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PERSPECTIVES

Conceptualisation and Implementation of a Competency-based Mutlidisciplinary Course for Medical Students in Neurosurgery

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Abstract: The field of medicine is quickly evolving and becoming increasingly more multidisciplinary and technologically demanding. Medical education, however, does not yet adequately reflect these developments and new challenges, which calls for a reform in the way aspiring medical professionals are taught and prepared for the workplace. The present article presents an attempt to address this shortcoming in the form of a newly conceptualized course for medical students with a focus on the current demands and trends in modern neurosurgery. Competency-based education is introduced as a conceptual framework comprising academic and operational competence as well as life-world becoming. This framework provides a sound educational foundation for future medical professionals, equipping them with the knowledge as well as skills needed to successfully navigate the medical field in the current day and age. Three competencies are identified that are central to day-to-day medical practice, namely digitalization, multidisciplinarity, and the impact of recent developments on the changing patient-practitioner relationship. These competencies are relevant for all medical disciplines, but are demonstrated here in a neurosurgical context and visualized using a real patient's case study. Students follow this sample patient's way through each step of the neurosurgical workflow, from planning to performing the procedure, and can see for themselves the importance and application of the aforementioned competencies based on this real-world example. Courses such as the one presented here may prepare medical students more adequately for their future work by combining theoretical and practical skills and critical reflection, thereby providing holistic and practical insights as well as a conceptual framework for their future careers.
Keywords: competency-based learning, medical education, multidisciplinarity

Introduction

The field of medicine is in a constant state of flux, yet medical education does not adequately reflect the changes that have long made their way into everyday medical practice. Identifying the need for a shift in medical education, large educational organizations are increasingly proposing sets of core competences required from aspiring medical professionals in order to ensure adequate quality of patient care. An example are the Milestones currently endorsed by the Accreditation Council for Graduate Medical Education (ACGME[1]) and its predecessor, the Outcome Project, which was launched in 2001 and included competences aimed at patient-centered care, interdisciplinary work, and the use of information technology, among others. Technological advances in particular are continuously reshaping the everyday working reality of medical professionals, and the classical approach of taking a medical history followed by a physical examination and synthesis is increasingly being aided by algorithmic and primarily visually-driven diagnosis and therapy planning. While this holds true for all medical specialties, neurosurgery is arguably at the forefront of these developments. Owing to the considerable complexity and intricacy of the performed procedures, neurosurgery is a particularly

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fast-paced specialty and is inextricably linked to the application and development of new technologies. These developments make neurosurgery not only an intriguing and cutting-edge specialty, but also an ideal setting for the adaptation and evaluation of current teaching methods and course designs. In combination with first-hand experience derived from clinical practice at our institution, the changes affecting the medical field as a whole and neurosurgery specifically prompted the identification of three skill sets that are of increasing importance for the successful transition of aspiring physicians into clinical practice. In our experience, recent and ongoing developments in medical practice not only necessitate a basic digital competence among medical professionals, but are also accompanied by inevitable changes in the patient-practitioner relationship. The increasing complexity of diagnostic and therapeutic technologies furthermore promises to erode the modular nature of different medical specialties and provides a fruitful opportunity for multi-disciplinary cooperation with medical and non-medical disciplines alike. We argue that all these developing facets of modern medicine should be represented in medical education to prepare medical students for their future careers.

For educational purposes, these skills may be conceptualized as different competencies that lend themselves well to be positioned at the core of a reformed curriculum within the framework of competency-based medical education (CBME).[2] Competency-based teaching methods place greater emphasis on the applicability of skills beyond the academic sphere, preparing graduates more adequately for clinical practice and thus making it a sound foundation upon which to build new curricula. Borrowing from the notion of CBME, a compulsive elective module was created in a joint effort by members of the Cluster of Excellence: Matters of Activity at Humboldt Universität zu Berlin, Charité - Universitätsmedizin Berlin and the Medical Futures Lab at Rice University in Houston, Texas, designed to address the aforementioned competencies in the context of a neurosurgery-focused university course for undergraduate medical students. The course was created in 2016 and has been run bi-annually ever since, while continuously being developed further in an iterative process based on participant feedback and various evaluation measures. In what follows we present the planning, structure, and participant evaluations of this neurosurgery-based course addressing currently neglected competencies relating to digitalization, changes in the patient-practitioner relationship, and multidisciplinarity.

