How Science Educators Still Matter: Leveraging the Basic Sciences for Student Success

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New Horizons: Restructuring the Basic and Clinical Sciences beyond USMLE

Presenters: Nadia Ismail, David Rowley, and Munder Zagaar; Baylor College of Medicine (BCM), Houston, TX

In the first session, Dr. Ismail discussed curricular trends based on published data from the Association of American Medical Colleges (AAMC), illustrating that, since 2017, approximately 20% of US medical schools completed curricular changes and approximately 65% planned or were in the process of implementation [1]. Most curricular changes targeted the pre-clerkship (“foundational sciences”) phase, typically by shortening its length. Other curricular changes focused on enhancing clerkship coordination and the increased use of simulation learning experiences, emphasizing interprofessional education, competency-based education, team-based learning, self-directed learning, and computer-based instruction. She noted that the goal of curricular change was not to limit foundational sciences content. Instead, educators hoped to better integrate basic science content throughout the whole medical school curriculum, highlighting foundational thinking by increasing the number and variety of applications for foundational sciences in clinically relevant teaching. She stressed that foundational sciences serve as the basis of critical thinking and clinical problem-solving. For example, they enable learners to understand normal homeostasis, its disruption due to disease or illness, and how to initiate clinical management. To do so effectively, medical students require a fund of foundational knowledge to evaluate multiple hypothetical possibilities to take appropriate action. For most physicians, medical practice is routine. They often use pattern recognition of signs and symptoms to make clinical decisions. However, expert physicians also rely on their robust understanding of basic sciences for complex cases to deviate from usual treatment patterns.
Dr. Rowley discussed curricular challenges at BCM, which has a history of experimenting with curricular change. In the 1970s, BCM explored an optional 3-year program with a truncated basic science curriculum but ultimately settled on an 18-month foundational sciences phase in a 4-year overall medical school curriculum. One major challenge was the departmental accountability for curricular content as experts in different departments directed courses. In the 1990s, BCM started to centralize oversight and accountability to curriculum deans and the curriculum committee, which was a first and necessary step to address meaningful content integration. Still, over time, it became apparent that content accountability was being managed in traditional siloed structures. In 2018, BCM embarked on an intentional curriculum renewal. BCM educators strategically incorporated foundational sciences throughout the 4 years by starting with the bulk of foundational content, including clinical relevance, during the first 12 months, followed by deliberate threading of foundational material into the clinical curriculum. To do so, it used the learning framework of Understanding by Design [2].

Dr. Zagaar explained the three major components of the Understanding by Design framework that are well suited for a competency-based medical education program: (1) start with the end in mind, (2) assess for understanding, and (3) design learning experiences to teach. This process, starting with outcomes and working backward to develop appropriate assessment tools before curricular content, is the opposite of the typical forward design method in which faculty members determine content first. A clear understanding of the destination assures that the steps taken are in the right direction and encourages a deeper understanding of transferrable concepts or skills (enduring knowledge) instead of just covering facts. He explained how they used these principles to guide their curriculum renewal process. First, they established essential understandings basic to the practice of medicine, including foundational sciences, clinical skills, metacognitive awareness, and inquiry. Second, they discussed acceptable evidence of learning that embraces individual student challenges; specifically, they pivoted from a traditional approach to assessment towards a multifaceted assessment that included qualitative and quantitative formative assessment with build-in remediation that encourages students to progress from competence towards excellence. Third, they developed an integration mechanism for tracking the alignment of the curriculum by using curricular threads that helped them move away from siloed structures towards shared accountability for learners, faculty, and curricular administrators. He illustrated that transitioning into medical school starts with a basic understanding and broad exposure to the principles of health and disease. From there, the foundational sciences are introduced from molecular to psychosocial levels, anchored with metacognitive and clinical contexts, and delivered using different learning methods such as self-directed learning. Students then progress to an integrated system-based framework of applied sciences in which they apply foundational knowledge to clinical problems. Faculty members use built-in remediation to capture all students by providing support, time, and opportunities to progress towards the desired outcomes. In the last phase, faculty reinforce foundational science knowledge and thinking skills through purposeful repetition through integrated teaching sessions and mentored experiences to apply foundational science towards discovering new knowledge and dissemination. Educators intertwine the three main curricular thread families throughout the phases: foundational sciences, metacognitive skills, and clinical preparation skills. These threads ensure flexible movement from understanding to reasoning to action and provide an accountability system for outcomes, assessments, and instructional content. Instructors deliver the connection in steps: hybrid case-based clinical scenarios, hybrid clinical encounters, simulation-based learning, clinical teaching integrative sessions, applied foundational science electives, and an inquiry project that deliberately ties foundational sciences into clinical decision-making.

