Defining Learning Outcomes as a Prerequisite of Implementing a Longitudinal and Transdisciplinary Curriculum with Regard to Digital Competencies at Hannover Medical School

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Nilufar Foadi[1], Christian Koop[1], Marie Mikuteit[1], Volker Paulmann[1], Sandra Steffens[1] and Marianne Behrends[2]

[1]Dean's Office, Hannover Medical School, Hannover, Germany. [2]Peter L. Reichertz Institute for Medical Informatics of TU Braunschweig and Hannover Medical School, Hannover, Germany.

ABSTRACT

BACKGROUND: Worldwide educational programs face the challenge how to define and integrate digital competencies in medical education. This article describes the implementation of learning outcomes with respect to digital competencies in the compulsory curriculum at Hannover Medical School (MHH).

METHODS: An interdisciplinary MHH project group was constituted consisting of physicians and experts in medical informatics and in curriculum development. Over the course of 7 work sessions the group compared different international and national frameworks dealing with digital competencies for physicians. By a consensus driven approach the working group drew up a collection of learning outcomes which were regarded relevant to be incorporated in the curriculum at MHH.

RESULTS: The analysis of different frameworks indicated that data literacy is a central domain within all viewed preexisting catalogs. During the course of the project group analysis, 57 learning outcomes with respect to digital competencies were identified as necessary to be integrated in the compulsory curriculum. They were divided in 5 main categories: "handling of medical data," "the digital infrastructure of the health system," "scope of application: usage in patient care and in the field of preventive medicine," "medico-legal and ethical basics," and "transformation processes in medicine due to digitalization."

CONCLUSIONS: The MHH project group concluded that medical students should be taught digital competencies that enable an understanding of underlying functional principles of digital systems rather than their correct utilization. The presented project indicates that a close interdisciplinary collaboration of physicians and medical informaticians can be a promising approach to incorporate digital competencies in the undergraduate medical curriculum.

KEYWORDS: Digital transformation, digital competencies, medical informatics, undergraduate medical education, compulsory curriculum

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CORRESPONDING AUTHOR: Nilufar Foadi, Dean's Office, Hannover Medical School, Carl-Neuberg Strasse 1, Hannover 30625, Germany. Email: foadi.nilufar@mh-hannover.de

Background

As the current coronavirus pandemic has clearly demonstrated, digital achievements have a significant impact on the advances in medicine.[1] The digital transformation has rapidly yielded a wide spectrum of new opportunities in patient care, health system organization, medical research, and education.[2,3]

These digital changes are mainly influenced by research in the field of medical informatics. With the aim to enable the managing, storing, processing and provision of data, information and knowledge in medicine and healthcare, medical informatics uses methods and procedures of computer science, and other sciences. It is undisputed that specialists in medical informatics are necessary to adequately reflect this scientific discipline. But on the other hand progress in digital technology and medicine make it necessary that also physicians reflect the role and the impact of medical informatics knowledge and skills in today's healthcare.[4,5] The definition of required digital competencies for physicians always requires a look at the principles of medical informatics. Though medical informatics associations worldwide strove to accelerate the implementation of medical informatics competencies in medical education,[6,7] there is still high catch-up demand for a systematic and well-structured incorporation of medical informatics and digital skills in medical curricula.[8-12]. Since the content of medical curricula needs to be adapted to the fast changing process of digitalization,[5,11] medical faculties should concern themselves how they can convey digital competencies in undergraduate medical training.

This paper provides an overview of different frameworks and catalogs relating to digital competencies within undergraduate medical education and postgraduate training. It further presents an approach by which learning outcomes with

regard to digital competencies have been started to be developed at Hannover Medical School (MHH). In 2019 a local project had been initiated to establish a longitudinal and transdisciplinary curriculum with regard to digital and scientific competencies at MHH (German acronym "DigiWissMed"). The project was funded by the Ministry for Science and Culture of Lower Saxony.

