Review Article
Do Medical Students Still Need Practicum and Laboratory Classes in the Age of Artificial Intelligence?

ABSTRACT

Aims: to revisited the irreplaceability of practicum and laboratory classes for medical student and its benefit, even in the artificial intelligence (AI) era
Discussion: The transformative potential of AI in every aspect of human also reshape the pedagogy of medical education. Integrating AI into medical education offers numerous potential benefits, including improved curriculum design and evaluation and the ability to refine the delivery of objective student assessment, better clinical simulation organization, and enhanced education transparency. On contrary, the main challenges of AI integration in medical education are ethical and legal issues, scalability limitations, technical difficulties, and evaluating the effectiveness of traditional educational methods such as practicum or laboratory classes. Fortunately, Practicums is still considering important because they provide students with real-world hands on experience and the opportunity to apply whatever theory taught in the classroom to practice. Furthermore, it can integrate knowledge and better understanding which acquired through coursework and other combined learning experiences. AI does not have the capability to replace human contact and moral values in practicum. The balance between AI and traditional hands-on learning is a must and the benefits of AI incorporation to medical curriculum, including practicum and laboratory classes with the enduring need for practical experiences will benefit all stakeholder
Conclusion: The irreplaceability of hands-on training and the balance between AI and human contact in medical education make traditional practicum and laboratory classes are still relevant, even in the era of AI.

Keywords: knowledge engineering, machine learning, medical education, skill, hands on experience

1. INTRODUCTION

Artificial intelligence, which is often referred to as AI, is an emerging branch of computer science [1] that focuses on things such as machine learning [2], or programming computers to behave more like people. The term is also used for any machinery to execute tasks once only done by humans [3,4]. Machines with artificial intelligence can learn and solve problems, acting on available information to improve over time [4] AI can penetrate every aspects of daily human [5], including revolutionizing medical education [6-8]; it rapidly transforming healthcare [9] and reshaping [10], learning [11], and educational practice [12] in medical education.
The emerging incorporation of AI into medical practice [13,14] and health care [15] has also led to an increase in the use of different AI methods in medical education [8], including Automated assessment [16], Natural language processing (NLP) [17], Adaptive learning such as Technology enhanced learning (TEL) [18], the making of correct diagnosis using

Diagnostic proficiency [19], Personalized learning by Generative and the personalization of health professional education [20], AI ethics education [21], Computer-assisted learning and teaching [22] and even Developing new teaching strategies [23]. It seems that AI has super potency to transform medical education.

Unfortunately, while AI pledges immense promise for personalizing learning [20] and enhancing educational experiences [6,14], it is also in the same crucial to acknowledge its potential downsides [24], challenges [25] and even obstacles [26] in applying AI into medical education, even if it is conducted in the medical student learning milieu [27].

Several advantages worth to be mentioned include a more objective student assessment [28], improvement in healthcare or clinical simulation arrangement [29], and strengthened Fairness, Accountability, Transparency, and Ethics (FATE) in higher education [30], including medical education. Contrariwise, the ultimate defiance of AI integration in education are scalability restriction [31], ethical [32] and legal [33] matters, appraising the actual effectiveness of sophisticated AI incorporated medical education methods [34], and technical difficulties [35] especially in practicum or laboratory classes [36].

The absence of human touch, which cannot be replaced by AI touch, is the ultimate disadvantage of incorporating AI in higher education [37], leading to a cold dehumanized learning encounter [38]. The great role of social interaction in human acquisition of new knowledge has been revealed by previous studies [39,40]. Traditional education relies heavily on human interaction, with teachers providing not only academic instruction but also emotional support and mentorship.

This paper aimed to revisited the irreplaceability of practicum and laboratory for medical student and its benefit, even in the AI era.

2. PRACTICUM AND LABORATORY CLASSES IN MEDICAL EDUCATION

A practicum in medical education is a structured and supervised experienced based learning that allow medical students to incorporate all classroom theory to real-world work/condition through hands on experience [41], while Laboratory classes, also known as lab courses, are a teaching method that involves students actively engaging with concepts through experimentation or exploration [42]. Furthermore, the two terms (practical or lab class) will be used interchangeably with the aim of referring to practical activities in the laboratory.
The integration of practical components into medical curricula varies widely [43,44]. Modification of curriculum [44, 45], e.g., shortening clinical rotation training for medical undergraduates [46,47], is associated with an unfortunate reduction in preparedness for practicum [47]. Hagan and Jaffe [48] reported the effect of curriculum changes on student performance during general surgical clerkship. They found out that Good clinical knowledge of anatomy, taught in anatomy laboratory, is necessary for practicing physicians. It is a key feature of performance on the United States Medical Licensing Examination Step 1 score [49]. Student performance on anatomy is also an early indicator of overall medical student performance. Unfortunately, curricular time provided for the teaching of anatomy [50] or other laboratory based subject such as Biochemistry [51], Microbiology [52], Physiology [53], Parasitology [54] and Histology [55] has declined significantly over the years, with most of the reason regarding the faculty shift into integrated curriculum leading to growing concerns that the knowledge of new medical graduates regarding Anatomy [50], Biochemistry [51], Microbiology [52], Physiology [53] and Parasitology [54] may not be sufficient during their clinical years. Although it is possible to teach those subjects in increasingly shorter periods

of time, e.g., via short courses or other modification, such that the students achieve high test scores in the standardized short answer examinations, it is clear that their knowledge, as applied to clinical care, rapidly declines and student's poorly retention of those basic medical science knowledge as the further they get away from basic or pre-clinical studying [56, 57]. In other words, without sufficient practicum and laboratory classes, it is doubtful that pre-clinical students will have retain sufficient knowledge and skills to be used at a higher level of education (clinical rotation phase).