Research in Medical School – Impact on Career Path

Presenter: Rachel Wolfson; University of Chicago Pritzker School of Medicine, Chicago, IL

In the second session, Dr. Wolfson discussed the medical student research participation landscape. Research during medical school is increasingly common and often supported by structured scholarly concentration programs providing protected time, dedicated mentors, and benchmarks for completion. However, comparing medical school research curricula across the nation is difficult. There are various curricular elements (optional versus required research projects, amount of protected time, nature of essential deliverables, different tracks in which inquiry projects have different emphases, and the definitions of “scholarly”). She emphasized that crucial critical thinking skills can be learned from diverse projects and are not limited to traditional basic science research projects. Using AAMC Graduation Questionnaire (GQ) data from the last 6 years, she showed that the number of medical research opportunities, publications, and poster presentations has increased by 10–12%. She also reviewed several publications that measured the impact of research on medical student education in single-center studies [3–8]. All discussed studies showed a positive correlation of research fellowships with increased publications, better residency match results, and a higher likelihood of attaining academic positions.
What is the impact of research participation during medical school on student career trajectory? In Dr. Wolfson’s institution, the faculty’s curricular goals are very different from those of medical students. The faculty hope to develop critical scientific thinkers, self-directed learning skills, and sustained interest in career-long research. However, medical students prefer to establish a solid mentoring relationship to enhance competitiveness for the residency match [9]. Addressing the latter, Dr. Wolfson mentioned anecdotal data about medical students’ perceptions that success in research during medical school is a vital variable in highly competitive specialties. It may become even more critical now that USMLE Step 1 is pass/fail. Therefore, publications of scholarly work, especially in highly competitive fields, are crucial. However, research projects in such areas are not always possible, or students are unsure which specialty they will eventually choose.

How do residency program directors regard scholarly work in evaluating applicants? Dr. Wolfson discussed a survey study from 2009, which indicated that scholarly work was at the bottom of initial selection criteria yet was decisive for ranking once applicants were scored “outstanding” [10]. Further, several specialty-specific studies indicated that research is an important selection criterion that has increased in recent years [11–13]. Program directors were concerned that students will look more similar with USMLE Step 1 being pass/fail, and research may become a more decisive selection factor. Dr. Wolfson raised two fundamental questions: (1) Is today’s goal to include research in the medical school curriculum to educate future researchers, or is it to enhance residency matching? and (2) Is success in research an independent variable, or is it a proxy for other applicant characteristics, such as enhanced communication and teamwork skills, intellectual curiosity, perseverance, or commitment?

Dr. Wolfson reviewed data from the 2020 National Resident Matching Program (NRMP) [14], correlating mean numbers of research experiences of medical students to matching results per specialty field. These data demonstrated that only in the highly competitive specialties, such as dermatology, neurological surgery, plastic surgery, and radiation oncology, did students who matched have more research publications and poster presentations than students who did not match. She then discussed the 2021 NRMP director survey. Only some program directors scored “involvement of research” and “interest in an academic career” as important decision factors for selecting an applicant for an interview. Even fewer program directors considered these two criteria as important for ranking applicants. As part of the Scholarly Concentration Collaborative (scollaborative.uchicago.edu), a multi-center collaborative aimed to improve and grow student research and discovery opportunities, her research team is currently involved in a similar study. In this study, they survey residency program directors to understand and describe the relevance of medical student research. Their goal is to identify the specialty fields that weigh research and the types of research they value in the applicant selection process. They also want to understand how this changes with USMLE Step 1 being pass/fail.

**Integrating Basic Science in the Clerkships: Innovative Strategies and Persistent Challenges**

**Presenter: Michelle Daniel; University of California San Diego School of Medicine, San Diego, CA**

Since the time of A. Flexner, faculty have taught basic and clinical sciences in discreet consecutive blocks, which has led to compartmentalization of knowledge. The resulting failure to transfer basic science principles into clinical practice negatively affects diagnostic and clinical treatment reasoning. Therefore, numerous institutions embarked on integrating the foundational and clinical sciences across all years of the medical school curriculum using various curricular models and pedagogies. Clinical education in the pre-clerkship years now commonly occurs in the context of clinical cases. However, incorporating basic science instruction during the clinical years has proven challenging.