In Germany a national catalog (National Competence-Based Learning Objectives for Undergraduate Medical Education [NKLM])[13] defines competencies that medical students should acquire during their studies. One of the starting points of the presented approach was the assumption that digital competencies were not extensively represented in the NKLM (version of 2015)[13] with regard to the status quo of digitalization. It was deemed necessary that medical teachers get deeply involved with the question how digital competencies can be defined. To cover the expertise that is needed to fully understand the principles which lay behind digital technologies a concerted action of medical informaticians and physicians participating in curriculum development was initiated.

By describing the development of learning outcomes at MHH the authors aim to give an impetus to other medical faculties to pursue the implementation of learning outcomes in the context of digital competencies. Certainly, there are learning needs both in the case of medical students and teachers.[10-12] Thus a transparent discussion of possible approaches and concepts, including different stakeholders and their perspectives, might help to align medical teaching around competencies which gain in importance in a digitalized healthcare system.

Methods

Since a number of existing frameworks addressing digital competencies were developed by medical informaticians the presented approach aimed to foster that physicians deal very closely with these frameworks and with the issue how to define learning outcomes referring to digital competencies. In Germany today's physicians do not have a profound and comprehensive expertise regarding the functioning of digital technologies.[14] In many curricula the topic is not systematically integrated.[12] However, even if teaching of medical informatics is already anchored in undergraduate education, as it is the case in the third year of medical school at MHH, it seems important to consider digitalization in the context of various medical disciplines in the sense of a deeper learning spiral. Therefore in this approach a local interdisciplinary collaboration of physicians and medical informaticians was established to include and reflect the point of view of both disciplines.

This paper focuses on the development of a local catalog with regard to digital competencies. The implementation and evaluation process are not addressed in this article. The different phases of the presented project were carried out in the style of the curriculum development concept developed by Kern et al[15] which comprises following steps: problem identification, needs assessment, goals and objectives, and educational strategies. With the aim to define a MHH-catalog of learning outcomes with regard to digital competencies following phases were initiated successively.

1. Constitution of an interdisciplinary project group to identify problems and needs
2. Comparison of existing national and international frameworks
3. Defining learning outcomes for the undergraduate curriculum as goals and objectives
   3a. Development of a MHH-catalog of learning outcomes as educational strategy
   3b. Classification of the developed learning outcomes in thematic categories

Constitution of an interdisciplinary project group to identify problems and needs

The project was designed by a collaboration of the Deans Office and the Institute of Medical Informatics. When selecting the members of the project group it was aimed to represent a wide spectrum of qualifications, ranging from students, young professionals to post-docs, and senior researchers. In addition to the different career status, different academic backgrounds (medicine, medical informatics, medical education, social sciences) were included. Thus, perspectives on digital competencies could be discussed from different angles based on a profound expertise of medical teachers and curriculum developers.

Comparison of existing national and international frameworks

First, the project group identified frameworks by mutual consensus that were regarded as adequate to provide guidance for the development of the MHH catalog. It was placed particular focus on the aspects to which extent the respective frameworks cover medical informatics background knowledge and a broad view on digital competencies. The level of detail by which learning outcomes were formulated was also considered important by the project group. During the analysis of the frameworks which are depicted in Table 1 additional frameworks were identified by a "snowball" technique. These frameworks were also collected and are listed in Table 2. All frameworks were studied and compared against the background of these questions: How comprehensive are digital competencies described? At which level of detail are learning outcomes formulated? Are action verbs used? Which target group and academic level are addressed (undergraduate/postgraduate)?

Defining learning outcomes for the undergraduate curriculum as goals and objectives

Development of a MHH-catalog of learning outcomes as educational strategy. The selection and the phrasing of learning outcomes took place on the basis of a consensus approach

Table 1. Frameworks that were used as basis for the MHH catalog.

