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Anatomical education and its innovations: an interdisciplinary, hands-on, team-building approach

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Abstract. Contemporary approaches in anatomical education, such as problem-based learning, case-based learning, and the flipped classroom, grounded in evidence and tailored to student needs, have demonstrated marked enhancements in student engagement and interactions. These methodologies shift the educational focus from passive knowledge transmission to active knowledge construction by students, fostering task-oriented learning. This inquiry explores the implementation of a dynamic, multimodal, and engaging learning approach to teach second-year MBBS students about musculoskeletal and splanchnic anatomy at the School of Medicine, The University of Bari 'Aldo Moro', Bari, Italy. Additionally, it investigates student perceptions regarding anatomy learning and traditional lectures, along with their views on participating in problem-based learning sessions. In these problem-based learning sessions, small groups of students engage in discussions, formulate hypotheses, establish learning objectives in anatomy, and virtually dissect human bodies using the Anatomage Table. This innovative approach provides a comprehensive view of the anatomy of the body region, aiding the exploration of structures relevant to the symptoms presented by patients described in the problem-based learning sessions. The academic performance of students exposed to active learning is compared with that of their more traditionally taught counterparts. Our findings underscore the efficacy of employing an active, multimodal, and engaging learning strategy based on Anatomage-enhanced problem-based learning as a potent additional tool in anatomy education. To further validate these outcomes, future research endeavors should include randomized controlled trials, aiming to assess the comparative effectiveness of different learning strategies that have the potential to advance medical education.

Keywords: anatomy, student-centred learning strategies, active and engaging learning, medical education, multimodal approach.

INTRODUCTION:

The Medicine and Surgery degree program aspires to equip students with a comprehensive set of the knowledge and skills, both technical and non-technical, demanded by society. The goal is to mould them into capable and confident medical practitioners or surgeons upon graduation. However,

in today's era characterized by rapid innovation, intense specialization, and heightened scrutiny of medical liability, ensuring students' proficiency in both technical and non-technical aspects poses a formidable challenge.

Numerous multicenter studies reveal a prevailing lack of readiness among medical and surgical graduates to independently execute fundamental procedures (Borman et al. 2008, Cardenas Lara et al. 2017, Coleman et al. 2013, Ellis 2001, George et al. 2017). The expanding role of simulation and augmented reality in learning is evident, yet, as reiterated in research studies (Mc Garvey et al. 2001, Moro, Smith, and Stromberga 2019, Rajeh et al. 2017, Theodoulou et al. 2020), nevertheless the most effective approach for medical degree courses still remains the multimodal-multidisciplinary approach. A progressive immersion in the field of medical knowledge through the use of different methods and stimuli ensures a contemporary and comprehensive training experience. In understanding human diseases, Mondino da Liuzzi's 1316 insight on anatomical dissection remains pertinent: "...the senses of touch and sight can be used to improve understanding of the human body. You can actually see and feel the structures moving under the skin." Human anatomy, rightly regarded as the cornerstone of medical knowledge, underpins competent and safe clinical practice, especially in surgical disciplines and advanced technological therapies like the modulation of neuronal activities through brain microelectrode implantation (Camp et al. 2016, Estai and Bunt 2016, Hu, Wattchow, and de Fontgalland 2018, Jeyakumar, Dissanayake, and Dissabandara 2020, Morris and Jacques 2018, Nazarali et al. 2019, Megevand et al. 2017).

Anatomical education has changed profoundly over the last few years. Sometimes, students seem less responsive and show little enthusiasm towards what they study. This is probably due to a new generation of students who learn differently from those of past years (Eckleberry-Hunt, Lick, and Hunt 2018). The coronavirus pandemic has greatly influenced some of the most sensitive members of society: young people and their mental health (Calbi et al. 2021). Isolation and even an excessive exposure to social media have sometimes caused a state of malaise (Gao et al. 2020, Karim et al. 2020). Nowadays students no longer tolerate anymore the classic didactic frontal lectures in which they usually take notes rather passively and with poor interactions with one other (Freeman et al. 2014). This tendency has made it necessary to adopt new methods and effective strategies in anatomical education in order to involve students and keep them as interested as much as possible (Singh et al. 2019). Numerous potent strategies and resources exist for instructing anatomy. While conventional approaches hinge on didactic lectures and exhaustive body dissection to impart topographical structural anatomy, the latter, although an exorbitant investment, remains a cornerstone. However, recognizing the financial constraints and the evolving landscape of education, virtual dissection has gained precedence in numerous medical schools. Its appeal lies in fostering independent learning and affording flexibility in scheduling. (Vasil'ev et al. 2023, Pasricha et al. 2023, Zhao et al. 2020, Bartoletti-Stella et al. 2021). Among different computer-based learning tools, the Anatomage Table 9.0 (Anatomage Inc., San Jose, CA, USA) offers a complete anatomical device for medical student education (Bartoletti-Stella et al. 2021).