In the third session, Dr. Daniel discussed that in medical education, “integration” refers to curricular integration that involves organizing teaching materials in a manner that interrelates subjects. There are three types of curricular integration: (1) horizontal integration (between parallel disciplines that are taught in the same phase of the curriculum); (2) vertical integration (between disciplines taught in different phases of the curriculum); and (3) spiral integration (combination of both horizontal and vertical integration that unites across both disciplines and time). Curricular integration alone may not achieve cognitive integration, which is another key goal in curriculum development. Cognitive integration occurs when individual learners comprehend the relationships between foundational science constructs and clinical care and the relevance of basic science principles to clinical decision-making (conceptual coherence).

Dr. Daniel outlined three instructional interventions but stressed that a multimodal approach is critical [15]. Program-level interventions require students to leave their clinical teams and return to the main campus (multi-week transitions, 1-week intersessions between clerkships, day-long sessions during clerkships). Clerkship-level interventions that highlight basic science as part of clerkship education (case-based learning). Bedside-level interventions are point-of-care activities that connect caring for patients with basic science principles. Faculty development is vital, as
practicing clinicians are often anxious about teaching basic science concepts due to a lack of expertise.

Dr. Daniel discussed assessment strategies, including low-stakes formative and high-stakes summative assessments. Most schools offer access to third-party question banks for USMLE Step 1 preparation and summative assessments in the form of customized NBME exams and Comprehensive Basic Science Exams (CBSE). In addition, many medical schools rely on spaced repetition of assessment using homegrown question banks and third-party vendors to test basic science content.

The USMLE Step 1 exam placement within the medical school curriculum is crucial. Delaying USMLE Step 1 until after clerkships encourages students to review basic science concepts directly connected to patient care. It also fosters cognitive integration during their study period after students have had extensive exposure to patient care and have a cadre of illness scripts in their repertoire. Dr. Daniel mentioned that her group collaborated with the NBME to perform multiple studies evaluating the impact of post-clerkship USMLE Step 1 administration. One study found that the mean USMLE Step 1 score increased and fewer students failed after moving the exam to post-clerkship [16]. Another study found that after rising national USMLE Step 2 scores were accounted for, there were no significant differences in USMLE Step 2 scores or failure rates [17]. Another study showed that many NBME subject exams scores decreased, particularly in medicine and neurology [18]. The earliest clerkships were most affected, but differences gradually disappeared with subsequent examination as students gained clinical experience. Overall, the outcomes of moving USMLE Step 1 after the core clerkships demonstrated no inferiority when it came to USMLE Step 1, Step 2, and CBSE scores.

Dr. Daniel discussed whether the placement of USMLE Step 1 after clerkships, curricular integration strategies during clerkships, or both, effectively promotes cognitive integration. Her team collected student perspectives at their institution [19]. They found that pulling students off their clerkships for full or half-day basic science instruction was not an effective integration strategy. In contrast, the explicit link between basic sciences to patient care promoted cognitive integration and long-term memory. Further, clerkships with applied science components were more effective at driving cognitive integration. Lastly, placement of USMLE Step 1 after the core clerkships had mixed impacts on students. When students began their clerkships, they felt like their science foundation was on shaky ground. Later on, however, students took advantage of having the clinical experience to facilitate cognitive integration. Their studies showed that cognitive overload and demands on time during clerkships led students to prioritize clinical over basic science learning. Educators facilitated this by focusing on teaching clinical science to the exclusion of basic science, seemingly making basic science irrelevant to patient care due to a lack of explicit connections. As a result, students often perceived longitudinal basic science curricula as well-intended but disconnected from clinical care.

Identity Shape-Shifting: How Basic Science Teaching Practices can Foster Identity Transformation from Medical Student to Medical Professional

Presenters: Michelle Lazarus and Shemona Rozario; Monash University, Melbourne, Australia

In the historical apprentice model, trainees watched and learned in a didactic fashion. In the present, medical curricula integrate simulation opportunities. Future curricula may be full of technology, including artificial intelligence (AI), and professional identity development must shift alongside this development.