Course Conceptualization

Theoretical Foundation: Competency-Based Medical Education

Over the course of the past decades, a progressive shift has become evident in the literature from structure- or time-based educational models towards competency-based ones,[3] promising a more comprehensive learning experience which not only focuses on knowledge but also on various practical skills. "Competencies" may be thought of as skills or abilities that describe components of the broader, multifaceted concept of competence.[4] The somewhat abstract nature of competencies, however, has resulted in justified criticism of their application in educational contexts, as this poses problems particularly with regard to their assessment.[5] In response to these criticisms and drawing on the work of ten Cate,[6] the notion of Entrustable Professional Activities (EPAs) has gained considerable momentum as a potential way of operationalizing competencies. EPAs are essentially competencies in context; that is, an integration of the competencies that allow one to perform the professional activities expected of a good doctor within a given specialty. In the words of Ten Cate,[7](p. 326) "competencies are abstract constructs describing capabilities of persons, EPAs just constitute the work that must be done". While competency-based teaching formats are increasingly being implemented in postgraduate resident training, where concepts such as EPAs can easily be implemented due to the embeddedness of this form of teaching in clinical practice, the literature on undergraduate programs explicitly emphasizing this approach is more scarce.

The shift towards more competency-based medical education encourages a change in the way in which a competent doctor is defined – not based on input in the form of the number of clinical rotations completed or years spent in training, but based on outcomes as represented by the competence they have achieved over the course of their educational career.[7] Consequently, curricula designed in this way are the result of a backward process that starts by listing all the relevant competencies that are to be addressed. To fulfil academic requirements, rankings and passing criteria are developed.[8,9] It has been remarked that competency-based courses focused solely on practical skills are too narrow an approach, and should rather constitute only one element of a multi-faceted educational program.[9] Barnett[10] proposed the distinction between two distinct types of competence – academic and operational. Representing opposing conceptions of the term competence, it is argued that in isolation, both are limited in their educational value. *Academic competence* broadly refers to knowledge and mastery of one's discipline, whereas *operational competence* describes the acquisition and application of practical skills. A key component argued to be missing from competence as conceptualized either academically or operationally is the lack of active reflection as opposed to mere reproduction of what has been learnt.[10] What is being neglected in education, Barnett contends, is the fact that everything that is taught should have the aim of adequately preparing students for their future work in the real world, a concept he terms *life-world becoming*. Going beyond the narrow scopes of either academic or operational competence, skills falling into the category of world-life becoming emphasize aspects such as transferability, flexibility, and reflection. The course herein described was conceptualized to address all three domains of competence.

While there are a multitude of examples of CBME in neurosurgical residency training,[8] the impact of which has been evaluated favorably,[11] courses for undergraduate medical students explicitly emphasizing competency-based teaching are scarce. Consequently, the competencies that should form the core of the present course were not sourced from previous publications and reports. Instead, competencies relevant to current and prospective neurosurgical practice were derived from first-hand experience at a large university hospital by the faculty involved in devising and teaching the course. To this end, current daily practice was carefully evaluated and discussed in order to foresee challenges that students may be confronted with upon entering clinical practice as a physician. This investigation of the current state of the art in medicine pointed to the need for inclusion of competencies relating to three topics in particular – digitalization, patient-practitioner relationship, and multidisciplinarity.

Student Feedback and Iterative Course Development

To ensure the continued relevance of the course as well as its seamless integration with and simultaneous novelty compared to the rest of the medical curriculum at our institution, student feedback was collected systematically for continuous course development. With regard to the digitalization aspect of the course, it was fed back that the more in-depth and at times critical coverage of new technologies in medicine that shaped this competency was "very important and is not dealt with enough in the medical curriculum". Students also reported practical hands-on sessions, implemented to consolidate as well as provide a more practice-driven approach to this competency, to be very informative and helpful, as they presented the only way to "get an idea of how to really apply these techniques".

Through their feedback it also became apparent that students appreciated the ways in which new insights could inform a better relationship with their future patients. During the first run of the course, for example, one student remarked that approaching the topic from a non-medical point of view provided the opportunity to reflect and gain the insight that one can get stuck in certain patterns of thinking, which can result in one-sided perspectives on topics and problems. This can make it more difficult to see things from a patient perspective.

An aspect that was highlighted as particularly insightful during every iteration of the course was multidisciplinarity. Students recollected that they appreciated being given an insight into other disciplines, which was interesting and more diverse – especially because our courses usually have a rather unipolar focus on imparting primarily strictly factual [medical] knowledge. Multiple students across different iterations of the course highlighted that such multidisciplinary perspectives are usually neglected in the curriculum, and that they provided a welcome addition to their educational repertoire. This feedback not only confirmed the impression gained from clinical practice that perspectives from different disciplines are beneficial in navigating the increasingly multidisciplinary and complex medical landscape, but also encouraged the gradual expansion on this competency as well as the inclusion of an even more diverse group of lecturers and tutors.

