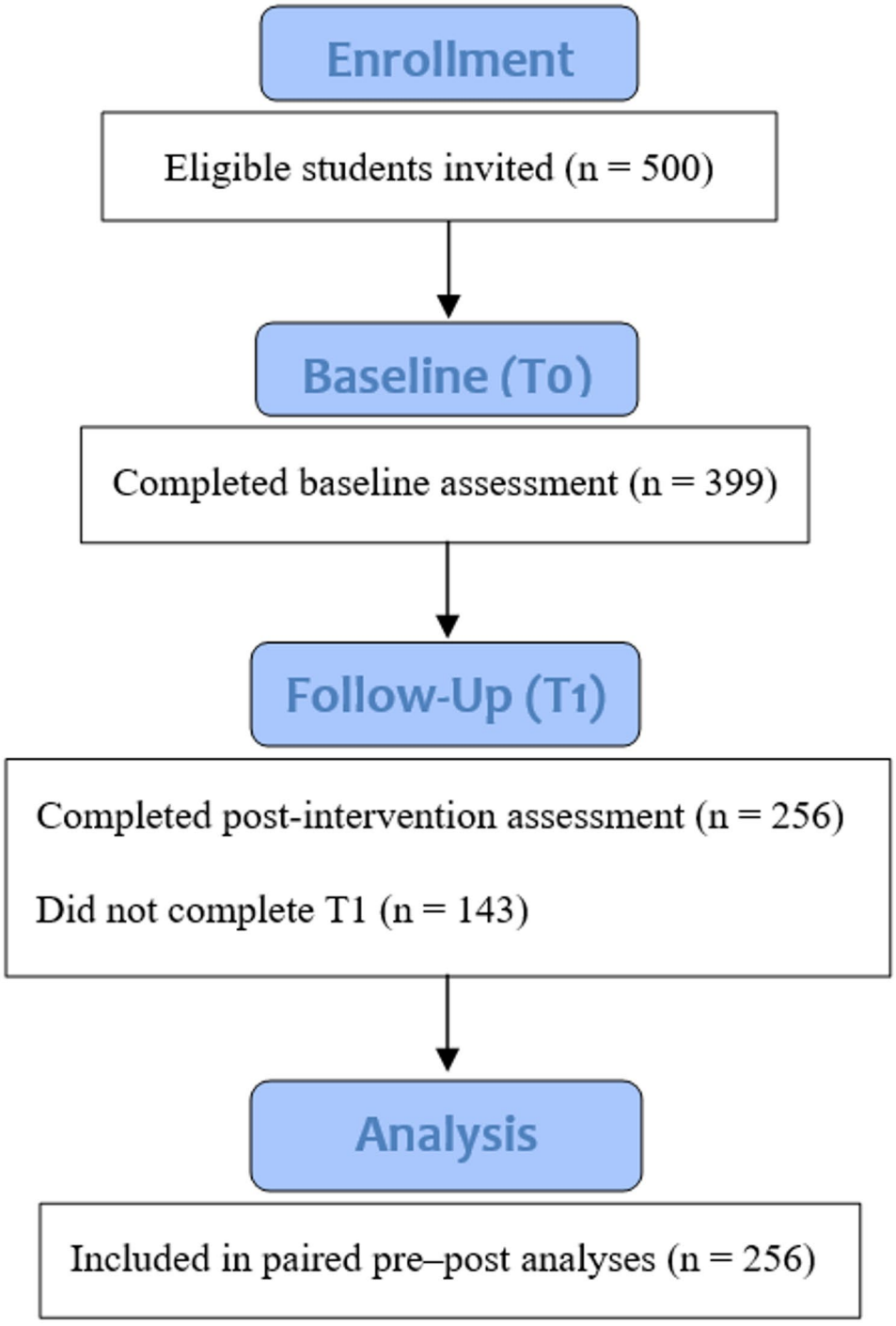

Fig. 2 Flow of participants through the CBLC recruitment and assessment phases

3.97 ± 0.820), indicating strong perceived value of inter-university engagement and content applicability.