Another study conducted by Schwartz and Chin-Hong [58] regarding the present state of Infectious disease education in undergraduate medical education across America revealed that 52% of medical schools surveyed uses laboratory for teaching and that almost all institutions use a lecture didactic method as a primary teaching modality. Furthermore, the study also screened recent curricular modifications and challenges in microbiology education. When their respondents asked about recent changes, incorporation of microbiology into other specific topics or the more common organ-system blocks was a dominant theme. Other studies revealed reasons for change in the curriculum design include meeting accreditation standards [59], enhancing clinical skills acquisition [60], and facilitating a reduce in preclinical time and quantity [61]. The primary challenge in curriculum development cited in the study conducted by Schwartz and Chin-Hong [58] mentioned by respondents was a depletion in time allocation for teaching microbiology. Beside that, difficulty in integrating microbiology into other courses in the preclinical curriculum [62] was also a big concern.

From other aspects of laboratory, Peeraer et al [63] reported that knowledge formed in five years and 200 hours of integrated undergraduate skills training in clinical skill's laboratory is more effective as a method of learning basic clinical skills, compared to learning these skills through 75 hours of traditional skill training and reinforcement of these skills in 12 month clinical internships, when measured by means of an OSCE.

In case of human cadaveric dissection in Anatomy laboratory during medical training, Webb et al [64] revealed that the preclinical phase as the optimal time to strategically integrate dissection in the Anatomy laboratory into medical training in order to maximize the benefits of this unique learning opportunity for students and minimize its impact upon curricular time.

Medical education has traditionally been compartmentalized into basic and clinical sciences, with the latter being viewed as the skillful application of the former. Over time, the relevance of basic sciences has become defined by their role in supporting clinical problem solving rather than being, of themselves, a defining knowledge base of physicians. Unfortunately, integrated medical curriculum often leads to the inappropriate balance between pure basic science and clinical skill [65]. Many stated medical curriculum was biased toward basic science [66], where almost all of the laboratory exists.

Poor knowledge, clinical unconfident and faulty patient management are actually the most affected by the reduction of time in practicum or laboratory classes [47]. Furthermore, the effect of undergraduate practicum directly affects the clinical ability and professional quality of graduates [67]. The negative impact for medical graduates, who during their education experience a reduce in the number of practicums, is that when they are entering in their professional career, they will show lack of professionalism, e.g., lack of interest in doing practice, poor doctor-patient communication skills and high potency of conflict with other clinical training doctors [68].

Challenges in implementing practicum or laboratory classes in medical schools is currently emerge to the surface. many medical laboratory science programs are dealing with numerous challenges that may negatively impact on the quality of the education and competency of the graduates. The types and scales of those challenges may vary from country to country, or from region to region [69]. Some common, but generally less discussed issues, are including restriction of the curriculum, Insufficient or inefficient laboratory trainers in the workplace, Insufficient communication between the higher

education sector and pathology industry. But still, practicum or laboratory classes is important part of medical education.

3. THE IMPORTANCE OF PRACTICUM IN MEDICAL EDUCATION

Practicum and laboratory classes are important for many reasons. The practicum for medical students aims to provide graduates with sufficient knowledge and skills needed to continue their education in the clinical rotation [70]. The practicum is actually the key mode of learning in health professions. It is the initial hands on experience that consolidates practical involvement and theoretical knowledge for medical student to become proficient in the field of their professions. Practicum standard ensures medical students can take the knowledge and critical thinking skills they have obtained throughout their education and apply them to their future position in healthcare profession--even if those needs do not seem immediately relevant at the moment.
Practicum environments are crucial links to successful experience(s) for medical students. Sufficient practical exposure to the suitable milieu, e.g., clinical or laboratory setting, can strengthens the development of several aspects of professionalism [71]. Here is some importance of practicum in medical education, namely:

3.1. Practical experience. Practicums allow medical student to apply their education in real-world healthcare or laboratory settings [72], such as an audiometry office or emergency room clinic or staining clinical sample prepared in a glass slide with coloring reagent. Practical experience during a laboratory class or practicum can help students develop a variety of skills such as practical or technical [73], problem solving orientation [74], data analysis [75], communication which was practiced using simulated patients or volunteer outpatients [76] and collaborative with teamwork [77]) and better conceptual understanding based on what medical student learn during practicum [78]. In laboratory experiences, students may learn to use the tools for specific purpose and conventions of science.

