Innovative Learning in Undergraduate Medical Teaching: Perspective Based on Thirty Years' Experience

Innovation in Undergraduate Medical Teaching

Aprendizagens Inovadoras no Ensino Médico Pré-graduado: Perspetiva Baseada em Trinta Anos de Experiência

Inovações no Ensino Médico Pré-graduado

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ABSTRACT

We reviewed an innovative project in undergraduate medical education, which used problem-based learning and concept maps in pathophysiology teaching. We analyzed publications starting in 1995 and until 2024, to identify factors contributing to its continuity and impact, nationally and internationally.

Problem-based learning was based on the methodology developed by Howard Barrows, a founder of the method. In 1998, we published, internationally, the results of this initial experience, completed by three international publications.

In the early 21st century, this methodology became closer to case-based learning but maintained tutorial sessions, self-directed orientation and small group learning. Simultaneously, concept maps, developed by Novak, as leading promoter of the method, began to be used and were part of final assessment tools. In 2006, an international publication emphasized meaningful learning, recognized by tutors and students, as facilitator to understanding pathophysiological mechanisms of disease, applying basic science to explain clinical manifestations. In 2020, another international publication revisited the whole teaching and learning process.

In 2023 and 2024, two international papers were published, a BEME systematic review on the effectiveness of concept maps in critical thinking and a scoping review on the need to standardize concept maps methodology. In 2024, for the first time in Portugal, we published two international papers on the use of concept maps to promote clinical reasoning in the undergraduate teaching of Family Medicine.

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Key elements of continuity and impact were: inclusion in the core curriculum, open information to students, training medical tutors, use of educational methods and materials validated internationally.

KEYWORDS: Clinical Reasoning; Curriculum; Education, Medical; Schools, Medical; Students, Medical

RESUMO

Revê-se um projeto inovador no ensino médico pré-graduado que utilizou aprendizagem por problemas e mapas concetuais no ensino da fisiopatologia, desde 1995 até final de 2024, para identificar fatores que contribuíram para a sua continuidade e impacto, nacional e internacionalmente.

Aplicou-se a metodologia desenvolvida por Howard Barrows, um dos fundadores do método. Em 1998, publicaram-se os resultados iniciais, e, em anos seguintes, três artigos, igualmente em revistas internacionais.

Na primeira década do século 21, esta metodologia aproximou-se da aprendizagem baseada em casos, mantendo sessões tutoriais, aprendizagem autónoma e ensino em pequenos grupos. Simultaneamente, começaram a utilizar-se mapas conceptuais, desenvolvidos por Joseph Novak, principal promotor do método. Em 2006, uma publicação internacional salientou a relevância da aprendizagem significativa, reconhecida por tutores e estudantes como facilitadora da compreensão dos mecanismos fisiopatológicos das doenças, aplicando conhecimentos das ciências básicas para explicar as manifestações clínicas. Em 2020, uma nova publicação internacional, revisitou toda este processo de ensino e aprendizagem.

Em 2023, publicaram-se dois artigos internacionais, uma revisão sistemática da série *Best Evidence Medical Education* sobre mapas concetuais e pensamento crítico e uma *scoping review* que apontou para estandardização dos mapas concetuais.

Em 2024, publicaram-se, pela primeira vez em Portugal, dois artigos internacionais sobre a utilização de mapas concetuais na promoção do raciocínio clínico no ensino pré-graduado da Medicina Geral e Familiar.

Os elementos-chave da continuidade e impacto do projeto foram: inclusão no *core* curriculum, acesso aberto à informação para os estudantes, formação de tutores e utilização de métodos e materiais pedagógicos validados internacionalmente.

PALAVRAS-CHAVE: Educação Médica; Escolas Médicas; Currículo; Estudantes Medicina; Raciocínio Clínico

INTRODUCTION

The acquisition of knowledge during the early stages of an innovative undergraduate medical curriculum, particularly when addressing basic sciences, involves integrating newly acquired useful information with prior knowledge, promoting long-term retention and its application in the clerkship phase of clinical training. Meaningful learning refers to this process, allowing learners to deeply understand and apply what they have learned. This concept was introduced by David Ausubel as part of his cognitive learning theory.[1] Ausubel distinguished between meaningful learning and rote learning, with the former characterized by integrating new knowledge into the learner's existing cognitive framework, in contrast to memorization without understanding, which characterizes rote learning.

