HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

INTEGRATING DICL AND SIMULATION-BASED LEARNING IN PATHOLOGICAL PHYSIOLOGY: EFFECTS ON DIAGNOSTIC COMPETENCE

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Abstract: Diagnostic competence — the ability to gather, integrate, and interpret clinical information to reach an accurate diagnosis — is a core learning outcome of pathological physiology education, yet traditional lecture-based instruction often fails to cultivate it. Two pedagogical strategies have independently shown promise in this regard: case-based approaches that emphasize diverse and inclusive clinical scenarios (conceptualized here as DICL — Diversity, Inclusion, Clinical Learning) and simulation-based learning, which situates students in realistic, interactive clinical environments. This narrative review examines the theoretical and empirical literature underlying both approaches and proposes a conceptual model for their integration in teaching pathological physiology. Drawing on dual-process theories of clinical reasoning, evidence from systematic reviews and meta-analyses of case-based and problem-based learning, and studies of simulation and virtual-patient technologies, we argue that combining diverse, inclusive case exposure with simulation-based practice may address complementary components of diagnostic competence.

Keywords: pathological physiology, diagnostic competence, clinical reasoning, simulation-based learning, case-based learning, diversity and inclusion, medical education, narrative review.

1. Introduction

Diagnostic competence — the capacity to gather relevant clinical data, generate and prioritize hypotheses, and reach a justified diagnostic conclusion — is widely regarded as a central objective of preclinical medical education. Pathological physiology occupies a pivotal position in this process, as it provides the conceptual bridge linking basic biomedical science to clinical presentation. However, when this discipline is taught primarily through lectures and static text-based cases, students often acquire declarative knowledge without developing the reasoning skills required to apply that knowledge in clinical contexts [1,2].

Two distinct lines of pedagogical innovation have addressed this gap. The first emphasizes the use of diverse and inclusive clinical case material — exposing students to a broad range of patient presentations, backgrounds, and disease patterns while ensuring equitable participation of all learners in the analysis of those cases. For the purposes of this review, we refer to this composite approach as DICL (Diversity, Inclusion, Clinical Learning). The second line of innovation is simulation-based learning, which places students in realistic, interactive clinical scenarios — using standardized patients, high-fidelity manikins, or virtual patients — to practice data-gathering and decision-making under conditions that approximate real clinical encounters.

Although each of these approaches has an independent evidence base, their potential integration within pathological physiology teaching has not been systematically examined. This narrative review synthesizes the theoretical foundations of diagnostic reasoning, summarizes the evidence supporting

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case-based and simulation-based methods, and proposes a conceptual framework for combining diverse, inclusive case exposure with simulation-based practice. Priority directions for future empirical testing of this framework are also identified.

2. Theoretical Foundations of Diagnostic Reasoning

Contemporary accounts of clinical reasoning are grounded in dual-process theory, which distinguishes two interacting modes of cognition: a fast, intuitive, pattern-recognition-based mode (System 1) and a slower, deliberate, analytical mode (System 2) [1,2]. Novice learners tend to rely heavily on System 2 analytical processing because they lack the extensive repertoire of clinical "illness scripts" that allows experienced clinicians to recognize patterns rapidly [1]. Building this repertoire requires repeated, varied exposure to clinical presentations, while error-resistant reasoning additionally requires deliberate practice in verifying and revising diagnostic hypotheses [2,8].

This dual requirement — breadth of case exposure to support pattern recognition, and structured, feedback-rich practice to support analytical verification — provides a theoretical rationale for combining two complementary instructional strategies: (a) exposure to a diverse range of clinical cases within an inclusive learning environment, and (b) simulation-based practice that allows deliberate, iterative rehearsal of the diagnostic process under realistic conditions [8].

3. Diversity and Inclusion in Case-Based Instruction

A growing body of literature emphasizes that the diversity of clinical cases to which students are exposed directly shapes the breadth of their diagnostic pattern recognition. Curricula that rely on a narrow, homogeneous set of case presentations risk producing clinicians whose illness scripts are poorly calibrated to the diversity of real patient populations [9,10]. Verbree and colleagues, in a focus-group study of medical students, found that learners themselves perceived a lack of diversity in their curriculum and expressed a need for greater inclusion of varied patient presentations and perspectives, alongside concerns about feeling excluded when teaching materials did not reflect their own backgrounds [9]. Similarly, Charnell and Dennis argue that embedding diverse patient representation into clinical teaching requires deliberate curricular design and resource investment, since case material and volunteer patients are not automatically representative of the populations students will eventually serve [10].

Within the DICL framework, the "Inclusion" component refers not only to the diversity of patients represented in cases, but also to instructional practices that ensure equitable participation of all students in case discussion — for example, structured small-group roles, scaffolded questioning, and explicit attention to language or cultural barriers to participation [9]. Evidence from broader case-based learning research suggests that active, participatory case discussion is associated with improved conceptual clarity and early clinical reasoning skills, although the overall empirical evidence on learning outcomes remains mixed [3,4].

4. Case-Based and Problem-Based Learning: Evidence Base

Case-based learning (CBL) is among the most extensively studied active-learning methods in health professional education. A BEME systematic review by Thistlethwaite and colleagues, encompassing a wide range of studies across medicine and allied health professions, concluded that while students and teachers overwhelmingly enjoy CBL and perceive it as motivating, the empirical

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evidence for its superiority over other teaching methods in terms of measurable learning outcomes is inconclusive [3]. This finding underscores the importance of rigorous outcome measurement in any evaluation of case-based approaches, including DICL.