Framework	IMIA (International Medical Informatics Association)[6]
Level	Postgraduates
Domains	1) BMHI core knowledge and skills 2) Medicine, health and biosciences, health system organization 3) Informatics/computer science, mathematics, biometry 4) Optional modules in BMHI and from related fields
Framework	IMIA+ (mixed-methods study, United Kingdom)[16]
Level	Postgraduates
Domains	1) Information governance and security 2) System use and clinician safety 3) Digital communication 4) Information and knowledge management 5) Patient empowerment 6) Emerging technologies
Framework	NKLM-MI (catalog of the GMDS*)[17,18]
Level	Undergraduates
Domains	1) Medical information management and communication 2) Medical classification systems and terminologies 3) Information systems in health care 4) Apps, clinical decision support and artificial intelligence 5) Telemedicine and telematics 6) Data protection and regulatory requirements 7) Access to medical knowledge 8) Medical signal and image processing 9) Other
Framework	NKLM** (German catalog of learning objectives)[13]
Level	Undergraduates
Domains	The framework for medical undergraduate education in Germany comprises 21 chapters. Seven of these chapters are orientated with respect to the key professional roles of a physician according to the CANMEDS framework.[19] The recently amended NKLM version (NKLM 2.0) includes concrete learning outcomes with regard to digital competencies.

*GMDS: German Association for Medical Informatics, Biometry and Epidemiology, its catalog is named NKLM-MI: (in German), Nationaler Kompetenzbasierter Lernzielkatalog Medizin—Medizinische Informatik.
**NKLM: national competencies-based catalog of learning objectives.

during the course of 7 group sessions. Each learning outcome of the selected frameworks was discussed in detail with respect to its role in undergraduate medical education and with respect to the way it had been worded. Besides the group evaluated each learning outcome critically with regard to its durability and its impact for the future of medical practice. In advance of the group sessions each member of the project group assigned in a tabular form if and at which academic year the respective learning outcome should be taught. For each learning outcome a target level of competence was assessed as described in the NKLM[13] and by Röhrig et al[16] (Supplemental Table 2). Each member of the project group assigned each learning outcome a target level of scientific competence as decribed in the NKLM.[13] Outcomes that were considered important to be taught within undergraduate medical education by all members of the project group were selected. In cases were several learning outcomes were consistently regarded to be referable to 1 thematic issue they were subsumed within 1 learning outcome. During the preparation of the local MHH catalog, the project group attached great importance to choose action verbs in a differentiated manner. It was intensively studied which verbs were used in the listed catalogs (Tables 1 and 2). Suitable action verbs were attempted to be found for each learning outcome of the local MHH catalog. According to the individual valuation of all project group members, the action verbs used for each learning outcome were iteratively re-evaluated in the course of the project group sessions.

Classification of the developed learning outcomes in thematic categories. In order to make the catalog more accessible superordinated categories were formed to sort the topics. Therefore a macro structural approach was helpful to ensure that the learning goals meet the requirements of the health sector. Haux provided an important reference point by embedding the role of medical informatics into a comprehensive healthcare framework.[26] According to Haux there are 3 application areas where medical informatics can improve clinical medicine:

Table 2. Selection of further frameworks.

Framework	AMIA and AHIMA[20,21]
Level	Postgraduates
Domains	1) Health information literacy and skills 2) Health informatics skills using the EHR 3) Privacy and confidentiality of health information 4) Health information/data technical security 5) Basic computer literacy skills
Framework	"eHealth competency catalog"—Academy of Medical Royal Colleges and the Scottish Government[22]
Level	Postgraduates
Domains	1) Clinical leadership and management 2) IT healthcare projects 3) Working with information 4) Clinical care records 5) Clinical IT systems and technologies 6) Knowledge management 7) Clinical and health IT standards
Framework	"Learning to manage health information"—National Health Service Connecting for Health (United Kingdom)[23]
Level	Undergraduates and postgraduates
Domains	1) Protection of individuals and organizations 2) Data, information, and knowledge 3) Communications and information transfer 4) Health and care records 5) The language of health: clinical coding and terminology 6) Clinical systems and applications 7) eHealth: the future direction of clinical care
Framework	National working group (United Kingdom)[24]
Level	Undergraduates
Domains	1) Digital health: work as a practitioner in the digital healthcare environment 2) Accessing data: access and interpret patient data to inform clinical decision-making 3) Communication: communicate effectively with healthcare professionals and patients in the digital environment 4) Generating data: generate data for and about patients within the electronic patient records 5) Multidisciplinary working: work with healthcare professionals with and alongside electronic patient records 6) Monitoring and audit: monitor and improve the quality and safety of healthcare
Framework	eHealth capabilities framework (mixed-methods study, Australia)[25]
Level	Undergraduates and postgraduates
Domains	1) Digital technologies, systems, and policies 2) Clinical practice and applications 3) Data analysis and knowledge creation 4) System and technology implementation