Nevertheless, several experts advocate a discerning application of a dynamic multimodal-multidisciplinary approach. This encompasses dissection, lectures, small group discussions utilizing problem-based learning (PBL), case studies, and living anatomy. This holistic strategy facilitates meaningful connections with faculty instructors, peers, diagnostic imaging, and embraces the evolving landscape of human-to-human and human-to-machine interactions. Its inherent benefits are particularly pronounced in addressing the challenges posed by post-COVID-19 student isolation (Evans and Pawlina 2021, Xiao et al. 2020, Pabst and Rothkotter 1997, Marks 2000, Levine et al. 1999). Indeed, the pandemic-induced absence of social interactions, coupled with the detrimental misuse of social media, is bound to exert significant and adverse consequences, particularly within the professional sphere in the imminent future (Gao et al. 2020, Karim et al. 2020).

PBL has been demonstrated to enhance the integration of students' knowledge (Barrows 1986). Through clinical cases, students adeptly forge connections between clinical features and fundamental scientific concepts. Cognitive psychology affirms that the integration of knowledge not only facilitates retention but also enhances the subsequent retrieval of pertinent information. Along with other scholars, we assert that Problem-Based Learning (PBL) should be geared towards equipping students more effectively for real-world clinical practice. (Regehr and Norman 1996). In addition, case-based learning (CBL) and flipped classroom in Anatomy have been demonstrated to be more effective than didactic lectures for improving and retaining of knowledge (Sangam et al. 2021, Kazeminia et al. 2022)

In the era of competency-based medical education, instilling clinical reasoning skills becomes imperative even in the pre-clinical stages, notably during the second year of the medical curriculum. This demands a profound comprehension of imaging and three-dimensional

anatomy, pivotal factors for accurate diagnosis, differentiation, and secure patient treatment. (Darras et al. 2018). With a focus on these critical aspects, this study endeavours to assess the viability, acceptance, and efficacy of implementing a cutting-edge multimodal-multidisciplinary approach to musculoskeletal and splanchnic anatomy learning. This approach is centred on virtual dissections utilizing Anatomage 9.0, case studies and flipped classroom lectures, along with small group discussions adopting Problem-Based Learning (PBL) methodologies. The aim is to enhance the teaching of gross and microscopic anatomy to medical undergraduates.

MATERIAL AND METHODS

The entire Human Anatomy 1 course, covering musculoskeletal and splanchnic anatomy from March 2023 to January 2024, was conducted at the University of Bari School of Medicine, encompassing all 151 students in the first and second years of the BSSM program. To progressively integrate a dynamic and engaging learning strategy, the course structure underwent progressive modification, featuring 40 traditional didactic lectures (66.6%), 5 flipped classroom sessions (8.5%) with 14 students as presenters, covering topics such as the temporal, sphenoid, maxilla, mandibular bones, urinary system, superficial anatomy and blood vessels of the neck, larynx. Additionally, there were 7 Case-Based Learning (CBL) sessions (11.6%; aortic dissection, acute cardiac tamponade, Lyme's disease, coronary artery lesions in Takayasu arteritis, tongue and oesophageal cancers, traumatic splenic rupture, anterior pituitary hypoplasia) and 6 Problem-Based Learning (PBL) sessions incorporating virtual dissections using Anatomage (13.3%; headache and transvers sinus thrombosis, unstable angina, pleural mesotelioma, lower urinary tract symptoms due to prostatic hyperplasia, cervical uterus cancer, Addison's disease).

The Anatomage Table version 9.0, a virtual table with four different cadavers providing a 3D spatial dissection view, played a pivotal role in enhancing PBL sessions. Learning materials for CBLs and PBLs involved clinical cases with specific anatomical questions, addressing areas like the aorta, heart, coronary arteries, iliac vessels, oesophagus, spleen, thoracic outlet, clavicle, hypophysis, tongue, transverse sinus, pleura, urethra, and prostate. In PBL, 66 students were divided into 6 groups with a tutor as a facilitator. The students analyzed case scenarios, discussed questions within their groups, and utilized textbooks and reference materials. Internet access was granted for additional resources and the Anatomage table was used to visualize anatomical structures during case analysis. Anatomage descriptions were incorporated during the 5th phase of the Maastricht model of PBL (Schmidt 1983). The tutor guided discussions, provoked critical thinking, and summarized topics at the session's conclusion. Extra assistance was provided to students unfamiliar with virtual dissections on Anatomage.