A piece of constructive criticism that informed a new addition to the course curriculum was the feedback that students would have appreciated more direct connections with clinical routine – particularly since neurosurgery as a specialty is not very well represented in the undergraduate curriculum, but interest in the topic is great. This prompted the inclusion of a sample patient case, which students are presented with during the first sessions and whose treatment course provides the common thread throughout the course. Newly introduced diagnostic and therapeutic techniques can thus be directly applied to this sample patient, and multidisciplinary input can be used to reflect on this case specifically. Furthermore, to comply with the wish for first-hand OR experience without introducing too much distraction into the operating room as would undoubtedly be the case if all students were to sit in on a surgery, a visit to our newly launched educational lounge was incorporated towards the end of the course. Designed specifically for educational purposes, this room located directly on the neurosurgical ward houses the infrastructure for real-time livestreams of the OR microscopic view. During these sessions, led by an attending neurosurgeon, the surgery can be openly discussed and student questions freely answered without disturbing the operating surgeons. Both of these additions were intended to give the course content a more directly clinical context, and have so far received positive feedback from students. All in all, student feedback helped to strengthen the focus on the three competencies comprising the core of this present course and finetune it in a way that is most helpful to student learners while nevertheless continuing to impart the skills and competences originally identified as integral to successful medical practice in neurosurgery specifically. The content relating to these three competencies will be discussed in the following sections.

Competencies

Digitalization

Whether it is the latest imaging techniques,[12] diagnostics based on artificial intelligence,[13] or augmented reality in the operating room,[14] it is getting increasingly difficult to imagine modern medicine without technological aids. More and more complex and highly specialized visualization strategies based on advanced imaging techniques are being used in diagnosis,[15] patient counselling,[16] treatment planning and therapy,[17] and a growing number are being supported by algorithmic clinical decision support systems.[18] However, a recent study found that the vast majority of surveyed medical students from Germany did not feel well prepared for a career in modern medicine that draws on progressively more complex digital technologies, indicating that they were offered hardly any courses focusing on digital competence.[19] This is despite the fact that 93% of surveyed members of medical faculties in Germany agreed that digitalization was essential for medical education, as another study found.[20]

Patient-Practitioner Relationship

The advent of new technologies and their widespread use also has implications for the patient-practitioner relationship. Digitalization has the potential to promote patient-centricity, but it may at the same time also lead to alienation from the patient as it carries a risk of increasing the perceived distance between patient and treating physician.[21] The digitalization and technologization of medicine can thus be considered a double-edged sword when it comes to patient orientation, which is something that current and future generations of physicians will have to learn to handle appropriately. To give them the tools to do so, medical education should cover the topics of patient empowerment, e-health, and the resulting consequences for classical medicine. The digital turn in healthcare has also led to a noticeable shift in patient self-care. Patients are increasingly being involved in the decision-making process regarding their health, and information about health and disease is more readily available now than ever before, which requires aspiring physicians to be experts in assessing credibility of diverse sources of information.[22] The result of these changes is increased patient autonomy but also responsibility, which is set to challenge the traditional role of the physician in their relationship to the patient and creates a need for clinicians to act as skilled communicators. This latter point also appears as one of the seven roles identified by the Royal College of Physicians and Surgeons of Canada as part of the CanMEDS competency framework,[4] emphasizing the importance of good communication skills among treating physicians with regard to quality of patient care.[23]

Multidisciplinarity

The increasing complexity of patient care brings with it the need for more specialized knowledge and thus leads to greater involvement of other professions and disciplines to complement the medical perspective of the treating physicians. It has long been known that the changing demographic profile of the patient population increasingly requires physicians to work in interdisciplinary teams so as to appropriately treat patients with complex or chronic illnesses as well as multiple comorbidities.[24] Additionally, even within the scope of one's own specialty it is often no longer sufficient to have the medical knowledge necessary to treat a patient – the sophisticated and intricate technology utilized across the course of treatment requires additional technical and multidisciplinary knowledge.[25] In light of these developments, it is foreseeable that in order to master the changing landscape of the health care system, it will be crucial to involve scholars from medical humanities, medical anthropology, design and computer science, to act as translators and facilitators of these new relationships. Understanding the added value of multidisciplinary perspectives as well as getting accustomed to viewing an issue through different interprofessional lenses is likely only gaining in importance for medical professionals and as such should be incorporated into medical education.