In the fourth session, Dr. Rozario explained that our identity development includes the formation of personal and professional identities that develop through social interactions over our life span. Pre-determined factors (genetics) are unchangeable. During childhood, we are most malleable to the social construction of personal identity formation, and the results are most resistant to later changes. The dynamic social construction of professional identity occurs in adult life when we interact more formally with our environment, other professions represented by different individuals, and a wider community (religion, culture, socioeconomics, status, personal relationships). She quoted work by Monrouxe & Poole, who compared the structure of identity with an onion (core = pre-determined internal identity, inner layers = early constructed identity that becomes internal, outer layers = constructed identity) [20]. As we grow and interact more widely with others, we add more layers (complexity) to our identity. Yet when professional and personal identities clash, identity dissonance occurs. Pratt described identity dissonance in a study investigating identity construction of medical residents in different specialties over 6 years [21]. They found that radiology residents spent more time attending lectures and thus developed a parallel identity as medical educators since their work did not match their expectations of the roles and responsibilities of a physician (identity splitting). Similarly, surgery residents spent more time on paperwork and thus developed a parallel identity as general physicians (identity patching). By contrast, primary care residents experienced only minor violations, reinforcing their current identity (identity enriching).

Dr. Lazarus discussed how basic science educators could help students develop their professional identity by
Dr. Lazarus used the field of anatomy as an example to explain the impact of technology on anatomy curricula. Her group performed a meta-analysis showing that anatomy was taught at every medical school using different modalities, yet all students learned it equally well [23]. She suggested integrating AI into the anatomy curriculum to deliver content more effectively and use the gained time to enhance critical thinking and thus increase professional identity development. Her work demonstrated that AI technology increased student engagement and learner monitoring, yet also developed a view that healthcare has singular logic, that individuals fit into categories, and that psychological skills have limitations. In another study, her group identified six themes linked to professional identity development: process, peer relationships, tutor relationships, ethics, tolerance of uncertainty, and exposure [24]. Of those, the tolerance of uncertainty, or managing novelty effectively, was the only theme that negatively impacted professional identity development in students. Using a clinical case, she illustrated the process of uncertain tolerance: the physician’s response to a patient’s symptom (the uncertain stimulus) is moderated by cognitive (doubt/confidence), emotional (fear/curiosity), and behavioral (avoidance/decisions) influences. Her group stated that basic science education is a powerful moderator during uncertain times. It can increase professional identity development, job satisfaction, independence, creative solutions, and curiosity and can decrease burnout, the requirement of supervision, difficulty in solving problems (insecurity), and disengagement.

Dr. Lazarus described how educators can stimulate students’ uncertainty in the classroom: (1) transferring knowledge to a real-world example; (2) gray cases in which parameters are changed; (3) providing multifaceted perspectives from different specialists; and (4) questioning preconceptions (e.g., show the same experiment with different outcomes). She also listed optional cultural literacy pedagogical components: critical incidents (case studies), destabilization (role-play, simulation), and iso-immersion (work-integrated learning, placements). She suggested bringing different moderators into the classroom once students have been stimulated, including educator- and student-sourced moderators (e.g., self-reflection, discuss career value, assessments with more than one correct answer, clinical cases without a diagnosis). It is essential to know which moderator(s) to use at what time and at what level.

Dr. Lazarus concluded that appropriately build-in of professional identity development in the basic science curriculum has several advantages. It prepares students better for the realities of their future careers. Creating a classroom fostering uncertainty tolerance helps students manage future transitions to work. Uncertainty tolerance will increase students’ ability to detect novelty and promote professional identity development.

Rethinking Assessment Strategies in the Basic Sciences as Step 1 Goes Pass/Fail

Presenter: David Harris; University of Central Florida (UCF) College of Medicine, Orlando, FL

In the fifth session, Dr. Harris described the changes in assessment strategies that UCF recently implemented. These changes targeted the first 7 months of their curriculum that covered most of the traditional basic sciences. He cautioned that these changes were still work in progress. A particular challenge they faced was UCF’s use of letter grades.

Dr. Harris cited external resources frequently used by students (Anki, Aquifer, Boards & Beyond). While many of these resources are well constructed with practice questions, feedback, and links to reliable sources, students struggle with how to effectively include them in their studies. Nevertheless and further driven by the COVID-19 pandemic, students accelerated their use of outside resources. In response, faculty changed from traditional textbook teaching to include other teaching resources. Citing work by Simpson et al. [25], Dr. Harris listed the expected roles of a future medical educator in 2025 as diagnostic assessor, content curator, technology adopter, learner-centered navigator and professional coach, clinician role model, and learning environment designer, architect, and implementer. Dr. Harris proposed that these role changes may happen more quickly than initially proposed.