The literature describes several ways to promote meaningful learning in undergraduate medical education. In this review, we will focus on the methods we have employed over the past thirty years, in Pathophysiology teaching, at NOVA Medical School (NMS), using problem-based learning (PBL) and concept mapping. PBL aims to develop reasoning skills through clinical problems that mirror real practice, to enhance contextual learning of the basic sciences.[2] It is an educational approach in which students actively engage in the problem-solving process, fostering their critical thinking and clinical reasoning skills. Concept maps (CMs) are visual representations of the acquired knowledge, developed by Joseph Novak.[3] By creating diagrams that illustrate learned concepts with their interconnections, students can more effectively integrate and retain information, promoting meaningful learning.

In the realm of undergraduate medical education, it is essential to foster skills that support both the retention of knowledge and its application in clinical settings. For a medical student to manage the necessary integration of vast amounts of knowledge, decision-making, and dealing with uncertainties in patient care throughout their training, competencies such as critical thinking and clinical reasoning are fundamental. Critical thinking can be defined by applying higher cognitive skills (...) to information (...) in a way that leads to actions that are precise, consistent, logical, and appropriate.[4] Clinical reasoning, a complex and multidimensional concept, is usually defined, in a general sense, as the thinking and decision-making processes associated with clinical practice and it goes far beyond mere problem-solving abilities. In the context of this manuscript, clinical reasoning is defined as a skill, process, or outcome wherein physicians and students observe, collect, and interpret data to diagnose and treat patients.[5–7]

Over the past three decades, our group has developed and implemented an innovative project in undergraduate medical education at NMS. This work has led to the publication of twelve peer-reviewed articles in international journals, the most relevant of which are listed in Table 1. In addition, two PhD theses related to this initiative have been successfully completed.[8,9]

This long-standing initiative prompted us to review the entire project to identify the factors that contributed to its longevity, given the widely recognized challenges to sustaining education innovations. This review aims to analyze the evolution of this innovative project since our initial publication, in 1995, and to identify the key factors that contributed to its continuity and impact. Since the project was designed for a single undergraduate discipline, we examined how the PBL educational process and the use of CMs were implemented alongside broader curricular changes which occurred during this period, at NMS. We aimed to identify and evaluate this pathway, recognize its successes and challenges, and assess its impact on undergraduate medical education at national level and its relation to similar international initiatives.

TABLE 1. Selected publications resulting from the undergraduate medical education project developed at NMS.

Article	Journal	Journal Category	SJR Quartil	Theme and focus
Rendas *et al.* 1995	Acta Med Port	Medicine	Q3	PBL: in basic sciences of medical course
Rendas *et al.* 1998	Teach Learn Med	Medicine Education	Q1 Q1	PBL: global evaluation of the 1st stage of the project
Rendas *et al.* 1999	Med Educ	Medicine Education	Q1 Q1	PBL: computer simulation
Rosado Pinto *et al.* 2001	Med Teach	Medicine Education	Q1 Q1	PBL: tutor's performance
Barahona Corrêa *et al.* 2003	Adv Physiol Educ	Physiology Education	Q3 Q2	PBL: relation between learning issues and content
Rendas *et al.* 2006	Adv Physiol Educ	Physiology Education	Q3 Q2	PBL and CM: global evaluation of the 2nd stage of the project
Neuparth *et al.* 2016	Psychiatr Danub	Medicine Psychiatry and Mental Health	Q3 Q3	PBL: Pathophysiology as an autonomous discipline
Fonseca *et al.* 2020	Adv Physiol Educ	Physiology Education	Q3 Q2	CM: revisiting its use in teaching and learning in the context of Pathophysiology
Fonseca *et al.* 2023	Med Teach	Medicine Education	Q1 Q1	CM: BEME systematic review to analyse its role as tool for critical thinking in undergraduate medical education
Oliveira *et al.* 2023	KM&EL	Education	Q3	CM: scoping review to standardize its use in medical education
Fonseca *et al.* 2024	Adv Health Sci Educ	Medicine Education	Q1 Q1	CM: promoting clinical reasoning in undergraduate Family Medicine: qualitative approach
Fonseca *et al.* 2024	BMC Med Educ	Medicine Education	Q1 Q1	CM: promoting clinical reasoning in undergraduate Family Medicine through multimorbidity cases

BEME: Best Evidence Medical Education; CM: concept map; NMS: NOVA Medical School; PBL: problem-based learning; SJR: Scientific Journal Rankings.