More recent, narrower meta-analyses present a somewhat more favorable picture. Cen and colleagues, synthesizing eight randomized controlled trials comprising 939 medical students, found that CBL produced statistically significant improvements in academic performance ($p = 0.03$) and, more markedly, in case-analysis ability ($p < 0.001$) relative to traditional teaching methods [4]. Comparable findings have been reported for problem-based learning (PBL): a scoping review by Trullàs and colleagues covering 124 publications found that PBL was generally rated highly by students and was associated with equal or better knowledge retention and academic performance compared with traditional methods, alongside gains in self-directed learning, communication, and problem-solving skills; the same review noted that most available studies were single-center, used small samples, and that PBL's resource intensity has limited its widespread adoption [5].

Taken together, this literature suggests that case- and problem-based approaches can support the development of clinical reasoning skills, but that their effects are heterogeneous across contexts and are constrained by implementation quality and resource availability — considerations directly relevant to the feasibility of a DICL-based curriculum in pathological physiology.

5. Simulation-Based Learning as the Clinical Learning Component

Simulation-based learning extends case-based instruction by allowing students to actively perform, rather than merely discuss, the clinical encounter. Chen and colleagues introduced high-fidelity manikin-based simulation into an undergraduate human pathophysiology course, enabling students to role-play history-taking, physical examination, and clinical decision-making around authentic disease scenarios; the authors reported that this experiential approach helped students see "pathophysiology in action" and bridged the gap between theoretical lecture content and clinical application [6]. Virtual patient technologies offer a scalable complement to manikin-based simulation: Isaza-Restrepo and colleagues, in a mixed quantitative-qualitative study, found that students valued virtual patients as a tool for practicing clinical reasoning in a low-stakes, repeatable format that allowed reflection on their own diagnostic process [7].

From the standpoint of dual-process theory, simulation directly supports the deliberate-practice component of expertise development: it allows learners to test hypotheses, receive feedback, and repeat the reasoning cycle under conditions that approximate, but do not carry the risk of, real clinical practice [8]. Within the proposed integrated framework, simulation constitutes the "Clinical Learning" component of DICL — the stage at which diverse case content, having been introduced and discussed inclusively, is translated into active clinical performance.

6. A Proposed Integrated Model: DICL Combined with Simulation

Building on the theoretical and empirical foundations reviewed above, we propose a three-stage conceptual model for integrating DICL and simulation-based learning in the teaching of pathological physiology.

Stage 1 — Diverse case introduction: Students are presented with a deliberately varied set of clinical vignettes representing different patient demographics, disease severities, and atypical presentations of the pathophysiological mechanism under study, so as to broaden the range of illness scripts to which they are exposed [9,10].

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Stage 2 — Inclusive collaborative analysis: In structured small groups, students construct the cause–mechanism–outcome chain underlying each case, with facilitation designed to ensure equitable participation regardless of language proficiency, prior clinical exposure, or cultural background [9].

Stage 3 — Simulation-based application: Selected cases are then re-enacted through manikin-based or virtual-patient simulation, requiring students to gather data, formulate and revise diagnostic hypotheses in real time, and receive structured feedback during a debriefing session [6,7,8].

We hypothesize — as a proposition to be tested empirically, not as an established finding — that this staged combination may produce effects on diagnostic competence greater than either diverse case-based discussion or simulation alone, because the two components target complementary cognitive demands: breadth of pattern exposure (System 1) and structured, feedback-driven analytical practice (System 2) [1,2,8].

7. Anticipated Benefits and Implementation Challenges

The proposed integration offers several anticipated benefits consistent with the reviewed literature: broadened pattern recognition through diverse case exposure, more equitable engagement of all learners, and hands-on consolidation of theoretical knowledge through simulation [4,6,7,9]. At the same time, the literature on both case-based/problem-based learning and diversity-focused curricular reform consistently identifies resource intensity — faculty time, simulation equipment, and training in inclusive facilitation — as a major barrier to sustained implementation [5,10]. Institutions considering this model should therefore anticipate the need for faculty development and phased implementation rather than wholesale curricular replacement.

A further challenge concerns assessment: because the BEME review found that much of the existing CBL literature relies on inconsistent or underdeveloped outcome measures [3], any evaluation of an integrated DICL-simulation model should employ validated instruments for diagnostic reasoning — such as script concordance tests, structured OSCE stations, or standardized clinical reasoning rubrics — rather than knowledge-recall tests alone.

8. Directions for Future Research

This review is conceptual in nature and does not report new empirical findings. Its central contribution is the theoretical integration of two literatures — diversity/inclusion in case-based teaching and simulation-based learning — that have largely developed independently. Future research should prioritize controlled, multi-site studies (given the small, single-center nature of much existing evidence [3,5]) that directly compare diverse case-based instruction alone, simulation alone, and the combined DICL-simulation model proposed here, using validated measures of diagnostic competence and clinical reasoning. Mixed-methods designs would additionally allow investigation of learners' subjective experience of inclusion and engagement alongside objective performance outcomes [7,9].

9. Conclusion

Diagnostic competence in pathological physiology depends on both the breadth of clinical patterns learners encounter and the depth of analytical practice they undertake. The DICL framework and simulation-based learning each address one of these requirements, and existing literature — though heterogeneous and, in the case of case-based learning generally, inconclusive regarding measurable outcomes [3] — provides theoretical and preliminary empirical support for both approaches individually [1,2,4,5,6,7,8,9,10]. Their combination, as outlined in the proposed three-

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stage model, represents a theoretically grounded but as yet untested instructional strategy. Rigorous empirical evaluation of this integrated approach is needed before firm conclusions about its effectiveness in developing diagnostic competence can be drawn.

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