Table 2

MHH catalog of learning outcomes with regard to digital competencies classified in five domains 1) - 5).

No.	Learning outcome	reference to NKL-MI catalog[18]	reference to IMIA catalog[6] no. of objective in IMIA-catalog which addresses the respective topic	reference to NKLM catalog (version of 2015)[13]
1.1.1	can explain and use criteria for formal and content-related quality of data (i.e. primary and secondary data collection sources).	1.3; 1.5	-	11.2.3.1
1.1.2	can describe the meaning of “characters”, “data”, “information” and “knowledge” and their content-wise interrelation.	-	14	-
1.1.3	can explain how data are digitalized (representation of data).	-	14	-
1.1.4	can describe different forms of data analysis and their differences (descriptive statistics, cluster analysis, data mining, near neighbours etc.).	-	14	-
1.1.5	can explain principles of storage and exchange of data (i.e.(amongst others) the FAIR principles).	5.2; 5.3; 6.3	14,27	-
1.1.6	can explain the structure and function of databases, data warehouse, data integration center and can apply them sufficiently as well as in patient care as in research.	1.4; 1.5; 7.4; 9.4	14, 27	14c.6.3 19.1.10.1 (databases are mentioned without further details)

1.1.7	is familiar with the opportunities and challenges of knowledge representation (i.e. formalization of medical knowledge, models for medical knowledge, rule-based model, linking medical knowledge etc.).	4.1	27,35	-
1.1.8	can describe different approaches in the context of artificial intelligence (neuronal networks,softcomputing) and can explain their differences.	4.2	35	-
1.1.9	can explain basic uses of artificial intelligence in medicine and can give examples of their clinical usage (i.e. deep learning, machine learning).	4.2; 4.3	37	-
1.2) recherche and management of knowledge				
1.2.1	can explain and use criteria for formal and content-related quality of information.	-	-	-
1.2.2	can explain cognitive processing of information (perception, storage, further processing).	-	37	-
1.2.3	masters effective research strategies to solve a problem according to the best available evidence.	7	5	6.1.2.2; 6.2.2.2; 14a.1.1.2
1.2.4	can provide qualitative criteria for a proficient utilization of electronic information sources and medical software (i.e. apps) for aquisition of state of the science knowledge.	7	4	19.1.10.2; 19.1.10.3 (electronic information sources are mentioned without further details)

Domain 2) digital infrastructure of the health system				
2.1) information systems				
2.1.1	can explain the necessity of systematic information processing in a digitalized health care system.	3	2	-
2.1.2	“can formulate requirements for departmental systems and provide feedback to existing systems. −Requirement specifications, performance and functional specifications −Procurement processes, tendering procedures,role of the physician”[18]	**= 3.3**	19	8
2.1.3	can describe the responsibility of physicans with respect to the operation and utilization of IT systems in outpatient care and in hospitals (IT-governance).	3.3; 3.9	8 (IT governance is adressed)	10.7.1.3
2.1.4	can explain the information system life cycle.	-	31	-
2.1.5	can explain and apply basic principles of systematic electronic information processing in a hospital and in outpatient care (in German: KIS, KAS).	3	6,7,8,12,30	19.1.; 10.3 (KIS and KAS are mentioned are mentioned without further details)
2.1.6	can give examples of information systems in health care and can exemplify possible sources of error within these information systems.	3.1; 3.7	31	14c.6.3.2; 10.6.1.5, 17.1.6
2.1.7	can describe challenges and pitfalls regarding electronic inter-and intraorganizational	5.2	7,10	-

	networks and regarding creation of suitable interfaces (i.e. user interfaces).			
2.1.8	can explain the role and main characteristica of well-structured workflows and a well organized development of efficient problem-solving strategies (amongst others analysis, interdisciplinary exchange, identification of necessary measures and questions to be addressed).	9.1	13	8.4.1.1; 8.4.1.3; 14a.2.2.13
2.1.9	can explain the role of workflow and re-organisation in the sociotechnical context.	-	13	-
2.2) quality of medical documentation				
2.2.1	can exemplify quality criteria for a well-structured and efficient documentation by physicians in IT-based systems.	1.2; 1.5; 9.1	11	10.5.1.1., 11.2.3.4 (IT based documentation is mentioned without further details)
2.2.2	can give examples why medical documentation is obligatory and is familiar with the legal regulation of medical documentation.	1.1; 1.5; 6.4	8	11.2.3.1
2.2.3	can explain “advantages and disadvantages of different types of electronic documentation, their differences to paper documentation and the problems of media disruption.”[18]	**= 1.3**	26 (electronic data exchange is mentioned without further details)	11.2.3.1 (electronic documentation is mentioned without further details)
2.2.4	can describe differences regarding construction and function of the electronic patient file, the electronic health record (EHR) and of patient-data-management	3 (structure and function of EHR, PDMS is mentioned; differences of these systems are not	9, 12 (PDMS and differences of these systems are not explicitly mentioned)	14c.6.3.1, 14c.6.3.2, (structure and function of EHR, PDMS is mentioned; differences of these systems are not

	systems (PDMS).	explicitly addressed)		explicitly addressed)
2.2.5	can reflect pitfalls and challenges when patients are identified electronically in healthcare facilities (i.e. consequences of the presence of multiple identifiers for one patient).	3.6	30	-
3) scope of clinical application: utilizing digital tools in patient care and in the field of preventive medicine				
3.1 signal and image processing				
3.1.1	can give and explain examples for biosignals in medicine.	**= 8.1**	38	-
3.1.2	can explain digital filtering of biosignals and can give clinical examples for this biosignal processing.	8.1	38	12.8.2.5 (algorithms of image processing are mentioned without further details)
3.1.3	can describe procedures of digital image enhancement.	8.3	38	12.8.2.5 (see above)
3.1.4	can describe different digital visualization processes and can explain their characteristic properties and peculiarities (i.e. artefacts).	**= 8.5**	-	-
3.1.5	can describe the use of digital tools in an exemplary way in the fields of biomedical modelling and medical physics-, nano-, chemo-, and bioinformatics.	9.4	15, 39, 42,43,47	6.1.1.3 (6.1.1.3 refers very generally to the field of biomedical technology)