Actually, AI is already in the laboratory, but it is mostly used in the core lab and other instrumentation [79]. The instrument manufacturers who are including AI algorithms that analyze the data as it comes off the line and give the results [80]. Currently, AI is most effective at narrow tasks, or in other word, is using a specific tool for a specific purpose [79,80]. Most AI tools typically do a single task. While AI does give a lot of benefits for the laboratory, and its future capacities are, as of yet, difficult to forecast [79,80], but it is doubtful to replace laboratory professionals or pathologists. For one thing, AI is not yet sophisticated enough to know when it is wrong and will require human oversight for most of its functions for the foreseeable future. Only humans can keep AI systems runs ethically, accurately, and fairly. AI has made strides in recent years, but it simply cannot replace the human experience. The benefit of AI in practicum that it will augment, not replace the human [15]. There is no new paradigm where the implementation of AI suddenly makes the AI takes responsibility for all the decisions it's making. Humans are still always needed. Even the most sophisticated AI cannot take the responsibility and human touch.

3.2 Hands-on training. Practicums combine hands-on training with mentorship from experts in the field (lecturer or laboratory technician) [42]. Hands-on practicum is important because it can help students and employees learn and retain information [56,57], develop critical thinking skills [69], and build confidence [73]. Hands-on learning via practicum also helps students to: (a) understand concepts and encourages problem-solving [74], which can lead to better performance in higher level education and future careers [46,48,49], (b) improves critical thinking [69] because during hands-on training

usually requires students to make decisions and use critical thinking skills to achieve their desired outcome [81], and last but not least (c) improves long term knowledge retention [56,57].

3.3 Communication skills. Practicums help students learn to communicate effectively with other human [76]; e.g., with lecturer and lab technician during Microbiology lab session, or with patients and other care providers during clinical lab session. In the practicum course, students will learn how to attain and integrate key relational and communication skills that take the whole person into account [43,76]. Through effective communication develop during communication skills practicum, students underwent collaboration, builds relationships and facilitates their own understanding.

3.4 Diagnostic competence. Practicums expose students to a variety of laboratory procedures, case simulations, and rare cases, which can help them develop diagnostic competence [82]. To develop certain diagnostic competence, medical students should practice with many examples of clinical problems to build rich mental representations of diseases [82,83]. By teaching medical students regarding the importance of preanalytic, analytic, and postanalytic variables that may affect laboratory or clinical results, lecturer implement structured teaching concept which takes place under supervision and in consideration of methodological-didactic concepts, ideally creating a milieu that allows the repeated, anxiety-free and happy practice of targeted skills [84]. Once again, heartless AI might be able to replicate some aspects of a teacher-student relationship. Still, it will never fully replicate the warmth, empathy, and other emotional perceptions which only living humans able to possess and exhibit [85].

3.5 Professional identity. Practicums can help students develop their professional identity and understand how to practice their professional values [20,71,77]. Professional identity is an ongoing lifelong process that occurs throughout life via repetitive exposure to conditions related to their profession [71]. It is very dynamic and context-specific, and it is not just simply all the sudden mastered by following a code of conduct or acquiring a set of rules. It starts from (1) understanding the medical student role since the very beginning of their education which can construct their identity as future doctors, including what it means to them and others [43,46,64] (2) experiencing the role, where through practicum medical student can gain experiences that help them build their identity [72,73,81], (3) obtaining feedback based on their practicum performance [46,70] and (4) implement strategies to continuously improvise the students' critical thinking proficiency [81].

3.6 Research skills. Research skills can be developed through practicum [83] by practicing the following skills such as evaluating sources, critical thinking, time management, note-taking, seeking feedback and understanding the research process [86]. All of those skills can help medical students to Identify new angles to pursue or drop topics that have already been covered. Once again, Skill can only be acquired through practice [67]. Once certain skill has been acquired, we stop being able to see the joins between all the knowledge that went into its creation. The more expert we become, the more invisible and automatic our skills become.

3.7. Evidence-based medicine. Practicums can help students learn about the importance of evidence-based medicine [23,87]. Evidence-based practice (EBP) is a process that involves integrating research evidence, clinical expertise, and patient values to make decisions. In a practicum, students can apply what they learn in the classroom by integrating theory and practice [87]. They can also observe experienced professionals and receive feedback on their own skills. Instead of knowing the theory behind different

solutions, the medical student will actually learn how to solve the problem using evidence based medicine taught in practicum.

3.8 Time management. Practicums can help students develop time management skills [88] and correct strategies in connecting to self-directed learning [89] such as: (a) prioritizing by appraising the importance and urgency of certain tasks, and design a precise schedule to finish them completely, (b) scheduling by way of create an organized schedule to prioritize responsibilities and avoid confusion and stress, (c) goal setting by way of set goals to help medical students to understand where to spend his/her time to achieve the desired results/goals, (d) avoiding distractions by way of eliminate distractions by dedicating a certain amount of time to each task and activity, including breaks, (e) resilience or stress management by way of administer stress levels to circumvent burnout and maintain the high level of productivity, concentration, and health, (f) strategic planning as a means figure out how much time is attainable and devote time blocks to specific laboratory tasks [88,89].

The benefit of time management skills enables future health professionals to get professional satisfaction and reduce stress, enhance career satisfaction, greater work-life balance, and long-term growth [90]. The implementation of sound management practices is a key point for maximizing productivity and quality [88-90].

3.9 Career pathways. Practicums can help students learn about career pathways in academic medicine [91]. Practicum learning actually provides medical students with practical experience [41] and allowing them to have direct interaction with leading professionals from the faculty, hospital, laboratory, industry and the community [92] Numerous studies have shown that career pathway through practicum experience can lead to deeper learning, higher levels of engagement, and better student outcomes when implemented skillfully.