IMPLEMENTATION OF PBL

In 1983, NMS introduced Pathophysiology as an independent academic discipline within Portuguese medical education, using innovative teaching methods that combined traditional approaches, mainly lectures, with small-group tutorials, fostering self-directed learning among students. This early phase laid the groundwork for adopting PBL, inspired by the pioneering work at McMaster University, in Canada, namely by Howard Barrows, where academic clinicians had developed PBL since 1965. The McMaster's approach was based on biomedical problem-solving and evolved over five decades through prioritization of health-related problems, concept-based learning, and a recent focus on transferable skills.[10]

In the early 1990s, the first author of this paper, was then the Head of Pathophysiology and Dean at NMS, and attended one of Howard Barrows's workshops on PBL, in Southern Illinois University School of Medicine (SIUSM), USA.[11] Recognizing the value of PBL in medical education, he invited Barrows and his team to Portugal, which led to educational seminars on PBL, in 1990 and 1992 supported by the Luso-American Foundation. These seminars were attended by academics from most Portuguese medical schools and provided the foundation for introducing PBL in NMS's undergraduate medical curriculum. Initially, NMS implemented PBL in Pathophysiology, using clinical problem simulations to help students understand complex disease mechanisms and body-system dysfunctions.[12] This pathophysiology-focused implementation served as a model and encouraged other disciplines, such as Biochemistry and Physiology, at NMS, to adopt PBL on a trial basis.

This approach followed Barrows's core principles: problem simulations, based on real patients, that were open-ended to encourage inquiry; self-directed learning, collaborative tutorials with the tutors acting as facilitators rather than traditional lecturers International publications from our project explored various PBL aspects, including the use of computer simulations, the role of tutors, and the importance of linking learning issues to the discipline content. NMS acquired PBL-modules for tutorials, from SIUSM, adapting them to computer-based simulations. By 1998, NMS published its experience with PBL in Pathophysiology, emphasizing how this model helped the students to bridge the gap between basic sciences and upcoming clinical disciplines.

The PBL project continued in the following years since Pathophysiology, as a discipline, was part of the core undergraduate curriculum at NMS, simultaneously with the use of traditional teaching methods by other disciplines. Our findings, based on the analysis of tutor's and student's questionnaires, showed that this innovation was useful as a method to improve learning of disease mechanisms and understanding clinical manifestations as biological and physiological dysfunctions of the body. However, PBL failed to give us concrete evidence on the way the students reasoned throughout the sessions, in terms of critical thinking, organization of the acquired information and application of the newly acquired knowledge to the analysis of the problem. This limitation led us to apply CMs as visual tools of the learning process.

IMPLEMENTATION OF CMS

In contrast to PBL, where established rules had been in place for decades and methods were already in use across a diverse range of medical schools around the world, some of them highly prestigious institutions, CMs had not yet achieved the same level of adoption and implementation in international medical education. Joseph Novak, as previously mentioned, was the founder of concept mapping, and is original focus was on science education, not medical education. According to Novak, concept mapping is a visual representation of the cognitive analysis of a focus question, illustrating how information is used, what concepts are involved, and the connections between them. To promote standardization in concept mapping, Novak developed specific procedures, later described by Pinto and Zeitz,[13] particularly concerning the construction of CMs, in medical education. According to Daley and Torre,[14] CMs help medical students to organize and integrate information into their existing knowledge networks, gain insights into new concepts, and apply them effectively.