Abbreviations: AHIMA: American Health Information Management Association; AMIA: American Medical Informatics Association.

"- good medicine and good health for the individual,

- good medical and health knowledge, and

- well-organized health care."[26]

Based on this thematic classification by Haux the project group discussed which thematic categories the developed learning outcomes could be classified in to.[26] Besides the classification by Haux the catalog developed by a national project group of the German Association for Medical Informatics, Biometry and Epidemiology (GMDS)[17,18] and the other frameworks listed in Tables 1 and 2 served as an orientation for the structure of the MHH catalog.

Results

Comparison of existing frameworks

According to previous reviews the framework of the International Medical Informatics Association (IMIA)[6] is regarded to cover digital competencies in a highly comprehensive and detailed manner.[16,27] In the view of the project group contents of medical informatics serve as a crucial basis for defining learning outcomes with regard to digital competencies. Therefore the catalogs of learning outcomes of the German and the International Medical Informatics Association were analyzed thoroughly.

Introduction of frameworks that were extensively analyzed in this project:

- 1999 IMIA published its catalog of learning outcomes which has been revised 2010[6] (Table 1).
- On the basis of an analysis which mapped the IMIA catalog of learning outcomes to 21 postgraduate curricula Jidkov et al complemented the IMIA catalog by additional learning outcomes.[16] This framework by Jidkov et al has been named IMIA+[16] (Table 1).
- The catalog of learning outcomes of the GMDS has been introduced 2012 in Germany by a GMDS working group called "Medical Informatics Education in Medicine."[17] 2020 a revised version of this framework was published.[18] In German this catalog is named "Nationaler Kompetenzbasierter Lernzielkatalog Medizin—Medizinische Informatik" (abbreviation: NKLM-MI) (Table 1). The national working group provided a reasoned argument for early integration of each of the learning objectives in medical education.[17]

In Tables 1 and 2, 9 frameworks with regard to digital competencies for physicians are listed. The IMIA recommendations address different education levels dependent on the career goals and field of expertise.[6] As stated in the IMIA recommendations the depth to which informatics knowledge and skills should be learned varies depending on the specializations (physician, biomedical and health informatics specialist, etc.), the professional role, and responsibility.[6] According to the IMIA recommendations students in medicine, nursing, and other fields of the health care sector should receive a minimum of health informatics education to "efficiently and responsibly use knowledge processing methodology and information and communication technology."[6]

In comparison to other catalogs listed in Tables 1 and 2, the IMIA catalog,[6] the IMIA+ catalog,[16] and the framework of AMIA and AHIMA[20,21] provide a wider range of detailed and basic informatics skills such as knowledge about programming languages, software engineering, and software architectures or data structures.