A practicum surely takes a significant amount of time, effort and even need financial certainty, but it actually offers the medical student a number of useful benefits for now and in the future, which still cannot be fully replaced by AI. Further study needed to justify this finding.
Having a well-organized and balanced approach to the consideration of the implementation of AI in learning environments including the laboratory will help all stake holder navigates the exciting yet complex world of AI-powered education. However, in order to support this argument, effort to carefully conduct searching empirical data or case studies regarding specific AI in the practicum or laboratory class in faculty of medicine setting was not successful, because such study or literature was not available at the moment of writing this review study. This limitation actually gives future direction for conducting a more extensive study regarding how specific AI contributes and balanced the practicum or laboratory classes in faculty of medicine.

4. MORAL VALUES IN PRACTICUM

Important moral values for students are compassion, Confidentiality and privacy, honesty, respect, gratitude, responsibility, fairness, empathy, equality, and integrity with the opportunity to share and apply all of these moral values during practicum and laboratory class. These values lead to right actions, positive relationships, and supportive learning atmospheres that help prepare the medical students for responsibility and compassion as they become future professional doctors.

5. CONCLUSION

Medical practicums are often used in fields like education, nursing and medicine, psychology, and clinical skill's. The type of practicum a student experiences can vary depending on their field. A practicum can provide many benefits for students, including practical application, critical thinking and problem-solving, employability, networking, feedback and professional identity. Some negative aspects of practicum include extracurricular time, duration, regulation and feedback. AI does not have the capability to fully replace human contact and moral values in practicum.

CONSENT (WHERE EVER APPLICABLE)

Not needed

ETHICAL APPROVAL (WHERE EVER APPLICABLE)

Not needed

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3

REFERENCES

1. Khaleel M, Jebrel A, Shwehdy D. Artificial Intelligence in Computer Science. 2024;2: 1-21.

2. Mosqueira-Rey E, Hernández-Pereira E, Alonso-Ríos D. Human-in-the-loop machine learning: a state of the art. Artif Intell Rev 56, 3005–3054 (2023). https://doi.org/10.1007/s10462-022-10246-w

3. Pelau C, Dabija DC, Ene I. What makes an AI device human-like? The role of interaction quality, empathy and perceived psychological anthropomorphic characteristics in the acceptance of artificial intelligence in the service industry. Computers in Human Behavior, 2021;122: 106855 https://doi.org/10.1016/j.chb.2021.106855.

4. Soori M, Arezoo B, Dastres, R. Artificial Intelligence, Machine Learning and Deep Learning in Advanced Robotics, A Review. Cognitive Robotics. 2023 ;3: 54-70 https://doi.org/10.1016/j.cogr.2023.04.001

5. Varghese M, Raj S, Venkatesh V. Influence of AI in human lives. 2022. https://doi.org/10.48550/arXiv.2212.12305

6. Narayanan S, Ramakrishnan R, Durairaj E, Das A. Artificial Intelligence Revolutionizing the Field of Medical Education. Cureus. 2023 Nov 28;15(11):e49604. https://doi.org/10.7759/cureus.49604.

7. Sun L, Yin C, Xu Q, Zhao W. Artificial intelligence for healthcare and medical education: a systematic review. Am J Transl Res. 2023 Jul 15;15(7):4820-4828.

8. Gordon M, Daniel M, Ajiboye A, Uraiby H, Xu NY, Bartlett R, et al. A scoping review of artificial intelligence in medical education: BEME Guide No. 84. Med Teach. 2024 Apr;46(4):446-470. https://doi.org/10.1080/0142159X.2024.2314198.

9. Silcox C, Zimlichmann E, Huber K. The potential for artificial intelligence to transform healthcare: perspectives from international health leaders. npj Digit. Med. 2024; 7, 88. https://doi.org/10.1038/s41746-024-01097-6

10. Khan R, Jawaid M, Khan A, Sajjad M. ChatGPT - Reshaping medical education and clinical management. Pakistan Journal of Medical Sciences. 2023;39. https://doi.org/10.12669/pjms.39.2.7653.

11. Seo K, Tang J, Roll I. The impact of artificial intelligence on learner–instructor interaction in online learning. Int J Educ Technol High Educ 2021;18: 54. https://doi.org/10.1186/s41239-021-00292-9

12. Mir MM, Mir GM, Raina NT, Mir SM, Mir SM, Miskeen E, Alharthi MH, Alamri MMS. Application of Artificial Intelligence in Medical Education: Current Scenario and Future Perspectives. J Adv Med Educ Prof. 2023 Jul;11(3):133-140. https://doi.org/10.30476/JAMP.2023.98655.1803.

13. Karalis VD. The Integration of Artificial Intelligence into Clinical Practice. Applied Biosciences. 2024; 3(1):14-44. https://doi.org/10.3390/applbiosci3010002

14. Alowais SA, Alghamdi SS, Alsuhebany N, Alqahtani T, Alshaya AI, et al. Revolutionizing healthcare: the role of artificial intelligence in clinical practice. BMC Medical Education, 2023; 23. https://doi.org/10.1186/s12909-023-04698-z

15. Bajwa J, Munir U, Nori A, Williams B. Artificial intelligence in healthcare: transforming the practice of medicine. Future Healthc J. 2021 Jul;8(2):e188-e194. doi: https://doi.org/10.7861/fhj.2021-0095.