In the teaching of Pathophysiology, we have used CMs to visually represent the learning process and stimulate both individual and group learning during the sessions, particularly in relating basic science concepts to the pathophysiological changes found in clinical cases to facilitate learning of the underlying disease mechanisms. We first introduced CMs in the academic year of 2002/03, in a class of 14 students, to help organize the information gathered during the analyses of long cases (lasting for several sequential sessions), using PBL. The students' maps, constructed on paper, were compared with a reference map. In the academic year of 2003/04, we used CMs, constructed from short clinical vignettes, using Inspiration® software, in single tutorial sessions. The aim of these CMs was to support better understanding and acquisition of specific content related to pathophysiological mechanisms. In the academic year of 2004/05, the use of CMs was expanded to all the tutorial sessions of the Pathophysiology discipline, and in 2010/11, we transitioned to using Cmap Tools® software, due to its wider range of graphical displays and its free availability.

In 2011, a major curricular reform took place at NMS, reorganizing all curricular units into semesters to fully align with the European Bologna process. In the case of Pathophysiology, the discipline was shifted from the 3rd to the 2nd year, but the syllabus was kept and maintained its innovative pedagogical approach, based on tutorial sessions and using clinical vignettes and CMs (Fig. 1 and Fig. 2). During this period, core concepts were identified for each clinical vignette, making a clear shift from PBL to case-based learning (CBL).

In 2017 and 2018, an additional review was carried out to adjust the format of the cases into shorter vignettes, enhancing pedagogical support for tutors, and refining student assessment methods.

A phase of improvement in the pedagogical methodology began, with more in-depth research on concept mapping, focusing particularly on its construction and use,[15] the relevance of linking words,[16] and its assessment and scoring.[17]

After 2020, while maintaining the use of CMs, as previously described, a project was initiated to expand their use in the clinical cycle. Relevant developments included a systematic review of the use of CMs in undergraduate education to promote critical thinking, the first BEME coordinated by a full Portuguese team, and a scoping review, comparing different types of CMs.

For the first time in the NMS curriculum, CMs were introduced in the Family Medicine discipline, using clinical vignettes, to promote the learning of clinical reasoning in patients with multimorbidity.