Course Execution

Target participants and Course Setting

The course is open to third-year medical students at Charité – Universitätsmedizin Berlin. To facilitate teacher-student interactions and enable participation in hands-on sessions, group size is limited to 18 students. Since the course was offered as an elective, students self-selected for participation by choosing from a number of courses offered during the same time period based on their respective interest profiles. At the time of course participation, they had finished preclinical modules and had already gained first insights into clinical subjects as part of the new revised medical curriculum at Charité. The course is designed as a condensed two-week program. This format provides the space to explore all the relevant disciplinary perspectives in an interconnected manner, while nevertheless maintaining a focus on the common thread throughout. Originally, the seminar ran for three weeks, but students reported difficulties in keeping track of the ways in which different sessions related to one another. Additionally, feedback revealed a preference among participating students for a more condensed and consequently overall shorter course structure, thus enabling complete immersion in the topics introduced therein without the need to work on other coursework in parallel, which could instead be completed after conclusion of the course. Overall, the module consists of 60 teaching units amounting to a total of 45 hours incorporating an integrated mixture of lectures, seminars, hands-on workshops, and on-site visits framed by blended learning elements, thus replicating the interprofessional nature of clinical routine in modern neurosurgery. Regular discussions of opinions and expectations about the ongoing iconic and digital turn in clinical practice are implemented to highlight heterogeneous paradigms and sources of friction between disciplines. In addition to in-person teaching content, students were assigned various tasks serving to prepare them for upcoming sessions and consolidate lesson content. These assignments consisted of reading, writing, or familiarizing themselves with various digital resources ahead of discussions. Importantly, students' performance on the course was not assessed. The difficulty in assessing performance in a competency-based teaching context is the subject of much discussion. While concepts such as EPAs[6] or Milestones[1] are able to address this issue in practice-based residency training to some extent, their implementation in an undergraduate, largely academically-based context is less straightforward.[26] This aspect in combination with the condensed two-week timeline led to the joint decision to forego assessment, instead encouraging and concentrating on students' ability to self-reflect on their experience during the course. The aim of the course was thus to provide a different perspective on the medical field and its multifaceted nature, allow for the exploration of different points of view, and provide an open space for discourse on the future of medicine and the changing role of the physician without the element of academic pressure.

Course Content

The course was designed to address the competencies described above and outlined again in Table 1. The theoretical input (listed under *Academic Competence*) is used in hands-on sessions (listed under *Operational Competence*) and the students' own experiences and reflections can be discussed with practitioners in on-site visits. Then, these insights are iteratively discussed later on in feedback and discussion sessions to consolidate the aforementioned input and solidify the competence for future use (listed under *Life-World Becoming*). Individual and group mind mapping is used to make explicit connections between the different inputs and to catalyze a sustained and applied learning experience. The choreography of different sessions is refined every year using the feedback and evaluation of both students and teachers. The current version of the timetable and an explanatory legend can be found in Supplementary Figures 1-3.

Table 1 Dimensions of Competence (Modified After Barnett, 1994;[10] Talbot, 2004[9])

Overall Competence	Academic Competence Theoretical input to build a foundation of required knowledge	Operational Competence Practical input and skills which are important in the given context	Life-World Becoming Combination of theoretical foundation and practical skills to be used in the future
Digitalization: **Comprehension of the impact of digitalization in healthcare in general and in neurosurgery in particular**	Surgical Image Worlds from 19th to 21st Century; Virtual Reality: Theory & Practice; Neurosurgery, Art history, Computer Science	Use case "the brain tumor patient"; Workshop 360° Videos and XR; App-based planning of patient positioning Computer Science, Neurosurgery	Awareness of and competence in dealing with different applications of digital technologies
Multidisciplinarity: **Understanding of basic principles of invasive and non-invasive brain function diagnostics, artificial intelligence and Big-Data analytics**	Image Techniques in Neurology & Neurosurgery; Functional Mapping Techniques & Tractography (Neurosurgery); Functional Guidance; Performative Design Research on Brain Mapping; Intraoperative Imaging; Plasticity & Neuromodulation; Digital Health: Machine Learning; TMS & EEG; Neurosurgery, Neurology, Neuroradiology, Medical Anthropology	TMS Motor Mapping; Tractography; Interactive MRI session; CyberKnife; Surgical Simulation practice session Neurosurgery, Computer Science	Multidisciplinary approach to various brain function diagnostics
Multidisciplinarity: **Understanding how design strategies to implement ideas work**	Visual History of Medicine in Art; Brain Roads: Exploring the White Matter of the Human Brain; Medicine & Media Studies: Introduction to Illustration Research Design, Medical Anthropology, Art History	Future OR Discussion Neurosurgery, Computer Science	Innovative problem solution mechanisms
Multidisciplinarity: **Internalization of social science perspectives on the interaction between humans and technology**	Digital Medicine & Social Science I & II; Human-Machine Interaction in Medicine; Interactive AI in Medicine; Medical Humanities, Neurosurgery, Computer Science	Workshop on Design & Perspectives; Design, Art, Medical Anthropology	Critical awareness of strengths and shortcomings of human-technology interactions
Patient-Practitioner Relationship: **Clear understanding of the changing role models of patients and healthcare professionals**	Diagnosis & Treatment Information: Shared Decision-Making; Medical Humanities & AI Neurosurgery, Medical Humanities, Computer Sciences	Standardized Patient Interview; Neurosurgery	Improvement, modernization of patient-practitioner relationship

