Recommendations of the International Medical Informatics Association (IMIA) on Education in Health and Medical Informatics

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Summary

The International Medical Informatics Association (IMIA) agreed on international recommendations in health informatics / medical informatics education. These should help to establish courses, course tracks or even complete programs in this field, to further develop existing educational activities in the various nations and to support international initiatives concerning education in health and medical informatics (HMI), particularly international activities in educating HMI specialists and the sharing of courseware.

The IMIA recommendations centre on educational needs for health care professionals to acquire knowledge and skills in information processing and information and communication technology. The educational needs are described as a three-dimensional framework. The dimensions are: 1) professionals in health care (physicians, nurses, HMI professionals, ...), 2) type of specialisation in health and medical informatics (IT users, HMI specialists) and 3) stage of career progression (bachelor, master, ...).

Learning outcomes are defined in terms of knowledge and practical skills for health care professionals in their role (a) as IT user and (b) as HMI specialist. Recommendations are given for courses/course tracks in HMI as part of educational programs in medicine, nursing, health care management, dentistry, pharmacy, public health, health record administration, and informatics/computer science as well as for dedicated programs in HMI (with bachelor, master or doctor degree).

To support education in HMI, IMIA offers to award a certificate for high quality HMI education and supports information exchange on programs and courses in HMI through a WWW server of its Working Group on Health and Medical Informatics Education (http://www.imia.org/wg1).

Keywords: Health Informatics, Medical Informatics, Education, Recommendations, International Medical Informatics Association, IMIA.

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1 Introduction

1.1 Why Do We Need Health and Medical Informatics Education?

Throughout the world, health care professionals often lack knowledge of the possibilities and limitations of systematically processing data, information and knowledge and of the resulting impact on quality decision-making. They are often asked to use information technologies of which they have limited appreciation, in order to enhance their practices through better use of information resources. However, for systematically processing data, information and knowledge in medicine and in health care, health care professionals who are well-trained in medical informatics or health informatics are needed[1]. It will only be through improved education of health care professionals and through an increase in the number of well-trained workers in health and medical informatics that this lack of knowledge and associated skills can begin to be reversed.

Health and medical informatics education is of particular importance at the beginning of the 21st century for the following reasons ([8], p.17):

1 progress in information processing and information and communication technology is changing our societies;
2 the amount of health and medical knowledge is increasing at such a phenomenal rate that we cannot hope to keep up with it, or store, organise and retrieve existing and new knowledge in a timely fashion without using a new information processing methodology and information technologies;
3 there are significant economic benefits to be obtained from the use of information and communication technology to support medicine and health care;
4 similarly the quality of health care is enhanced by the systematic application of information processing and information and communication technology;
5 it is expected, that these developments will continue, probably at least at the same pace as can be observed today;
6 health care professionals who are well-educated in health or medical informatics are needed to systematically process information in medicine and in health care, and for the appropriate and responsible application of information and communication technology;
7 through an increase in scope and the provision of high quality education in the field of health and medical informatics, well-educated health care professionals world-wide are expected to raise the quality and efficiency of health care.

1.2 IMIA-Recommendations for Health and Medical Informatics Education

There are different opportunities world-wide for obtaining an education in this field. In some countries there are extensive educational components in health and medical informatics at different levels of education and for the different health care professions. Many other countries have not, or at least not sufficiently, established such opportunities until now, with all the consequences concerning the quality and effectiveness of health care.

According to its aims and because of the situation just described, the International Medical Informatics Association (IMIA, [9], [15]) felt the need to develop international recommendations in health and medical informatics education. These recommendations shall help to establish education in this field, to further develop existing educational activities in the various nations and to support international initiatives concerning education in health and medical informatics.

Because a variety of educational and health care systems exist all over the world, programs, courses and course tracks in health and medical informatics may vary in different countries. In spite of this variability, basic similarities in health and medical informatics education can be identified and used as a framework for recommendations. Such recommendations are also necessary for enabling an international exchange of students and teachers and for establishing international programs.

The IMIA recommendations, presented here, have taken into consideration the various existing, mainly national recommendations in health and medical informatics education (e.g. [1], [2], [4], [6], [12], [13], [14]). The IMIA recommendations should be regarded as a framework for national initiatives in health and medical informatics education, and for constituting international programs and exchange of students and teachers in this field. They shall also encourage and support the sharing of courseware.