16. Gao R, Merzdorf H, Anwar S, Hipwell M, Srinivasa A. Automatic assessment of text-based responses in post-secondary education: A systematic review. Computers and Education: Artificial Intelligence. 2024;6:100206. https://doi.org/10.1016/j.caeai.2024.100206.

17. Chary M, Parikh S, Manini AF, Boyer EW, Radeos M. A Review of Natural Language Processing in Medical Education. West J Emerg Med. 2019 Jan;20(1):78-86. https://doi.org/10.5811/westjem.2018.11.39725.

18. Sharma N, Doherty I, Dong C. Adaptive Learning in Medical Education: The Final Piece of Technology Enhanced Learning? Ulster Med J. 2017 Sep;86(3):198-200.

19. Göndöcs D, Dörfler V. AI in medical diagnosis: AI prediction & human judgment. Artificial Intelligence in Medicine, 2024; 149:102769. https://doi.org/10.1016/j.artmed.2024.102769.

20. Almansour M, Alfhaid FM. Generative artificial intelligence and the personalization of health professional education: A narrative review. Medicine (Baltimore). 2024 Aug 2;103(31):e38955. https://doi.org/10.1097/MD.0000000000038955.

21. Usher M, Barak M. Unpacking the role of AI ethics online education for science and engineering students. IJ STEM Ed 2024;11: 35. https://doi.org/10.1186/s40594-024-00493-4

22. Santhanalakshmi P, Oommen S, Alwar MC, Arya J. Effectiveness of computer-assisted learning as a teaching method in experimental pharmacology. Natl J Physiol Pharm Pharmacol 2018;8(11):1470-1474. https://doi.org/10.5455/njppp.2018.8.0723926072018

23. Arango-Ibanez JP, Posso-Nuñez JA, Díaz-Solórzano JP, Cruz-Suárez G. Evidence-Based Learning Strategies in Medicine Using AI. JMIR Med Educ 2024;10:e54507. https://doi.org/10.2196/54507

24. Promethean. Potential downsides of AI in education. Downloaded from https://www.prometheanworld.com/resource-center/blogs/potential-downsides-of-ai-in-education/

25. Azer SA, Guerrero APS. The challenges imposed by artificial intelligence: are we ready in medical education?. BMC Med Educ, 2023; 23: 680. https://doi.org/10.1186/s12909-023-04660

26. Salloum SA, Salloum A, Alfaisal R. Objectives and Obstacles of Artificial Intelligence in Education. In: Al-Marzouqi A, Salloum SA, Al-Saidat M, Aburayya A, Gupta B. (eds) Artificial Intelligence in Education: The Power and Dangers of ChatGPT in the Classroom. Studies in Big Data, 2024, vol 144. Springer, Cham. https://doi.org/10.1007/978-3-031-52280-2_38

27. Civaner MM, Uncu Y, Bulut F, Chalil EG, Tatli A. Artificial intelligence in medical education: a cross-sectional needs assessment. BMC Med Educ. 2022 Nov 9;22(1):772. https://doi.org/10.1186/s12909-022-03852-3.

28. González-Calatayud V, Prendes-Espinosa P, Roig-Vila R. Artificial Intelligence for Student Assessment: A Systematic Review. Applied Sciences. 2021; 11(12):5467. https://doi.org/10.3390/app11125467

29. Hamilton A. Artificial Intelligence and Healthcare Simulation: The Shifting Landscape of Medical Education. Cureus. 2024 May 6;16(5):e59747. https://doi.org/10.7759/cureus.59747.

30. Memarian, B, Doleck T. Fairness, Accountability, Transparency, and Ethics (FATE) in Artificial Intelligence (AI) and higher education: A systematic review. Comput. Educ. Artif. Intell.2023; 5: 100152. https://doi.org/10.1016/j.caeai.2023.100152

31. Govea J, Ocampo Edye E, Revelo-Tapia S, Villegas-Ch W. Optimization and Scalability of Educational Platforms: Integration of Artificial Intelligence and Cloud Computing. Computers. 2023; 12(11):223. https://doi.org/10.3390/computers12110223

32. Farhud DD, Zokaei S. Ethical Issues of Artificial Intelligence in Medicine and Healthcare. Iran J Public Health. 2021 Nov;50(11):i-v. https://doi.org/10.18502/ijph.v50i11.7600.

33. Naik N, Hameed BMZ, Shetty DK, Swain D, Shah M, Paul R, et al. Legal and Ethical Consideration in Artificial Intelligence in Healthcare: Who Takes Responsibility? Front Surg. 2022 Mar 14;9:862322. https://doi.org/10.3389/fsurg.2022.862322.

34. Sallam M, Barakat M, Sallam M. A Preliminary Checklist (METRICS) to Standardize the Design and Reporting of Studies on Generative Artificial Intelligence–Based Models in Health Care . Education and Practice: Development Study Involving a Literature Review. Interact J Med Res 2024;13:e54704. https://doi.org/10.2196/54704

35. Cigoj M. AI in Medical Devices and Healthcare: Challenges and What Lies Ahead. 10 May 2023. Downloaded from https://htec.com/ai-in-medical-devices-and-healthcare-challenges-and-what-lies-ahead/

36. Gonzalez VH, Mattingly S, Wilhelm J, Hemingson D. Using artificial intelligence to grade practical laboratory examinations: Sacrificing students' learning experiences for saving time? Anat Sci Educ. 2024 Jul-Aug;17(5):932-936. https://doi.org/10.1002/ase.2360.