Notes: Disciplines: Neurosurgery, Medical Humanities, Medical Anthropology, Art history, Design, Computer Science. Description in dark blue indicates the associated specialty.

Addressed Competencies

Digitalization

A real-life oncological neurosurgical case serves as a common thread that is developed from the initial diagnosis to the performance of image-based surgery over the duration of the seminar. This simulation of a neurosurgical workflow is the result of students' request for more clinically applied course content. The students use the technologies to build an Adaptive Digital Twin to create a treatment plan and thus gain unique first-hand insights into neurosurgical treatment planning. Continuing this exploration of digital techniques in neurosurgery, they experience state-of-the-art diagnostic procedures in the treatment of brain tumor patients and discuss the best treatment options as well as safe surgical access methods on the digitized patient. The focus is on the use of modern MR imaging, non-invasive functional diagnostics, and artificial intelligence in data analysis.

Patient-Practitioner Relationship

Another focus is on conversations with patients and how to explain the technological innovations. Building on the planning they have done themselves, students will counsel a simulated patient about their disease and treatment options. The progressive distancing of staff and patient in terms of planning, remote control, and robotics are contextualized and discussed from various angles during the seminar. Lastly, the e-patient movement, self-assessment measures and medical data acquisition outside of the health professional sector is discussed in seminars addressing a variety of concurrent technologies and therefore new types of representation of and engagement with medical data.

Multidisciplinarity

By integrating disciplines such as medical humanities, medical anthropology, art history, design, and computer science, the students gain insights from experts of these related fields. This interdisciplinary perspective was iteratively strengthened as a result of overwhelmingly positive reception from participating students. Concepts of network analysis, artificial intelligence, and extended reality are discussed alongside the social and ethical impact of these technologies. Students are taught in-depth neurosurgical knowledge about anatomy, function, pathology, and treatment methods on the one hand, while on the other hand being guided to develop an analytical and methodological toolkit from various disciplines, which they will apply in different exercises. The focus throughout the seminar is on intertwining theoretical input and practical application from a wide range of disciplines. In addition, theoretical inputs are always presented in such a way that each lecturer is matched with a lecturer from a complementary discipline as a sparring partner in order to promote disruptive discussions, new insights and, above all, out-of-the-box thinking on the part of the students.

Conclusion

To conclude, medical education is in need of reform to more adequately prepare medical students for their role in the continuously evolving field of medicine. CBME is a promising teaching format that has the potential to prepare aspiring physicians better for their working lives by focusing more strongly on the application of newly obtained skills in practice. Based on this approach and clinical experience at our institution, we focus our course on the competencies of basic digital competence, contemporary communication skills and the broad range of possibilities offered by multidisciplinary treatment approaches in line with recent advances in daily clinical practice. Overall, the overarching aim was to give students comprehensive insights into the highly technical field of neurosurgery and to strengthen the core competency of being able to work with different forms of knowledge, discourse and methods, as well as being able to reflect on them and to engage in constructive discussions with different professions and disciplines. We felt this was a feat not achievable by the medical faculty alone, resulting in the involvement of medical humanities, social scientists, interaction designers, visualization specialists, gaming experts, anthropologists, media scientists, engineers, cultural historians, and physicians in the instruction process. This integrated, multidisciplinary set-up allowed for the exploration of new perspectives on research questions within multifaceted and dynamically evolving fields. It is foreseeable that the strengthening of multidisciplinary communication skills will be increasingly necessary for decision-making and future work in heterogeneous clinical environments involving multiple stakeholders, suggesting that current medical students will likely benefit from the incorporation of these topics into the medical curriculum.

Abbreviations

CBME, Competency-based Medical Education.

Declaration of generative AI in scientific writing

The authors did not use any generative AI or AI-assisted technologies during the process of manuscript writing.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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