Dr. Harris discussed the role of the medical educator as an “assessor.” He reviewed that most assessments to test basic science content were multiple-choice questions (MCQs). He argued that while MCQs work well to assess content knowledge, they do not assess how learners apply what they memorized. They also do not measure skills and attributes, such as critical thinking, good communication skills, and life-long learning. He advised that students with disabilities and specific learning difficulties should not be disadvantaged by the assessment method (disability inclusion). He specifically outlined how faculty will have to adapt to being an “assessor” and “coach” to provide feedback for skills that cannot be fostered by outside resources or tested in MCQs.
Several goals guided UCF’s changes in assessment strategies: (1) USMLE Step 1 going pass/fail; (2) emphasis on communication, critical thinking, and self-regulation; (3) limiting the use of MCQs; and (4) providing opportunities for cognitive integration (metacognition) early in the curriculum. With these goals in mind, UCF focused its efforts on four learning approaches: (1) concept mapping, (2) high-fidelity patient simulations, (3) team-based learning sessions, and (4) case-based learning. UCF has not implemented the fourth focus since this will require the uniform use of case presentations.

UCF integrated concept mapping exercises at various points during the first 7 months of their preclinical curriculum for formative and summative assessments. For each exercise, students received the following: (a) the overall (“terminal”) objective, (b) specific (“enabling”) objectives, each of which had to be addressed, (c) instructions including rules for resources, (d) clinical vignette, (e) list of facts, (f) starter map, (g) tools to build the map, and (h) the rubric by which faculty assess student performance. Students worked in groups of six, applying their knowledge of foundational content and using available technology (“Cmap” software); faculty acted only as facilitators. Content and non-content experts performed the assessments. Several challenges arose: Non-content experts needed too long for grading, contributed to high variability in grading, and were unable to provide in-depth content feedback; the inability to comment directly in the Cmap file; and increased student stress.

UCF used high-fidelity patient simulations to highlight essential physiology concepts underlying various diseases. Students started in the classroom with an introduction, then entered the simulation center, then came back to the classroom for debriefing. To increase student engagement, students needed to answer (individually or in teams) specific essay questions on which they received feedback from faculty. Educators then asked the students to complete a self-reflection exercise on their simulation experience on which faculty again provided narrative feedback (to foster self-regulation skills). Dr. Harris stated that this process’s advantages (e.g., clinical application) and disadvantages (e.g., resource and time extensive) were still under debate.

UCF implemented changes to their team-based learning process: all parts were made summative, faculty replaced MCQs with other question types, modified the grading scale, and added peer evaluation.

Dr. Harris encouraged to modify what you have or is available, recognize the “cultural” shift for students and faculty roles, and focus on what you want the students to be able to do, what you value, and measure those.

We wish to thank each of our presenters for their contributions to this series!

Declarations

Ethical Approval N/A.

Informed Consent N/A.

Conflict of Interest The authors declare no competing interests.

References

1. AAMC. Curriculum reports, curriculum design, and structure, curriculum change in US medical schools. 2018. https://www.aamc.org/data-reports/curriculum-reports/interactive-data/curriculum-change-us-medical-schools.

2. Wiggins G, McTighe J. Understanding by design, expanded 2nd edition. Association of Supervision and Curriculum Development (ASCD), Alexandria VA. 2005.

3. Areepanthu CJ, Bole R, Stratton T, Kelly TH, Starnes CP, Sawaya BP. Impact of professional student mentored research fellowship on medical education and academic medicine career path. Clin Transl Sci. 2015;8(5):479–83.

4. Wolfson RK, Alberson K, McGinty M, Schwanz K, Dickins K, Arora VM. The impact of a scholarly concentration program on student interest in career-long research: a longitudinal study. Acad Med. 2017;92(8):1196–203.

5. Conroy MB, Shaffey S, Jones S, Hackam DJ, Sowa G, Winger DG, Wang L, Boninger ML, Wagner AK, Levine AS. Scholarly research projects benefit medical students’ research productivity and residency choice: outcomes from the University of Pittsburgh School of Medicine. Acad Med. 2018;93(11):1727–31.

6. Radville L, Aldous A, Arnold J, Hall AK. Outcomes from an elective medical student Research Scholarly Concentration program. Journal Invest Med. 2019:67(6):1018–23.