Conversely, lower mean scores were observed in items related to technical aspects and time management, including Item 12 (2.98 ± 0.980) and Item 10 (3.08 ± 1.085). These results suggest areas for potential improvement in future iterations of the CBLC, particularly regarding organizational logistics and clarity of instructions.

Overall, satisfaction ratings were generally above the neutral midpoint for most items, indicating acceptability of the initiative while also highlighting specific organisational and technical aspects that may be optimised in future iterations. Results are detailed in Table 3.

Table 2 Item-level accuracy rates before (T0) and after (T1) the intervention, grouped by subscale of the competence questionnaire

Subscale	Item	Correct T0 (*n*/%)	Incorrect T0 (*n*/%)	Correct T1 (*n*/%)	Incorrect T1 (*n*/%)
General Section	1	324 (81.2%)	75 (18.8%)	214 (83.6%)	42 (16.4%)
	2	264 (66.2%)	135 (33.8%)	172 (67.2%)	84 (32.8%)
	3	200 (50.1%)	199 (49.9%)	140 (54.7%)	116 (45.3%)
	4	309 (77.4%)	90 (22.6%)	198 (77.3%)	58 (22.7%)
	5	276 (69.2%)	123 (30.8%)	158 (61.7%)	98 (38.3%)
Case-Specific Section	6	385 (96.5%)	14 (3.5%)	244 (95.3%)	12 (4.7%)
	7	384 (96.2%)	15 (3.8%)	248 (96.9%)	8 (3.1%)
	8	162 (40.6%)	237 (59.4%)	104 (40.6%)	152 (59.4%)
	9	195 (48.9%)	204 (51.1%)	126 (49.2%)	130 (50.8%)
	10	238 (59.6%)	161 (40.4%)	173 (67.6%)	83 (32.4%)

Table 3 Descriptive statistics for each item measured on a 5-point Likert scale of the satisfaction survey

Item	Total Responses	Mean	Standard Deviation (SD)
Item 1	256	3.87	0.715
Item 2	256	3.72	0.798
Item 3	256	4.14	0.748
Item 4	256	3.97	0.820
Item 5	256	3.84	0.913
Item 6	256	3.83	0.904
Item 7	256	3.23	1.059
Item 8	256	3.64	0.867
Item 9	256	3.09	1.008
Item 10	256	3.08	1.085
Item 11	256	3.37	0.991
Item 12	256	2.98	0.980

Table 4 Comparison of mean competence questionnaire scores before and after the CBLC

Section	Before CBLC (mean ± SD)	After CBLC (mean ± SD)	*p*-value
General Section (Items 1–5)	3.59 ± 1.043	4.02 ± 1.414	< 0.001
Case-Specific Section (Items 6–10)	3.46 ± 0.932	3.46 ± 1.035	0.945
Full Questionnaire (Items 1–10)	7.05 ± 1.390	7.47 ± 1.879	< 0.001

Inferential analysis

To evaluate the effectiveness of the CBLC, inferential statistics were employed to compare within-group differences in students' competence scores before (T0) and after (T1) the intervention. All statistical assumptions were verified prior to analysis. The Shapiro–Wilk test indicated normal distribution for the overall scores and subscale scores of the Competence Questionnaire ($p > 0.05$), thus justifying the use of parametric testing. Consequently, paired-sample t-tests were conducted to detect changes over time.

As shown in Table 4, a statistically significant improvement was observed in the General Section of the Competence Questionnaire, with mean scores increasing from 3.59 ± 1.043 at baseline to 4.02 ± 1.414 post-intervention ($p < 0.001$). The corresponding effect size was small (Cohen's d = 0.33; 95% CI: 0.21 to 0.45), indicating a modest but meaningful short-term educational impact. Similarly, the total score across all ten items showed a significant increase, from a pre-intervention mean of 7.05 ± 1.390 to 7.47 ± 1.879 at T1 ($p < 0.001$), indicating a small but statistically robust gain in competence, with a small effect size (Cohen's d = 0.29; 95% CI: 0.18 to 0.40).

These findings remained statistically significant when applying a Bonferroni-adjusted threshold for the three pre-specified scale-level comparisons (adjusted $\alpha = 0.0167$).