The NKLM-MI catalog focusses on education in medical informatics in the undergraduate medical curriculum.[17,18] It contains a number of concrete descriptions with respect to digital competencies at the interface between clinical medicine and digital achievements, that is [the student] "understands the possibilities of patients to take an active role in health care, e.g. through patient-apps"[18] or "knows the term interoperability and its necessity, levels and requirements and can explain these using a clinical example."[18] The project group of the GMDS[17,18] pointed out, that medical informatics skills are relevant for each of the several roles of a physian with regard to the CANMEDS competency framework.[19] Consequently each learning outcome of the NKLM-MI catalog was assigned to the respective CANMEDS roles in the NKLM-MI project.[17]

In contrast to the NKLM-MI catalog the learning outcomes in the NKLM[13] (version of 2015) referring to digital competencies are often subsumed in general formulations, that is "the graduates reflect the specific requirements of oral, written and electronic communication and of public communication and interact context-sensitively in compliance with the principle rules of data protection" (objective 14c.6, NKLM [version of 2015]).[13]

The analyzed frameworks address target groups with different educational levels. Most of the catalogs predominantly describe competence profiles at a postgraduate level. While the "eHealth competency catalog" by the Academy of Medical Royal Colleges focusses on postgraduate competencies of clinical experts,[22] the framework "learning to manage health information"[23] aims to provide guidance for educational programs as well for medical students as for graduates (Table 2).

The domains of competences identified by the respective frameworks have basic aspects in common. All frameworks listed in Tables 1 and 2 contain domains which refer to the use of digital technologies in medicine and health as well as aspects of data literacy and information management.

AMIA provided specified frameworks for informaticians.[20] In a joint working group AMIA and AHIMA developed a catalog of core competencies for individuals working with electronic health records.[20,21] The framework presented by Pontefract and Wilson[24] (Table 2) is based on a review of a national working group in the United Kingdom. This framework and the catalog developed by AMIA and AHIMA[20,21] predominantly focus on the electronic patient record. But they also point out to more general competencies such as communication in the digital environment. The IMIA+ framework covers the latter aspect as well.[16]

Development of a MHH-catalog of learning outcomes. The comparison of the frameworks listed in Tables 1 and 2 revealed that some catalogs rather have a special focus on specific technological systems than covering a broad field of informatics competencies. As an example the framework presented by Pontefract and Wilson[24] and the catalog developed by AMIA and AHIMA[20,21] (Table 2) predominantly address electronic health records.

Since the NKLM-MI catalog[17,18] covers a wide range of medical informatics topics that are related to day-to-day medical care, the MHH project group decided to analyze and discuss each learning outcome of the NKLM-MI catalog as a first step. Out of 45 learning outcomes of the NKLM-MI catalog 37 learning outcomes were selected to be considered for the MHH catalog. Most of the 8 learning outcomes that were not further discussed address topics that were regarded as too detailed or too specific in the opinion of the project group (ie, specific coding systems for diagnoses and procedures). The project group pointed out that special terminology and specific coding systems represent mere factual knowledge which might get outdated over time.

As the IMIA framework is regarded to cover digital competencies in a highly comprehensive manner[16,27] as the next step