7. DiBiase RM, Beach MC, Carrese JA, Haythornthwaite JA, Wheelan SJ, Atkinson MA, Geller G, Gebo KA, Greene JA, Sozio SM. A medical student scholarly concentrations program: scholarly self-efficacy and impact on future research activities. Med Educ. 2020;52(1):1786210.

8. Jeffe DB, Yan Y, Andriole DA. Do research activities during college, medical school, and residency mediate racial/ethnic disparities in full-time faculty appointments at U.S. medical schools? Acad Med. 2012;87(11):1582–93.

9. Alberson K, Arora VM, Zier K, Wolfson RK. Goals of medical students participating in scholarly concentration programmes. Med Educ. 2017;51(8):852–60.

10. Green M, Jones P, Thomas JX Jr. Selection criteria for residency: results of a national program directors survey. Acad Med. 2009;84(3):362–7.

11. Huang MM, Clifton MM. Evaluating urology residency applications: what matters most and what comes next? Curr Urol Rep. 2020;21(10):37.

12. Bowe SN, Schmalbach CE, Laury AM. The state of the otolaryngology match: a review of applicant trends, “impossible” qualifications, and implications (Review). Otolaryngology Head & Neck Surgery. 2017;156(6):985–90.

13. Vinagre R, Tanaka P, Park YS, Macario A. Red flags, geography, exam scores, and other factors used by program directors in determining which applicants are offered an interview for anesthesiology residency. Cureus. 2020;12(11).
14. National Residency Matching Program. https://www.nrmp.org/wp-content/uploads/2021/08/Charting-Outcomes-in-the-Match-2020_MD-Senior_final.pdf.
15. Daniel M, Morrison G, Hauer KE, Pock A, Seibert C, Amiel J, Poag M, Ismail N, Dalrymple JL, Esposito K, Pettepher C, Santen SA. Strategies from 11 U.S. medical schools for integrating basic science into core clerkships. Acad Med. 2020. Publish Ahead of Print. https://doi.org/10.1097/ACM.000000000003908.
16. Jurich D, Daniel M, Paniagua M, Fleming A, Harnik V, Pock A, Swan-Sein A, Barone MA, Santen SA. Moving the United States Medical Licensing Examination Step 1 after core clerkships: an outcomes analysis. Acad Med. 2019;94(3):371-7.
17. Jurich D, Santen S, Paniagua M, Fleming A, Harnik V, Pock A, Sein A, Barone M, Daniel M. Effects of moving the United States Medical Licensing Examination (USMLE) Step 1 after core clerkships on Step 2 Clinical Knowledge (CK) performance. Acad Med. 2020;95(1):111–21.
18. Jurich D, Daniel M, Hauer K, Seibert C, Chandran L, Pock A, Fazio S, Fleming A, Harnik V, Santen S. Does delaying the United States Medical Licensing Examination Step 1 to after clerkships affect student performance on clerkship subject examinations. Teach Learn Med. 2020;33(4):366–81.
19. Kercheval JB, Mott NM, Kim EK, Boscardin CK, Klein BA, Hauer KE, Daniel M. Students’ perspectives on basic and clinical science integration when Step 1 is administered after the core clerkships. Teach Learn Med. 2022;9:1–11. https://doi.org/10.1080/10401334.2022.2030235. Online ahead of print.
20. Monrouxe LV, Poole G. An onion? Conceptualizing and researching identity Medical Education. 2013;47(4):425–9.
21. Pratt MG, Rockmann KW, Kaufmann JB. Constructing professional identity: the role of work and identity learning cycles in the customization of identity among medical residents. Acad Manag J. 2006;49:235–62.
22. Woods NN. The role of basic knowledge in clinical reasoning and the development of medical expertise. KIPRIME podcast episode 6. https://staff.ki.se/kiprime-podcast-episode-6-nicolen-woods. Accessed 22 Mar 2022.
23. Wilson AB, Miller CH, Klein BA, Taylor MA, Goodwin M, Boyle EK, Brown K, Hoppe C, Lazarus M. A meta-analysis of anatomy laboratory pedagogies. Clin Anat. 2018;31(1):122–33.
24. Stephens GC, Rees CE, Lazarus MD. Exploring the impact of education on preclinical medical students’ tolerance of uncertainty: a qualitative longitudinal study. Adv Health Sci Educ. 2021;26(1):53–77.
25. Simpson D, Marcdante K, Souza KH, Anderson A, Holmboe E. Job roles of the 2025 Medical Educator (Editorial). J Grad Med Educ. 2018;10(3):243–6.

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