37. Grandi LC, Bruni S. Will the Artificial Intelligence Touch Substitute for the Human Touch? NeuroSci. 2024; 5(3):254-264. https://doi.org/10.3390/neurosci5030020

38. Bender E. Resisting dehumanization in the age of AI. CogSci: Interdisciplinary Study of the Mind. 2022-07-29. Available from https://www.youtube.com/watch?v=wuU-5rGPbyg

39. De Felice S, Hamilton AFC, Ponari M, Vigliocco G. Learning from others is good, with others is better: the role of social interaction in human acquisition of new

knowledge. Philos Trans R Soc Lond B Biol Sci. 2023 Feb 13;378(1870):20210357. https://doi.org/10.1098/rstb.2021.0357.

40. Yu H, Shi G, Li J, Yang J. Analyzing the Differences of Interaction and Engagement in a Smart Classroom and a Traditional Classroom. Sustainability. 2022; 14(13):8184. https://doi.org/10.3390/su14138184

41. Dornan T, Conn R, Monaghan H, Kearney G, Gillespie H, Bennett D. Experience Based Learning (ExBL): Clinical teaching for the twenty-first century. Medical Teacher,2019; 41(10), 1098–1105. https://doi.org/10.1080/0142159X.2019.1630730

42. Colthorpe K, Ainscough L. Do-it-yourself physiology labs: Can hands-on laboratory classes be effectively replicated online? Adv Physiol Educ. 2021 Mar 1;45(1):95-102. https://doi.org/10.1152/advan.00205.2020.

43. Rasenberg E, Brand G, van Weel-Baumgarten E. Integrating medical and practical skills in communication skills training: Do students feel it supports them with transfer from classroom to practice? PEC Innov. 2023 Apr 25;2:100158. https://doi.org/10.1016/j.pecinn.2023.100158.

44. Kaufman, D.M. and Mann, K.V. (2010). Teaching and Learning in Medical Education: How Theory can Inform Practice. In T. Swanwick (Ed.). Understanding Medical Education, © 2010 The Association for the Study of Medical Education. ISBN: 978-1-405-19680-2 2010. https://doi.org/10.1002/9781444320282.ch2

45. Gold I. Shortening the medical curriculum. CMAJ. 2008 Mar 25;178(7):883; author reply 884. https://doi.org/10.1503/cmaj.1080008.

46. Strowd LC, Hartman N, Askew K, Vallevand A, McDonough K, Goforth J, Manthey D. The Impact of Shortened Clinical Clerkships on Medical Student Performance and Clerkship Assessment. Med Sci Educ. 2021 Jun 4;31(4):1333-1341. https://doi.org/10.1007/s40670-021-01309-8.

47. Chaou CH, Yu SR, Ma SD, Tseng HM, Ou LS, Huang CD, Fang JT. Effect of national curriculum reform on medical students' preparedness for practice: a prospective cohort study from undergraduate to postgraduate periods. BMC Med Educ. 2022 Nov 30;22(1):826. https://doi.org/10.1186/s12909-022-03909-3.

48. Hagan EA, Jaffe BM. Effect of Curriculum Changes on Student Performance During General Surgical Clerkship. Journal of Surgical Education, 2018; 75(3):622-7 https://doi.org/10.1016/j.jsurg.2017.08.020

49. Peterson CA, Tucker RP. Medical gross anatomy as a predictor of performance on the USMLE Step 1. Anat Rec B New Anat. 2005 Mar;283(1):5-8. https://doi.org/10.1002/ar.b.20054.

50. Hołda MK, Stefura T, Koziej M, Skomarovska O, Jasińska K, Sałabun W, Klimek-Piotrowska W. Alarming decline in recognition of anatomical structures amongst medical students and physicians. Annals of anatomy = Anatomischer Anzeiger : official organ of the Anatomische Gesellschaft, 2019;221: 48-56 . https://doi.org/10.1016/j.aanat.2018.09.004

51. Erdem S, Yiğitbaşı T, Yigit P, Emekli N. Compliance of medical biochemistry education in medical schools with national core education program 2014. Turkish Journal of Biochemistry. 2019;44(5): 578-584. https://doi.org/10.1515/tjb-2018-0282

52. Melber DJ, Teherani A, Schwartz BS. A Comprehensive Survey of Preclinical Microbiology Curricula Among US Medical Schools, Clinical Infectious Diseases. 2016;63 (2):164-8 https://doi.org/10.1093/cid/ciw262

53. Hasan Z, Sequeira R. Challenges of Teaching Physiology in an Integrated System-Based Curriculum. Can Med Educ J. 2012 Mar 31;3(1):e73-6.

54. van Doorn DCK, Nijsse ER, Ploeger HW. Pitfalls and opportunities of teaching veterinary parasitology within an integrated curriculum. Vet Parasitol. 2018 Mar 15;252:85-88. https://doi.org/10.1016/j.vetpar.2018.01.036.