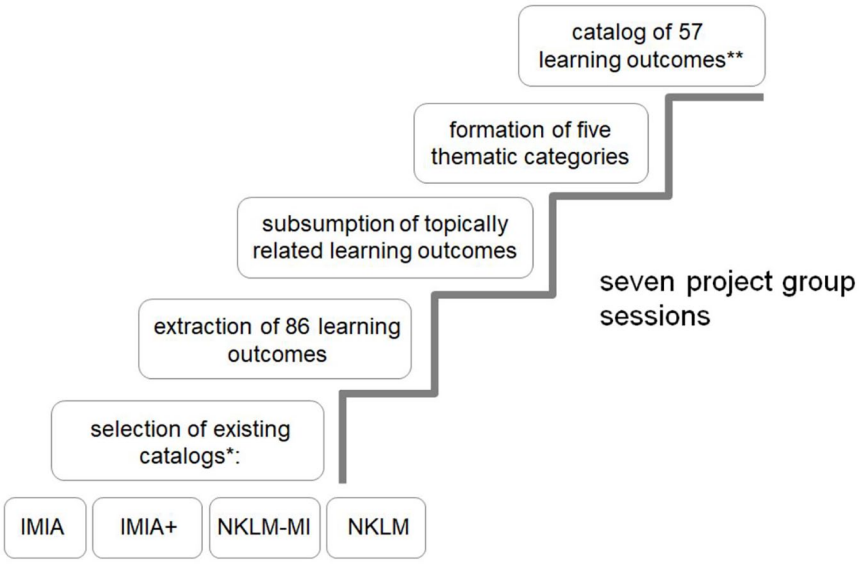

Figure 1. Individual work steps of the presented approach. The flow diagram depicts the development of a local catalog of learning outcomes with regard to digital competencies at MHH.
*Analysis of existing catalogs: each learning outcome of the NKLM-MI[17,18] catalog, the IMIA framework,[6] and the IMIA+ framework[16] was analyzed and discussed. Topically related learning outcomes of the NKLM[13] were also viewed. In the first phase 86 learning outcomes were extracted by the interdisciplinary project group. After subsuming learning outcomes which referred to similar topics 57 learning outcomes were defined to be integrated in the curriculum at MHH.
**see Supplemental Table 2.

learning outcomes of the IMIA[6] (containing 48 learning outcomes) and the IMIA+ catalog[16] (covering 50 learning outcomes) were analyzed and discussed. Forty-five learning outcomes were derived from the IMIA+ catalog. Learning outcomes which were not selected address general and more holistic topics for example "fundamentals of what constitutes health" (learning outcome no. 2.2, IMIA framework)[5] or "organization of health institutions" (learning outcome no. 2.4).[6] Four additional learning outcomes were developed in the project group sessions: the project group considered it important to distinguish between the terms "data" and "information." Therefore these issues were addressed in 2 separate learning outcomes. They also found it relevant to incorporate virtual and augmented reality technologies (learning outcome no. 3.2.7, Supplemental Table 1), principle tasks of medical and health informatics (5.2, Supplemental Table 1), and biases in artificial intelligence (5.14, Supplemental Table 1) The derived learning outcomes were compared with thematically related learning outcomes of the NKLM (version of 2015).[13] It was particularly payed attention to the wording of the NKLM learning outcomes (Supplemental Table 1).

Next, topically related learning outcomes were subsumed within 1 learning outcome. Finally 57 learning outcomes were formulated to be implemented in the compulsory curriculum (Supplemental Table 1; Figure 1).

The majority of the learning outcomes (n = 33/57) were assigned by all group members to be taught from the first academic year on. All members assessed that all learning outcomes should be conveyed before the start of the practical year.

The analysis of the different catalogs and existing frameworks made obvious that data literacy is a central domain of high relevance in medical education. It is closely related to information literacy and to the management of medical knowledge. Therefore, the first domain of the developed MHH catalog was reserved for the issue "data handling and data management." Due to the important domain of data and knowledge management the differentiation of the terms "data," "information," and "knowledge" and the quality of data and information were explicitely and separately addressed in the MHH catalog (1.1.1, 1.1.2, and 1.2.1; Supplemental Table 1).

The project group concluded that there are learning outcomes which are considered most crucial and therefore should be achieved by all students at the same competence level (ie, most of the outcomes of the section "handling of medical data"). Some learning outcomes (ie, 2.1.5–2.1.7) included deeper-focusing medical informatics knowledge and were regarded as more specific. The project group discussed for these outcomes if they might exceed the expected level of competence for undergraduate education.

Classification of the developed learning outcomes in thematic categories. The learning outcomes were divided into 5 domains with different subcategories:

1. **Handling of medical data**
   - 1.1 Data literacy
   - 1.2 Knowledge search and management
2. **Digital infrastructure of the health system**
   - 2.1.1 Information systems
   - 2.1.2 Quality of medical documentation

3 Scope of clinical application: usage in patient care and in the field of preventive medicine
- 3.1 Signal and image processing
- 3.2 Systems used for decision support and for support to determine a diagnosis
- 3.3 Telemedicine