By contrast, no significant difference was found in the Case-Specific Section, with identical mean scores at both time points (3.46 at T0 and T1; $p = 0.945$), and the associated effect size was negligible (Cohen's d = 0.01; 95% CI: − 0.10 to 0.12) indicating no measurable change following the intervention.

This null finding was considered a meaningful result of the present evaluation and is addressed in greater depth in the Discussion.

Table 5 Internal consistency analysis of the satisfaction survey

Item	Cronbach's Alpha if Item Deleted	Corrected Item–Total Correlation
Item 1	0.912	0.472
Item 2	0.911	0.500
Item 3	0.907	0.614
Item 4	0.908	0.580
Item 5	0.912	0.506
Item 6	0.907	0.611
Item 7	0.899	0.780
Item 8	0.902	0.716
Item 9	0.900	0.759
Item 10	0.899	0.781
Item 11	0.900	0.762
Item 12	0.904	0.684
Total	**0.913**	—

Psychometric properties

As part of the secondary objective, the internal consistency of the Competence Questionnaire and the Satisfaction Survey was assessed using Cronbach's alpha (Table 5). The Competence Questionnaire showed borderline internal consistency (Cronbach's $\alpha = 0.691$),

slightly below the conventional acceptability threshold (≥0.70). Given the dichotomous scoring format and the heterogeneity of item content across general and case-specific domains, this pattern is more consistent with limited internal coherence than with uniformly poor item performance. Accordingly, competence scores should be interpreted with caution, particularly for subscale-level comparisons or summative interpretations.

In contrast, the Satisfaction Survey demonstrated excellent internal consistency, with an overall Cronbach's alpha of 0.913. Corrected item-total correlations ranged from 0.472 (Item 1) to 0.781 (Item 10), and all "alpha if item deleted" values remained below the total scale alpha, reinforcing the coherence of the instrument.

Discussion

In interpreting these findings, it is important to distinguish between the broader educational aims of the Case-Based Learning Challenge (CBLC) and the specific student-level outcomes assessed in the present evaluation, which examined the feasibility and short-term educational impact of a digitally mediated, inter-university simulation for third-year physiotherapy students in Italy. Overall, the CBLC was associated with modest yet statistically significant improvements in general cardiorespiratory physiotherapy knowledge and was perceived as an acceptable and educationally relevant experience by participating students across institutions.

Given the timing of the assessment, the observed pre–post differences should be interpreted as short-term educational outcomes rather than evidence of durable learning or transfer to clinical practice. In final-year students, immediate post-intervention performance may reflect consolidation and reorganisation of existing knowledge stimulated by structured peer discussion and increased salience of key decision points, rather than acquisition of new factual content. Accordingly, in the present study the competence questionnaire captured short-term performance on applied decision-making items within a controlled educational context.

Our findings align with prior evidence that case-based and simulation-informed approaches can support clinical reasoning and related cognitive skills across health professions education. Systematic reviews reported that CBL can facilitate knowledge integration, problem-solving, and communication skills development [39, 40], and similar benefits have been described in physiotherapy education [41]. In line with this literature, the CBLC was associated with improvements in general domains relevant to evidence-informed exercise prescription and clinical data interpretation.

However, the absence of measurable improvement in the case-specific section warrants consideration. High baseline accuracy in several items suggests a ceiling effect that may have constrained detectable change. Persistent difficulty in selected domains—most notably interpretation of the 6-Minute Walk Test—also suggests that a brief single-session intervention may be insufficient to shift performance in technically demanding areas. More broadly, this pattern is consistent with the possibility that the CBLC preferentially supports generalisable reasoning strategies (e.g., prioritisation and justification of decisions) rather than immediate gains in case-bound item performance.

The CBLC differs from standard CBL implementations by integrating synchronous, inter-university peer comparison within a digitally mediated simulation. This emphasis on cross-institutional dialogue and peer critique is consistent with evidence that structured digital case-based activities can support collaborative readiness and reflective learning [42, 43]. The feasibility of enrolling a large national cohort also supports the reach of synchronous online delivery, consistent with prior physiotherapy education literature on digitally supported formats that improve accessibility while maintaining learning outcomes [19, 44].