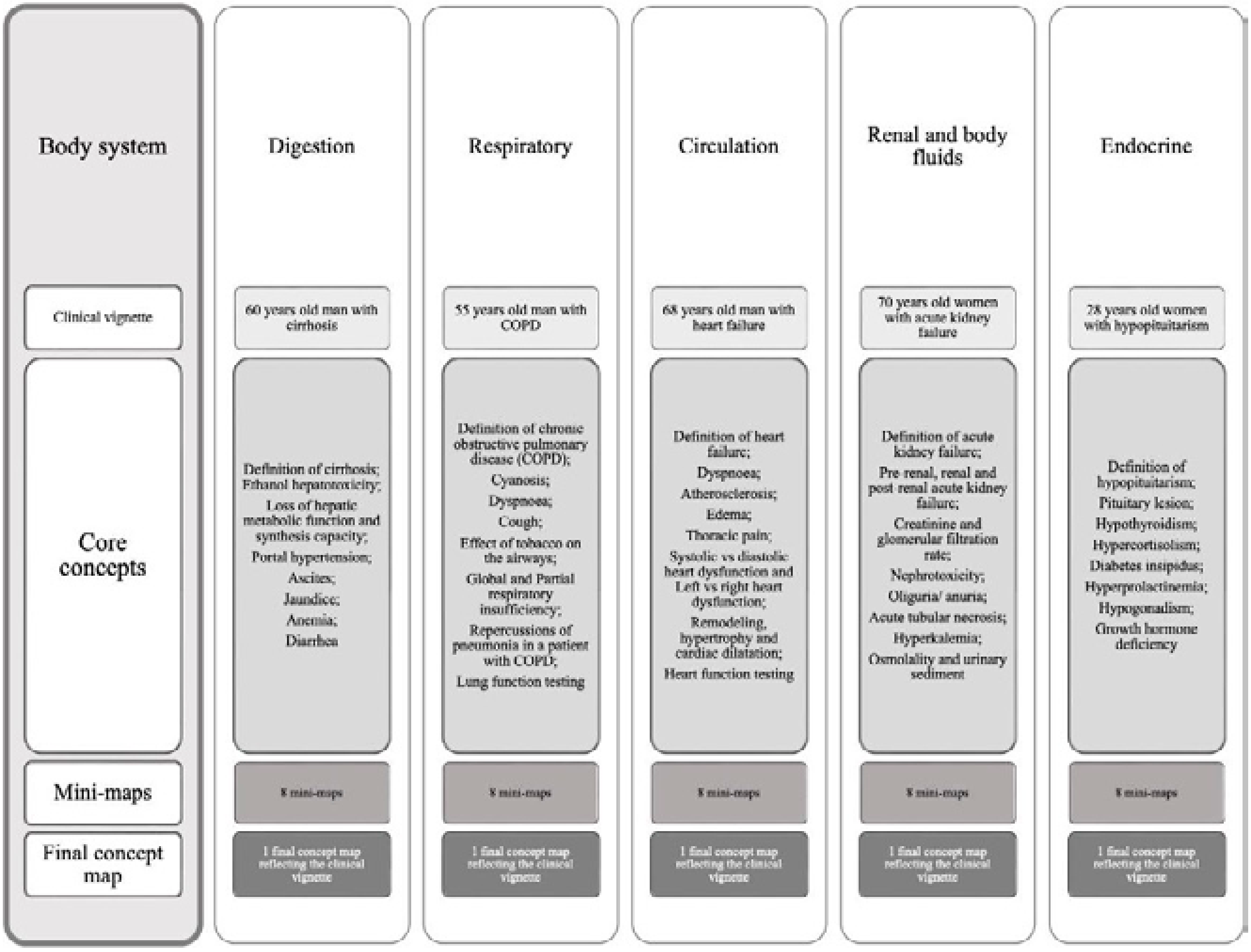

FIGURE 1. Curricular organization of the semestral tutorial sessions using clinical vignettes with specific core concepts and different concept maps.