3.2) systems used for decision support and for support to determine a diagnosis				
3.2.1	can give examples how patient safety can be strengthened by digital systems.	1.1; 3.5; 7.4; 9.1	24	10.6.2 (10.6.2 refers to critical incident reporting system)
3.2.2	can explain the usage of digital tools as medical devices (from mobile applications (app) to cochlear implant devices).	3.7; 4.3; 6.4	-	-
3.2.3	can explain the functional principles of clinical decision support systems and can give examples for challenges in clinical decision support.	4.1	3, 20, 35	-
3.2.4	can reflectively integrate the use of digital tools such as apps and other smart devices in the clinical workflow.	4	9	-
3.2.5	can give examples for usage of digital tools in the field of personalized medicine.	4.3	-	-
3.2.6	can give examples and can describe basic conditions for the usage of electronic assistance systems in real life environment to improve health and living conditions (i.e. ambient assisted living).	5.4	36,40	-
3.2.7	can explain methods of virtual reality, assisted and augmented reality, computer-assisted surgery and computer assisted stereotactic methods.	-	-	-

3.3) telemedicine and telehealth				
3.3	"can use telemedicine in a patient-oriented manner and can explain required structural conditions and telehealth-related legal frameworks."[13]	5.3; 5.4	10, 29	**= 10.7.1.5**
4) medical-legal and ethical basics				
4.1	can determine and reflect the responsibilities (physician/IT provider etc.) regarding data privacy and data protection along the interorganizational exchange of confidential patient data in the health system and along the use of central data bases.	3,9; 6.1; 6.3	16	11.1.1.3; 11.1.2.1; 11.1.3.1
4.2	can explain the legal framework upon which an electronic system (software, device) is declared as a medical device.	4.3; 6.4	-	-
4.3	"can use, evaluate and choose appropriate digital procedures to securely transmit and store patient data."[13]	6.1; 6.3; 6.4	8, 16	**= part of 14c.6.3.1**
4.4	masters pseudonymization as well as anonymization of patient data for research purposes and can explain the difference of pseudonymisation and anonymization.[18]	**= content of 6.2**	-	10.7.1.4; 11.1.3.1 (anonymization and pseudonymization are named without further details regarding their difference)

4.5	can explain the legal and ethical frameworks and the challenges with respect to data protection when using digital tools and digital communication media.	6.1; 6.3; 6.4	16, 22	-
5) transformation processes in medicine due to digitalization				
5.1	can describe the historical evolution of informatics and medical informatics as a discipline and as a profession.	-	1	-
5.2	can name principle tasks of medical and health informatics.	-	-	-
5.3	can explain the contribution of the interface of medicine and medical informatics for the further development in medicine with the help of practical examples from the clinical setting.	6.5	41	-
5.4	can give examples for innovative advancements in the field of medical informatics that foster progress in medicine.	6.5	41	6.1.1.3 (general advancements in medicine are mentioned without explicit reference to medical informatics)
5.5	"can explain the impact of new technological advancements on the physician/patient relationship."[13]	5	-	**= 11.4.3.5**
5.7	can reflectively evaluate the impact of digital devices and services (i.e. data from weareables, social	5	9	-

	media services) on the physician/patient communication and relation.			
5.8	masters to convey a differentiated and goal-directed utilization of modern information technology to patients with the aim to increase the capacity of patients to gain an active role in their personal healthcare (= fostering the empowerment of patients).	4.4	9	-
5.9	can adjust their acting flexibely with regard to changing requirements in a digitalized working environment.	-	-	6.1
5.10	can proactively reflect transformational changes within the healthcare system with respect to the physician's role.	-	41, 46	6.1
5.11	can describe basic principles of the network architecture of information and communication technology (client server architecture, protocols, services).	-	29	-
5.12	can describe basic components of theoretical and practical informatics (i.e. most common programming languages, software architecture, cryptography).	6.3 (cryptography is mentioned)	27,28	-
5.13	can give examples for the use of digital methods to foster learning processes.	9.3	18	-

5.14	can give examples for unjustified discriminatory conclusions by use of learning digital systems (i.e. gender bias in algorithms).	-	-	-

The three columns on the right list the number of closely related learning outcomes of the NKL-MI[18], the IMIA catalog[6] and the NKLM catalog[13]

Learning outcomes whose wording was taken over one to one from the NKL-MI[18] or the NKLM[13] catalog are set in quotation marks.

Those learning outcomes of the NKL-MI[18] and the NKLM[13] catalog which are given in bold letters and signed by “=” indicate that the respective learning outcome of the MHH catalog was derived from the NKL-MI[18] or the NKLM[13] catalog contentwise. Wording was slightly adapted in these cases. Therefore these outcomes are not set in quotation marks.