Of the entire cohort, 66 students (44%, voluntary participation) actively participated in both two online feedback questionnaires (Ahaslides, phone-based: https://ahaslides.com/) assessing the quality, potential, and outcomes of teaching musculoskeletal and splanchnic anatomy using active learning methods such as PBL. The list of post-session multiple-choice questions used in the online tests is detailed in Table 1.

Table 1. Feedback survey questions posted to students after completing musculoskeletal and splanchnic anatomy.

1.	Do you find the PBL self-learning method useful?
2.	Is the PBL method of learning more interesting and useful than traditional lectures?
3.	Does the PBL method slow down studying for the anatomy exam?
4.	Was the PBL method perceived as overly challenging?
5.	Was the planning of the PBL considered well-executed?
6.	Did the PBL effectively stimulate group discussions?
7.	Did the PBL encourage independent learning?
8.	Did the PBL contribute to integrating various disciplines?
9.	Was there unanimous agreement within the group to adhere to the study topic?
10.	Did every student uphold the commitments they made within the group?
11.	Was the overall group climate considered pleasant?
12.	Did you acquire substantial knowledge from participating in the PBLs?
13.	Comparatively, did you learn more from traditional lectures than PBLs?
14.	Did the teacher effectively stimulate and motivate interest in the discipline?
15.	Do you prefer active teaching methods (PBL, case studies) with consistent student involvement?
16.	If yes, specify the type of teaching that satisfied you (PBL, case study, flipped classroom, etc.). Write freely.
17.	Would you be interested in actively participating in developing next year's program as a co-project?
18.	Are the supplementary teaching activities (Anatomage virtual dissections, peer tutoring, musculoskeletal laboratories, etc.) useful for learning the subject?
19.	Are you satisfied overall with how the exercises were set up?

* Choices for each question: 1) Definitely No; 2) More No than Yes; 3) More Yes than No; 4) Definitely Yes.

To gauge conceptual retention, we scrutinized the final scores of the Anatomy 1 examination within two distinct student cohorts. These cohorts underwent the examination utilizing identical methods, involving a multiple-choice test and Anatomage axial section description, followed by an oral examination encompassing microscopic and topographic anatomy. The assessments were conducted by the same two instructors during the initial three sessions at the conclusion of the course in two successive years (2023: 100% traditional teaching method and 2024: 67% traditional, 33% engaging students).

RESULTS

The instructional intervention reached the entire group of 151 students enrolled in the Anatomy course. Of this cohort, 66 students (44%) actively engaged in both online tests at the end of musculoskeletal and splanchnic anatomy.

Initial surveys conducted at the end of the musculoskeletal session revealed that 63% of students favoured an innovative educational approach with continuous engagement, while 42% preferred lessons supported by case studies. Others indicated a variety of preferences, such as Team-Based Learning (TBL), PBL, and flipped classrooms.

Subsequent surveys administered at the end of the anatomy course disclosed that 96% of students expressed a preference for innovative education, deeming it more beneficial and engaging than traditional frontal lectures. The same percentage acknowledged that PBL had stimulated group discussions, fostering an enjoyable teamwork experience. Additionally, 91% believed they had significantly learned from PBL, with 95% noting that the new method had promoted self-study, and 100% attesting that it facilitated an interdisciplinary perspective. Eighty-six percent found the proposed PBL and CBL well-structured. Ninety-five percent asserted the usefulness of additional teaching activities like tutorials and workshops for learning, expressing overall satisfaction with their organization. Every student affirmed enjoyment in active lessons with consistent student involvement, with approximately 70% favouring the Anatomage-enhanced-PBL approach, while others preferred the flipped classroom and CBL approaches. In addition, the percentage of students who said that the teacher stimulated/motivated their interest in studying anatomy has increased from 92.4% (n. 424; 2020, 2021, 2022 groups of the BSSM students) to 94.7% (n. 66; 2023 group). After self-assessment, surveys on anatomy knowledge demonstrated positive outcomes, suggesting the effectiveness of this active learning method in enhancing students' understanding of anatomy.

Regarding the teacher-assessed efficacy of active learning versus traditional frontal didactic lectures, a comparative analysis of final marks from two different student cohorts revealed consistent methods and teacher involvement in exams across two consecutive years (2023 and 2024). The students exposed to multimodal active learning (n. 51, verbalized exams during first trimester of 2024) reached an average of final marks equal to 27.27/30 whereas the students exposed to didactic lectures reached 27.75 (n. 57, verbalized exams during first trimester of 2023; p:> 0.05).