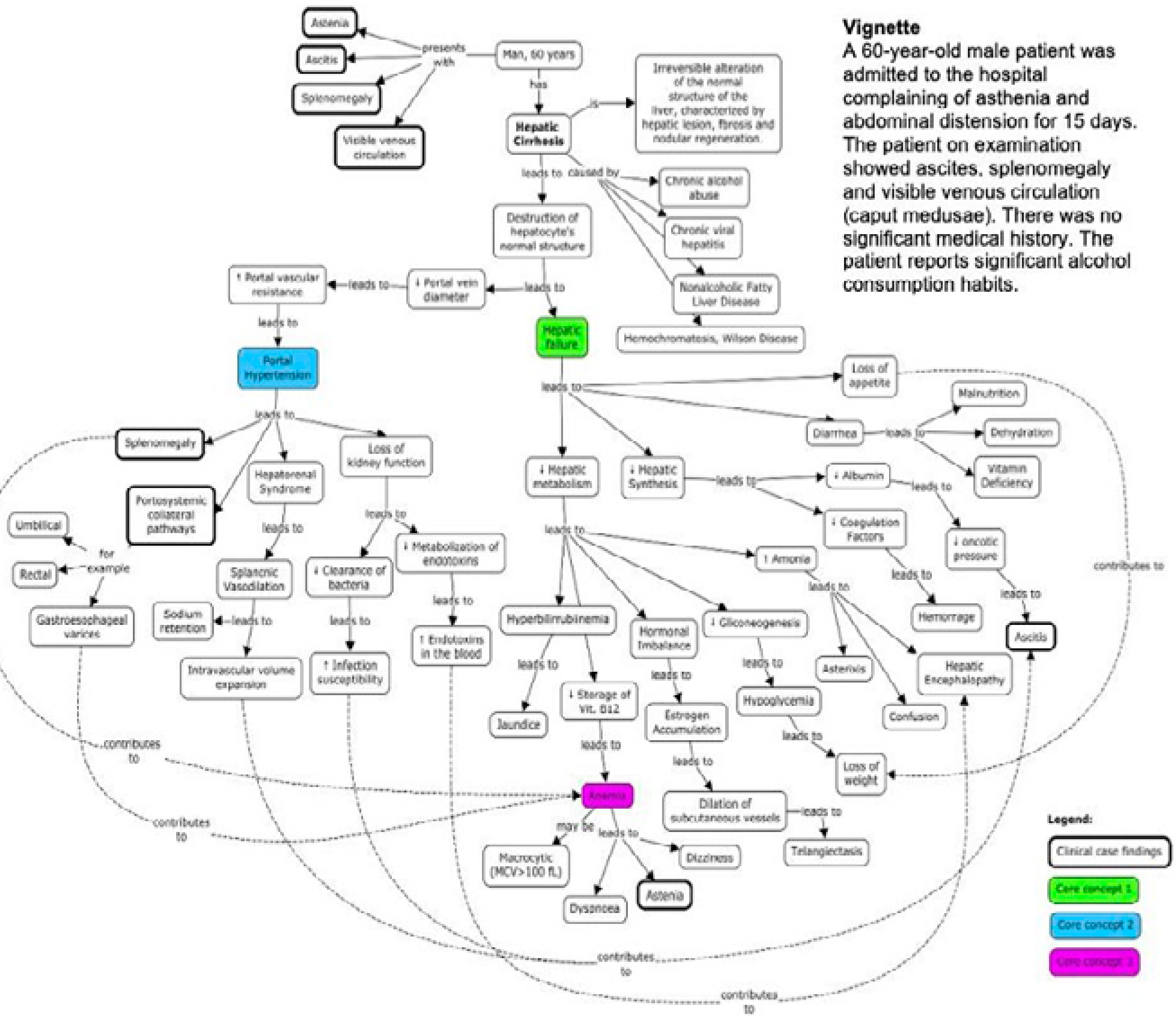

FIGURE 2. Example of a final concept map displaying the pathophysiological mechanisms of three specific core concepts (adapted from Fonseca M *et al.* 2020).

DISCUSSION

Long-term continuity of educational innovations in medical education is uncommon, as most initiatives focus on short-term, small-scale interventions based on optional disciplines not part of the core curriculum. Furthermore, many of these projects are not pursued over time, lack in-depth validation, and fail to evaluate their longitudinal impact. The implementation of PBL and CM at NMS stands out in this regard, having been formally integrated into the core curriculum, applied to entire student class, and sustained for over three decades.

A fundamental aspect of this longevity was that students experienced PBL alongside traditional teaching methods, including lectures and structured assessments, ensuring a balanced approach. The final multiple-choice examination, which accounted for 50% of the final grade, was maintained to align with institutional assessment standards. These elements ensured broad acceptance and reinforced the legitimacy of the innovation.[18]

Several key factors contributed to the successful long-term implementation of PBL and CMs at NMS. One of the most significant was the formal inclusion of PBL in the core curriculum. Unlike many educational innovations that remain experimental, the integration of PBL as part of the mandatory curriculum was crucial for its sustainability. This institutional commitment provided a stable framework for its continued development and refinement.

Another critical factor was clear communication with students and faculty training. A common challenge in implementing student-centered learning methods is the initial resistance from students and faculty accustomed to traditional lecture-based education. At NMS, detailed explanations of the PBL process were provided to all students, particularly during the initial tutorial sessions, ensuring clarity on its objectives and structure. Additionally, tutors were formally trained in PBL and CM methodologies and were all medically qualified, ensuring they could effectively facilitate the learning process. The Barrows-inspired tutorial model, based on open inquiry and student-centered learning, was consistently applied, with faculty acting as facilitators rather than lecturers. This alignment with internationally recognized methodologies enhanced the credibility and effectiveness of the approach.

The adaptability of PBL to curricular changes also played a crucial role in its sustainability. The 2011 curricular reform at NMS, which reorganized courses into semester-based structures, necessitated a shift from full case studies to shorter vignettes, resembling CBL. This transition required identifying and focusing on core pathophysiological concepts, which were effectively structured using CMs. The progressive evolution of PBL at NMS—from full case studies to short vignettes and ultimately expanding into clinical reasoning education—demonstrates its flexibility and resilience over time.

The analysis of student feedback and assessment outcomes indicates that PBL and CM successfully facilitated a shift from rote memorization to meaningful learning, which is essential for developing clinical reasoning skills. PBL enhanced self-directed learning and problem-solving abilities, helping students integrate knowledge across disciplines. At the same time, CMs provided a structured approach to visualizing complex relationships between basic sciences and clinical manifestations, reinforcing knowledge retention and application. However, one limitation of early PBL implementation was the difficulty in explicitly assessing students' reasoning processes. While PBL fostered active learning, it lacked a structured means of evaluating how students organized, connected, and applied information during problem-solving.[11] The introduction of CMs addressed this gap by providing a tangible representation of students' cognitive processes, enabling tutors to evaluate and refine reasoning skills.