55. Gribbin W, Wilson EA, McTaggart S, Hortsch M. Histology education in an integrated, time-restricted medical curriculum: Academic outcomes and students' study adaptations. Anat Sci Educ. 2022 Jul;15(4):671-684. https://doi.org/10.1002/ase.2127

56. Blenda A, Chosed R, Bailes C, Caldwell M, Tucker M. Retention of Biomedical Knowledge in Medical Students Predicts USMLE Step 1 Scores. MedEdPublish (2016). 2021 Mar 12;10:70. https://doi.org/10.15694/mep.2021.000070.1.

57. Zafar I, Chilton J, Edwards J, Watson H, Zahra D. Exploring basic science knowledge retention within a cohort of undergraduate medical students in the United Kingdom: A longitudinal study'. The Clinical Teacher. 2023; https://doi.org/10.1111/tct.13633

58. Schwartz BS, Chin-Hong PV. A Call to Action: Infectious Diseases Medical Educators Needed, The Journal of Infectious Diseases. 2017; 216 (suppl_5): S600–S605, https://doi.org/10.1093/infdis/jix325

59. Arja SB, White BA, Fayyaz J, Thompson A. The impact of accreditation on continuous quality improvement process in undergraduate medical education programs: A scoping review. MedEdPublish (2016). 2024 May 23;14:13. https://doi.org/10.12688/mep.20142.2.

60. Pattinson S R, McInerney P. Perceptions of changes made to a clinical skills curriculum in a medical programme in South Africa: A mixed methods study. Afr. J. Health Prof. Educ. (Online) [Internet]. 2020; 12(1): 12-16. http://dx.doi.org/10.7196/AJHPE.2020.v12i1.1220.

61. Murphy B. Medical schools ponder move to shorter pre-clerkship curriculum. 2021/11/17. Downloaded from https://www.ama-assn.org/medical-students/clinical-rotations/medical-schools-ponder-move-shorter-pre-clerkship-curriculum

62. Khan MS, Poyil MM. A Review of Medical Microbiology Curriculum Integration in the Integrated Modular System of Education At Medical Schools in Saudi Arabia. Sudan JMS [Internet]. 2023Jun.30 [cited 2024Oct.17];18(2):231–241. https://doi.org/10.18502/sjms.v18i2.13606

63. Peeraer G, Scherpbier AJ, Remmen R, De winter BY, Hendrickx K, van Petegem P, Weyler J, Bossaert L. Clinical skills training in a skills lab compared with skills

training in internships: comparison of skills development curricula. Educ Health (Abingdon). 2007 Nov;20(3):125.

64. Webb AL, Smyth L, Hafiz M, Valter K. The question of dissection in medical training: Not just "if," but "when"? A student perspective. Anat Sci Educ. 2022 Mar;15(2):281-290. https://doi.org/10.1002/ase.2168.

65. Quintero GA, Vergel J, Arredondo M, Ariza MC, Gómez P, Pinzon-Barrios AM. Integrated Medical Curriculum: Advantages and Disadvantages. J Med Educ Curric Dev. 2016 Oct 11;3:JMECD.S18920. https://doi.org/10.4137/JMECD.S18920.

66. Fincher RM, Wallach PM, Richardson WS. Basic science right, not basic science lite: medical education at a crossroad. J Gen Intern Med. 2009 Nov;24(11):1255-8. https://doi.org/10.1007/s11606-009-1109-3.\

67. Corkhill M. Undergraduate Clinical Practicum and the opportunity to practice skills in preparation for the graduate year: A review of the literature. Contemporary Nurse, 1998;7(2): 80–83. https://doi.org/10.5172/conu.1998.7.2.80

68. Wei J, Zhou H, Luo Q, Lu D, Wang J, Yu D, et al. Problems Existing in the Process of Clinical Medicine Undergraduate Practice and Coping Strategies. Creative Education,2021; 12: 2090-2097. https://doi.org/10.4236/ce.2021.129160.

69. Mortazavi R. Critical Look At Challenges In The Medical Laboratory Science Training In The Workplace. International Journal of Medical Science and Education 2020; 7(4):1-4. http://www.ijmse.com/uploads/1/4/0/3/14032141/ijmse2020_7_4__1-4.pdf

70. Sharma A, Abunada T, Said SS, Kurdi RM, Abdallah AM, Abu-Madi M. Clinical Practicum Assessment for Biomedical Science Program from Graduates' Perspective. Int J Environ Res Public Health. 2022 Sep 29;19(19):12420. https://doi.org/10.3390/ijerph191912420.

71. Armitage-Chan E. Best Practice in Supporting Professional Identity Formation: Use of a Professional Reasoning Framework. J Vet Med Educ. 2020 Apr;47(2):125-136. https://doi.org/10.3138/jvme.0218-019r.

72. Anderson K, Heenan M. Rethinking health policy student practicums through the application of the multiple streams framework: A case study. Healthc Manage Forum. 2021 Jul;34(4):211-215. https://doi.org/10.1177/08404704211009231.

73. Mosiienko H, Dziamko V, Ievstigneieva I, Kuninets O, Tsyganok V. Laboratory Practicums As The Main Form Of Integration Of Students' Theoretical And Methodological Knowledge And Practical Skills. Conhecimento & Diversidade. 2023;15: 306-326. https://doi.org/10.18316/rcd.v15i38.11054.