4 Medico-legal and ethical basics

5 Transformation processes in medicine due to digitalization

All reviewed frameworks have in common that they comprise the domain of data analysis and data management (Tables 1 and 2). Consequently, the MHH catalog intended to provide a sufficiently differentiated approach with regard to data, information, and knowledge literacy. Assessing the level of scientific competence associated with the outcomes, for all learning outcomes of domain 1 all members of the project group rated the 2 highest competence levels (learning outcome 1.1.1–1.2.4). In accordance with this, all group members regarded data literacy as a key element at the interface of medicine, medical informatics, and research confirming "handling of medical data" as the first domain in the MHH catalog. In this domain "data literacy" and "search and management of knowledge" are subsumed. The group regarded it as important that students master sufficient and efficient approaches to acquire, analyze, evaluate, and manage medical knowledge. They should learn to internalize scientific competencies and digital literacy.[28,29]

Discussion

In the presented project a local MHH catalog of learning outcomes with regard to digital competencies has been developed after analysis of existing national and international frameworks in order to develop a deeper understanding of digital competencies, especially on the part of physicians. Medical schools need to keep pace with the transformational changes that occur in health care.[30,31] Nowadays, digital competencies are important for all medical disciplines[16] and various approaches for the implementation of digital competencies are being developed at German medical faculties. So far, however, these offers have not been included in all curricula.[12]

As described by Haux, medical informatics can contribute to "good medicine and good health for the individual," "good medical and health knowledge," and a "well-organized health care."[26] These areas are also addressed in our catalog. The learning outcomes of domain 1 of the MHH catalog can be regarded as a prerequisite to enable sufficient acquisition of medical and health knowledge and are in line with important research fields of medical informatics.[26] The domains 2 and 3 serve a similar purpose. Regarding the aspect of a "well-organized health care"[26] the project group agreed that future physicians—in their role as managers—should understand the structures of a digitalized work place. This is addressed by domain 2 in the local MHH-catalog ("the digital infrastructure of the health system"). Domain 3 addresses technology usage in patient care and in the field of preventive medicine which can foster the "good health for individuals."[26]

Ethical principles and medico-legal aspects like data protection, data security, and opportunities for participation play an important role in the digitalization of medicine and are represented in domain 4. Finally, domain 5 encompasses general and specific transformation processes concerning medical self-image and role models.

Necessity of a periodic adaptation of the developed catalog

The digitalization of medicine is a field characterized by dynamic changes. Although each learning outcome was critically evaluated with regard to its durability and its essential impact for the future work of physicians, the catalog therefore is not considered a static construct. It is intended to be re-evaluated and adjusted at regular intervals to revise and modify learning outcomes. One example is the "ability to use personal computers"[6]—a learning outcome which nowadays is not necessarily worth mentioning when mostly everyone owns a mobile phone. Currently, students are considered "digital natives" that are familiar with the use of digital tools. What, however, currently seems to be missing in the curricula and what the frameworks in Tables 1 and 2 address, is a differentiated understanding of the underlying functional principles of the growing number of digital applications and systems that are shaping the daily clinical work.[10,32]

Since medicine is subject to ever more rapid transformation, curricula need to react to the fast-changing processes. Accordingly catalogs such as the developed MHH catalog can be regarded an approximation to the broad topic of digitalization in medicine. It needs to be re-adapted regularly as it happened with the NKLM which has recently been revised.[33-35]

Distinguishing between core digital competencies and deeper informatic knowledge

By assigning each learning outcome a sought level of competence at each respective academic year the members of the MHH-project group mainly regarded it desirable that the majority of the derived learning outcomes should be introduced in the first 2 years of studies. However, it still might be worth distinguishing which outcomes of the developed catalog rather refer to expert knowledge that might exceed the undergraduate education level. If it will be discussed to establish subspecializations in the undergraduate medical education in the future, there might be different competence levels assigned to learning outcomes in a curriculum for a subspecialization in medical informatics. Interested students who strive for a career in this field should achieve the level of mastery with regard to topics such as neural networks or cryptography while for the rest of the students it can be acceptable to be familiar with these topics without the need for a comprehensive and deeper understanding of the underlying theoretical principles.