DISCUSSION

This study analyzes student assessments concerning the integration of traditional musculoskeletal and splanchnic anatomical lectures with an innovative multimodal-multidisciplinary learning approach. The adoption of new methodologies aims to foster critical thinking and active study, steering away from mere rote memorization of topics. Anatomists, recognizing the need for evolution in pedagogy, must explore inventive and stimulating multimodal strategies that encourage proactive and profound learning (Singh et al. 2019). The ultimate goal is to cultivate long-term memory in students, thereby enhancing engagement and aligning learning outcomes with their professional aspirations.

While traditional lectures remain the most widely employed and cost-effective means of teaching anatomy, their efficacy is marred by global criticism (Verma et al. 2024). Despite their capacity to impart substantial information swiftly, they often lead to disengagement and negative mental states such as frustration, anger, apathy, or somnolence. These detrimental states can be attributed to factors like audience dynamics, environmental conditions, and lecturer style (McLaughlin and Mandin 2001). It is crucial to acknowledge that, more often than not, the responsibility for these issues rests with the lecturers (McLaughlin and Mandin 2001). To prevent this and to plan effective lectures, the Association for Medical Education in Europe (Brown and Manogue 2001) and Italian ANVUR (Felisatti 2023) provided guidelines for lecturers and promoted students' active participation. Many different activities can be proposed during lectures to increase students' involvement (Giorgdze and Dgebuadze 2017). This study delves into the feedback garnered from undergraduate medical students, revealing a consistent inclination towards interactive teaching

methods over traditional lectures (Kuchynska et al. 2019, Keedy et al. 2011). The incorporation of interactivity into didactic lectures not only shifts the focus towards students but also heightens concentration and active participation. Interactive teaching methods allow encoding of information intertwined with emotional experiences, the emotional learning often leads to stronger and more enduring memories (Pare and Headley 2023, Wang et al. 2020, Tyng et al. 2017). The engagement of multiple brain regions involved in attention, perception, emotion processing, and memory consolidation contributes to the formation of strong and long term memories (Eriksson et al. 2015). However, the transition between traditional and active learning demands increased effort from educators, as the preparation of learning material and resources necessitates a more time-intensive approach (Kuchynska et al. 2019).

Recognizing the need for change, we adopted an interdisciplinary, hands-on, team-building approach based on Problem-Based Learning (PBL). PBL focuses on engaging students with curiosity, bringing future doctors closer to real-world medical contexts (Barrows 1980). PBL, introduced in the late 1960s at McMaster medical school, originated from the concern that students struggled to apply basic knowledge to clinical problems (Wijnia and Servant-Miklos 2019). Its inception by neurologist Howard Barrows, starting with real clinical problems, demonstrated increased skills in problem discussion and self-study among students (Tamblyn and Barrows 1980). This method, subsequently adopted by institutions like Harvard Medical School, transformed medical education, empowering students to become the protagonists of their learning journey (Trullas et al. 2022). PBL, following the Limburg University model with seven jumps/steps, encourages critical thinking, problem-solving, self-study, and teamwork (Schmidt 1983, Dangerfield, Bradley, and Gibbs 2000). It enables the application of theory to practice through real clinical cases, fostering a 'learn to learn' mindset. Moreover, PBL is an interdisciplinary method, emphasizing practical case studies with patient symptoms and diagnostic exams for analysis (Cheng et al. 2021). Beyond academic benefits, PBL promotes team building and effective collaboration (Ghani et al. 2021). In a PBL session, students share ideas without judgment, fostering an environment where cooperation is prioritized over evaluation. This collaborative experience contributes to building effective teamwork, helping students exchange information seamlessly as future doctors focused on preserving patient health.

In this study, six PBLs, centered around various medical conditions such as stroke, tumors, and diabetes, were proposed to small groups of students. An innovative aspect was the integration of Anatomage table usage, offering a comprehensive view of anatomy related to the clinical cases presented. The Anatomage table not only enhanced the PBLs but also facilitated bonding among students during small group sessions. While cadaveric dissection remains a gold standard for anatomy learning (Burgess and Ramsey-Stewart 2015), this approach alone may fall short of meeting modern medical curricular needs. Integrating technological methods, such as virtual human cadaver dissection, offers a comprehensive educational model for anatomical science.

The study acknowledges certain limitations, including the online administration of post-session surveys and the voluntary nature of student participation, which may have biased responses selecting more motivated students from a single institute. Despite these constraints, the study underscores the value that students placed on PBL-based interactivity, indicating its potential incorporation into routine didactic teaching.

CONCLUSIONS

These findings constitute good evidence affirming the efficacy of Problem-Based Learning (PBL) as an augmentative approach capable of enhancing medical education of anatomy. By engaging successive generations of students in problem-centered learning, PBL fosters enthusiasm and proficiency, contributing significantly to the educational landscape.

In summary, this method serves as a compelling and practical avenue for medical students to promptly apply their acquired knowledge to patient care.

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