74. Diana R , Surahman E, Makiyah Y. The Effect of Problem Based Learning with Laboratory Activities on Students' Problem-Solving Skills. Jurnal Pendidikan MIPA. 2023; 23: 1017-1029. https://doi.org/10.23960/jpmipa/v23i3.pp1017-1031.

75. Seth P, Hueppchen N, Miller SD, Rudzicz F, Ding J, Parakh K, Record JD. Data Science as a Core Competency in Undergraduate Medical Education in the Age of Artificial Intelligence in Health Care. JMIR Med Educ. 2023 Jul 11;9:e46344. https://doi.org/10.2196/46344.

76. Adnan AI. Effectiveness of Communication Skills Training in Medical Students Using Simulated Patients or Volunteer Outpatients. Cureus. 2022 Jul 10;14(7):e26717. https://doi.org/10.7759/cureus.26717.

77. Kolbe M, Goldhahn J, Useini M, Grande B. "Asking for help is a strength"-how to promote undergraduate medical students' teamwork through simulation training and interprofessional faculty. Front Psychol. 2023 Aug 28;14:1214091. https://doi.org/10.3389/fpsyg.2023.1214091.

78. Franz A, Oberst S, Peters H, Berger R, Behrend R. How do medical students learn conceptual knowledge? High-, moderate- and low-utility learning techniques and perceived learning difficulties. BMC Med Educ. 2022 Apr 6;22(1):250. https://doi.org/10.1186/s12909-022-03283-0.

79. Undru TR, Uday U, Lakshmi JT, Kaliappan A, Mallamgunta S, Nikhat SS, Sakthivadivel V, Gaur A. Integrating Artificial Intelligence for Clinical and Laboratory Diagnosis - a Review. Maedica (Bucur). 2022 Jun;17(2):420-426. https://doi.org/10.26574/maedica.2022.17.2.420.

80. Vora LK, Gholap AD, Jetha K, Thakur RRS, Solanki HK, Chavda VP. Artificial Intelligence in Pharmaceutical Technology and Drug Delivery Design. Pharmaceutics. 2023 Jul 10;15(7):1916. https://doi.org/10.3390/pharmaceutics15071916.

81. Julita J, Sunandar A, Hanum HM. Practicum-Based Learning to Improve Critical Thinking Ability and Student Learning Outcome on Cell Metabolism Material. Jurnal Bioeduin, 2023; 13(2):88-96

82. Mamede S, van Gog T, Sampaio AM, de Faria RM, Maria JP, Schmidt HG. How can students' diagnostic competence benefit most from practice with clinical cases? The effects of structured reflection on future diagnosis of the same and novel diseases. Acad Med. 2014 Jan;89(1):121-7. https://doi.org/10.1097/ACM.0000000000000076.

83. Shrivastava SR, Shrivastava PS. Training Medical Students to Develop the Skills for Establishing Clinical Diagnosis. Journal of the Scientific Society 2021;48(1): 10-12, https://doi.org/10.4103/jss.jss_123_20

84. Bugaj TJ, Nikendei C. Practical Clinical Training in Skills Labs: Theory and Practice. GMS J Med Educ. 2016 Aug 15;33(4):Doc63. https://doi.org/10.3205/zma001062.

85. Grandi LC, Bruni S. Will the Artificial Intelligence Touch Substitute for the Human Touch? NeuroSci. 2024; 5(3):254-264. https://doi.org/10.3390/neurosci5030020

86. Lee MGY, Hu WCY, Bilszta JLC. Determining Expected Research Skills of Medical Students on Graduation: a Systematic Review. Med Sci Educ. 2020 Aug 31;30(4):1465-1479. https://doi.org/10.1007/s40670-020-01059-z.

87. van Woezik TET, Oosterman JP, Reuzel RPB, van der Wilt GJ, Koksma JJ. Practice-based learning: an appropriate means to acquire the attitude and skills for evidence-based medicine. Int J Med Educ. 2020 Jul 24;11:140-145. https://doi.org/10.5116/ijme.5ee0.ab48.

88. Kulkarni M., Meenal. Time management skills among medical students. Indian Journal of Public Health Research & Development. 2020;11: 488-493. https://doi.org/10.37506/ijphrd.v11i6.9825.

89. Al-Otaibi M. Medical Students' Time Management Skills and Strategies in Connecting to Self-Directed Learning: A Qualitative Study. PEOPLE: International Journal of Social Sciences, 2019;5(2): 222–237. https://doi.org/10.20319/pijss.2019.52.222237

90. Addis BA, Gelaw YM, Eyowas FA, Bogale TW, Aynalem ZB, Guadie HA. "Time wasted by health professionals is time not invested in patients": time management practice and associated factors among health professionals at public hospitals in Bahir Dar, Ethiopia: a multicenter mixed method study. Front Public Health. 2023 Jul 21;11:1159275. https://doi.org/10.3389/fpubh.2023.1159275.

91. Markus JF, Rudenberg FH, Haskin DE. Graduate Teaching Practicum: preparation for careers in academic medicine. Medical Teacher, 1987; 9(4): 479–481. https://doi.org/10.3109/01421598709008345

92. Watson I, Wilkie P, Hannan A, Beastall G. Role of laboratory medicine in collaborative healthcare. Clinical Chemistry and Laboratory Medicine (CCLM). 2019;57(1): 134-142. https://doi.org/10.1515/cclm-2017-0853