Domains of the developed catalog—reflection of the physician's role in transformation processes

When health care is faced with complex adaptive changes as it is the case in the era of digitalization, current and future generations of physicians need to examine the impacts of this process on their daily work to maintain best-possible medical care. It is desirable that students learn to reflect a physician's role and responsibility in a rapidly evolving health care system. To this end, the project group included a separate domain in the presented catalog ("transformation processes in medicine due to digitalization"; Supplemental Table 1) to emphasize the importance of a proactive approach as it is also addressed in the IMIA+ framework (learning outcome 50, IMIA+ catalog).[16] The working group aimed to point out that higher order competencies like reflective and critical thinking should already be addressed at an early stage of medical training. Students should be enabled to capture the scientific character of medicine since scientific competence is one basic prerequisite for evidence-based performance.[28,29] Therefore, the MHH project group aimed to emphasize that both scientific and digital competency are, amongst others, generic abilities for physicians of the 21st century.[28,29] The competencies that need to be taught should help to foster lifelong learning in a sustainable manner.

Essential collaboration of physicians and medical informaticians

The presented project describes an approach in which physicians intensively dealed with the topic of digital competencies at a local level. Medical informaticians provided the required know how without which some informatics and technological issues would have remained a "black box" for the participating physicians. Therefore the interprofessional collaboration of medical informaticians and physicians was regarded crucial for the presented attempt. The project group considered it necessary to break down essential digital competencies into concrete formulations that could be implemented in the curriculum at MHH. Since April 2021 a revised version of the NKLM is available.[35] Joint working groups of physicians and experts in medical informatics participated in the revision process and incorporated concrete learning outcomes with regard to digital competencies in the NKLM 2.0.[35] This revised NKLM version could not yet be taken into account when developing the MHH catalog of learning outcomes. Further processing of this local catalog will therefore certainly be necessary.

As with the joint working groups at national level the interdisciplinary collaboration of medical informaticians and physicians at medical faculties might provide a promising foundation for curriculum adaptation with regard to the incorporation of digital competencies.

First approaches to integrate learning outcomes of this catalog into the existing curriculum at MHH have already been launched. And it seems that the interdisciplinary collaboration between physicians and medical informaticians can also work in teaching. Further investigations are needed to evaluate these attempts. It is conceivable that the prerequisites for an interdisciplinary collaboration between medical professionals and medical informaticians are not met at every medical faculty. Thus the availability of experts in medical information technology may turn out to become a "bottleneck" for such implementation processes.

Conclusions

The digital transformation entails an adaptation of medical curricula to enable future physicians to work sufficiently in a digitized healthcare environment. The basis of the presented project was an interprofessional cooperation of physicians and medical informaticians. Interdisciplinar joint working groups are already established at the national level as can be seen by the revision process of frameworks such as the NKLM 2.0. The presented project initiated an interdisciplinary collaboration at the local level to develop a catalog of learning outcomes with regard to digital competencies to be used at MHH. This catalog cannot be regarded a rigid construct and needs to be regularly reevaluated since it addresses a thematic field which is very broad and subject to ongoing dynamic changes.

Author Contributions

N Foadi: wrote the manuscript, analysis of existing catalogs of learning outcomes, data interpretation; C Koop: analysis of existing catalogs of learning outcomes, data interpretation, editing manuscript; M Mikuteit: analysis of existing catalogs of learning outcomes, data interpretation, editing manuscript; V Paulmann: project design; analysis of existing catalogs of learning outcomes, data interpretation, editing manuscript; S Steffens: project design; analysis of existing catalogs of learning outcomes, data interpretation; M Behrends: project design; analysis of existing catalogs of learning outcomes, data interpretation, editing manuscript.

ORCID iD

Nilufar Foadi https://orcid.org/0000-0001-9705-5144

Supplemental Material

Supplemental material for this article is available online.

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