Pedagogically, the CBLC was grounded in active learning principles, prioritising learner autonomy, peer interaction, and evidence-informed reasoning. These elements are consistent with work indicating that metacognitively oriented collaborative tasks can strengthen clinical insight and contextual flexibility [45]. Within this framework, student feedback provides complementary information on acceptability and feasibility.

Although the CBLC was innovative in design, satisfaction ratings should be interpreted as moderate rather than uniformly high. Large-scale synchronous delivery may reduce opportunities for direct interaction, personalised feedback, and sustained engagement. In addition, most participants contributed as observers rather than presenters, potentially attenuating perceived involvement. Lower ratings related to time management and technical organisation further suggest that logistical constraints inherent to multi-institutional events influenced students' overall experience. In this context, the satisfaction survey is best interpreted as an indicator of feasibility and acceptability rather than a direct measure of educational effectiveness.

Finally, evaluation findings highlight implications for measurement. While the satisfaction survey demonstrated excellent internal consistency ($\alpha = 0.913$), the competence questionnaire showed borderline reliability. This may reflect the dichotomous scoring format and heterogeneity of item content across general and case-specific domains, which can limit internal coherence when a tool is used as a scale. Borderline reliability may reduce measurement precision and attenuate observable effects, particularly at the subscale level; therefore, fine-grained

interpretations of competence change should be made cautiously. This aligns with prior observations regarding the limited availability of validated instruments targeting clinical reasoning assessment in physiotherapy education [46].

Generalizability and implications

From a resource perspective, the CBLC required organisational coordination (case development, moderation, and administration of evaluation tools), yet its delivery model was intentionally designed to minimise direct costs and maximise reach. In the present implementation, the digital infrastructure was already available within participating universities, and the primary investment consisted of academic and coordination time rather than additional financial expenditure. While measured short-term improvements were modest and no change was detected in the case-specific section, the educational rationale of the CBLC extends beyond immediate test performance in final-year students who are expected to already possess core theoretical content. By requiring structured preparation, peer comparison, and evidence-informed justification of clinical decisions, the CBLC provides a national formative context that may foster critical thinking and an EBP-oriented professional mindset—competencies central to contemporary physiotherapy training and to the longer-term development of the profession. In this sense, the present findings support the CBLC as a feasible national prototype with low marginal cost per additional participant, whose educational impact may be strengthened through iterative refinements (e.g., repeated editions, enhanced active roles for observers, and assessment approaches better aligned with reasoning processes and longer-term retention).

Although implemented within a single-country context, this model may be adaptable to other healthcare education systems seeking to extend access to collaborative case-based learning. Practical barriers for broader dissemination may include language and coordination requirements; however, these constraints may also be leveraged to promote engagement with the international scientific community and shared evidence standards [43, 47].

From a policy and curriculum-development perspective, the CBLC functions as a proof-of-concept for national coordination in physiotherapy education. Its development within the framework of the Italian Permanent Conference of Health Professions Degree Courses offers a replicable structure for embedding peer-led, simulation-informed learning activities within broader educational strategies. However, programme-level alignment was not directly evaluated in the present study, and conclusions should therefore be limited to feasibility and student-level outcomes.

Limitations of the study

Several limitations should be acknowledged. First, the absence of a control group and randomisation limits causal inference, and external factors may have contributed to the observed changes. Although inferential analyses focused on a small set of pre-specified scale-level comparisons, any exploratory interpretation of multiple item-level tests would warrant formal multiplicity adjustment to control Type I error. Because participation was voluntary and delivered outside scheduled curricular teaching hours, self-selection bias is possible, and the sample may over-represent students with greater motivation or interest in cardiorespiratory physiotherapy and digitally mediated learning.

Second, attrition between baseline and post-intervention assessments may introduce selection bias. Because reasons for non-completion were not systematically captured, it cannot be determined whether students completing T1 differed from those who did not. Consequently, observed pre–post differences should be interpreted cautiously as short-term outcomes among participants with paired responses. Future evaluations should prospectively record reasons for non-completion and, where feasible, conduct attrition analyses (e.g., baseline comparisons between completers and non-completers).