Recently, interest in PBL in medical education has increased, as evidenced by three major systematic reviews. A scoping review by Trullàs et al. examined the effectiveness of PBL on medical learning,[19] while two reviews published in 2024, identified over 500 universities worldwide—particularly in Asia, Africa, and the Middle East—that have adopted PBL-based curricula.[20,21] These studies highlight the need for adaptations to local scientific, social, and cultural contexts. However, none of these reviews explored assessment methodologies, a crucial aspect for evaluating the impact of PBL on student performance.[22] This lack of focus on assessment further underscores the significance of our approach at NMS, where the need for evaluation and reflection led to the integration of CMs into PBL tutorials.

At the national level, it remains difficult to evaluate whether any significant impact has occurred, but it is interesting to note that all new medical courses established in Portugal in the last decade mention the use of PBL methodology, either globally or partially. As far as we could determine, there are no Portuguese publications describing the use of CMs in national medical education. This global pattern reflects the scarce and heterogeneous contributions of Portuguese publications in undergraduate medical education, as we have recently reported.[23] In addition, the output of international papers on innovations in medical education, from undergraduate to postgraduate and continuing medical education, by Portuguese authors, remains scarce.

International publications on the combined use of PBL and CMs are also scarce. Notably, a study by Addae et al. explored a hybrid system integrating PBL, lectures, and CMs, finding improvements in critical thinking and integration of clinical information.[24] Similarly, Veronese et al. conducted a randomized study demonstrating that CMs enhanced basic science learning and clinical application, bridging the gap between preclinical and clinical education.[25] More recently, Peñuela-Epalza and De La Hoz examined the use of CBL combined with CMs to support clinical reasoning in internal medicine training.[26]

Our latest research has further contributed to these discussions by extending the use of CMs beyond preclinical education into Family Medicine, where they serve as tools for clinical reasoning in multimorbidity cases. This vertical integration represents a promising direction for medical education, strengthening the connection between basic sciences and clinical practice.

In our experience, CMs have proven to be a valuable tool to complement active teaching methods, especially PBL, and to facilitate knowledge organization, critical reasoning and integration between basic science and clinical teaching. Given the possibility of future introduction of Team-Based Learning (TBL) at NMS, it can be anticipated that a similar synergy could occur, reinforcing meaningful learning. In this new context, CMs may serve as a cognitive support for analyzing and discussing content while structuring teamwork and developing problem-solving skills, thus promoting better retention and applicability of knowledge. CBL in small groups will be implemented and probably complement individual and group assessments in large groups through TBL.[27] The content integration of the different disciplines will occur progressively during the first years of the curriculum, enabling pedagogical methods to be student-centered allowing critical thinking and the progressive development of clinical reasoning skills. This will represent a challenge for educational innovations, through new digitally supported approaches. Future research should investigate how these innovations can be effectively integrated and how they might impact in clinical reasoning and self-directed learning. However, rather than replacing existing methods, a more comprehensive educational strategy that combines traditional and innovative approaches could provide a richer learning experience that benefits both students and teachers.[28]

Moving forward, the sustainability of our approach will depend on continuing faculty development, digital integration, and collaboration with other institutions. Future research should focus on refining assessment methods, evaluating long-term clinical impact, and exploring new applications of CMs in clinical training. By building national and international partnerships, we can further enhance the visibility and impact of these methodologies in medical education.

CONCLUSION

The introduction of PBL in Portugal in the last decade of the 20th century had limited impact at a national level, despite the direct involvement of Howard Barrows—one of its founding figures—in faculty training workshops. While local implementation at NMS was successful, at the level of a single discipline, broader local and national adoption remained fragmented and inconsistent. Interestingly, however, all new Portuguese medical schools established in the past decade claim to incorporate some degree of PBL methodology, suggesting that its influence may be more subtle and yet enduring.

In contrast, as far as we could determine, CMs have not been widely applied in Portuguese medical education. This reflects a broader trend of limited scholarly contributions from Portugal in the field of medical education innovation, as previously noted in our reviews. Despite this, we hope that the international publications stemming from our project have contributed to global discussions on integrating PBL and CMs in medical education.

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