Third, most students participated as observers rather than presenters; despite interactive opportunities during the Q&A phase, limited direct involvement in case preparation may have reduced the depth of experiential learning for some participants. This asymmetry in roles (active presenters vs. guided observers) may also have influenced both competence performance and satisfaction ratings and could not be disentangled in the present study. Furthermore, observer participants were recorded as a single aggregated group and institution-specific identifiers were not collected, precluding analyses at the individual programme level and limiting any assessment of baseline equivalence between role groups.

Finally, no follow-up period was included to assess longer-term retention or translation of learning into clinical practice. Conclusions about sustained impact therefore remain speculative. Taken together, the present results should be interpreted as evidence of feasibility and short-term educational impact rather than durable learning or clinical competence development. In addition, we did not conduct a formal economic evaluation or prospectively quantify staff time and coordination workload; therefore, cost–benefit considerations should be interpreted qualitatively rather than as estimates derived from measured resource metrics.

Conclusions

The Case-Based Learning Challenge (CBLC) represents a novel and scalable approach to fostering clinical reasoning, communication, and decision-making skills in physiotherapy education through a digitally mediated, inter-university format. By integrating simulation-based learning with peer-led discussion and national collaboration, the CBLC enabled active engagement across a large and diverse cohort of students.

Within a low-cost digital delivery framework, the CBLC appears feasible for repeated national implementation, particularly as an adjunct to existing curricula. The observed improvements in general clinical knowledge, together with generally favourable student perceptions, support its acceptability and short-term educational value. At the same time, the findings underscore the need for future evaluations to incorporate outcome measures more sensitive to reasoning processes, as well as follow-up assessments capable of capturing longer-term learning and transfer to clinical practice.

Although further refinement of assessment tools and more rigorous comparative designs are warranted, the CBLC offers a scalable template for delivering a shared national learning experience in physiotherapy education. Future research incorporating institution-level indicators and predefined benchmarking metrics will be necessary to evaluate its potential contribution to harmonised training expectations across programmes.

Abbreviations

AIFI	Associazione Italiana di Fisioterapia
CBL	Case-based learning
CBLC	Case-based learning challenge
COPD	Chronic obstructive pulmonary disease
EBP	Evidence-based practice
GDPR	General Data Protection Regulation
ID	Identification document
Q&A	Question and answer
QR code	Quick response code
SPSS	Statistical package for the social sciences
TREND	Transparent Reporting of Evaluations with Nonrandomized Designs
6MWT	Six-minute walk test

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12909-026-08610-3.

Supplementary Material 1.

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Authors' information

All authors are active members of Italian physiotherapy academic or clinical institutions with expertise in simulation-based and case-based education.

Authors' contributions

Giovanni Sellitto: Conceptualization; methodology; project coordination; writing – original draft. Giovanni Galeoto: Statistical analysis; methodology; writing. Manuela Deodato: Case development; data collection; writing – review & editing. Mauro Di Bari: Literature review; peer-review facilitation; manuscript revision. Daniela Garaventa: Recruitment strategy; participant engagement; review. Marco Testa: Evaluation design; supervision; review. Elisa Pelosin: Validation; educational strategy; review. Paolo Pillastrini: Critical revision; methodology alignment. Roberto Gatti: Pedagogical oversight; review. – review & editing; Marco Trucco: Methodology; supervision; data interpretation; writing – review & editing; final manuscript approval.

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Data availability

The datasets generated and/or analysed during the current study are not publicly available due to participant anonymity and institutional data protection protocols. However, data are available from the corresponding author (GS) upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was reviewed and approved by the Ethics Committee for Transdisciplinary Research of Sapienza University of Rome (Approval No. CERT_195E1A36C08). Written informed consent was obtained digitally from all participants prior to participation. The study was conducted in accordance with the Declaration of Helsinki and the European General Data Protection Regulation (GDPR – EU Regulation 2016/679).

Consent for publication

Not applicable. The manuscript does not contain any individual person's data in any form (including images, video, or identifying details).

Competing interests

The authors declare no competing interests.

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