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[1] The meaning of the terms health informatics and medical informatics varies within and between different nations. Both terms will be used here interchangeably in a broad and comprehensive manner, in terms of the discipline dealing with the systematic processing of data, information and knowledge for optimal decision-making in medicine and health care. In order to recognize this point of view, the term health and medical informatics (HMI) will normally be used.

2 General Considerations

2.1 Key principles of the IMIA-Recommendations

In order to provide good quality health care, training and education in health and medical informatics is needed ([16], p. 537-547):

h for various health care professions,
e in different modes of education,
a with different, alternate types of specialisation in health and medical informatics, and
l at various levels of education, at respective stages of career progression. There must be
t qualified teachers to provide health and medical informatics courses which lead to
h recognised qualifications for health and medical informatics positions.

In more detail, 'health' means:

- h Practically all professionals in health care should, during their studies, be confronted with health and medical informatics education: e.g. physicians, nurses, pharmacists, health care managers, health record administrators, and also health and medical informaticians who are graduates from specialised programs in health and medical informatics. Computer scientists/informaticians and other scientists (e.g. engineers), who intend to work in the fields of medicine and health care also need health and medical informatics education.
- e Various education methodologies are needed to provide the theoretical knowledge, practical skills and mature attitudes that are required. In addition to traditional classroom-based models, there are many different models of flexible, distance and supported open learning to be considered. The explosive growth of the Internet and World Wide Web are additionally having great impacts on all educational methodologies, and in particular will favour flexible and distance learning. Inter-university collaborations might also facilitate curricular choice.
- a Alternate routes to different types of specialisation in health and medical informatics will depend on career choice. The majority of health care professionals (e.g. physicians, nurses) need to know how to efficiently and responsibly use information and communication technology, but only a few will choose to have accredited specialisation in this field. They should, however, also be able to acquire an additional specialist qualification in health and medical informatics as part of their chosen career development. Health and medical informatics specialisations may be different to suit the various types of health care professionals. Finally, it should also be possible to acquire specialist qualifications in health and medical informatics via specific health and medical informatics programs leading to accreditation at different levels, e.g. master or Ph.D.
- l Every profession in health care even at an early stage needs some core health and medical informatics knowledge. Different levels of education, respectively stages of career progression, (bachelor, master, doctor, ...) have different health and medical informatics education needs according to experience, professional role and responsibility. A junior professional uses information differently compared to a senior professional. As well as there are specialised health and medical informatics university programs, health and medical informatics instruction should be integrated within other professional educational programs (medicine, nursing, informatics/computer science etc.). Thus educational components will vary in depth and breadth to suit specific student groups. Subsequent continuous education programs in health and medical informatics also need to be available.
- t The content and delivery of health and medical informatics courses and programs must be of good quality. Teachers of health and medical informatics courses must have adequate and specific competence in this field.
- h There must be recognised qualifications in health and medical informatics for positions in this field. Accreditation of educational content and competence in health and medical informatics is required, to eventually have recognition on an international basis.

The IMIA recommendations concentrate on the 'dimensions' h, a and, to a certain extent, l. Comments on the other components e, t and h, are given in sections 6 and 7.

2.2 Structural Outline of the IMIA-Recommendations

The IMIA recommendations centre on educational needs for health care professionals to acquire knowledge and skills in information processing and information and communication technology as it is needed and used in medicine and health care. The educational needs are described as a three-dimensional framework with dimensions 'professional in health care', 'type of specialisation in health and medical informatics' and 'stage of career progression' (figure 1). For these various educational needs learning outcomes are suggested (see section 3), either for courses[1]/course tracks[2] in health

1 Course: Unit of study consisting of a set of lectures, exercises, ..., dedicated to a certain field, e.g. 'introduction to hospital information systems', 'medical decision making'.

2 Course Track: Set of courses, dedicated to a certain field as part of an educational program, e.g. 'health informatics' (as set of courses in this field) in a nursing program.

and medical informatics as part of educational programs (see section 4) or for dedicated programs[1] in health and medical informatics (see section 5).

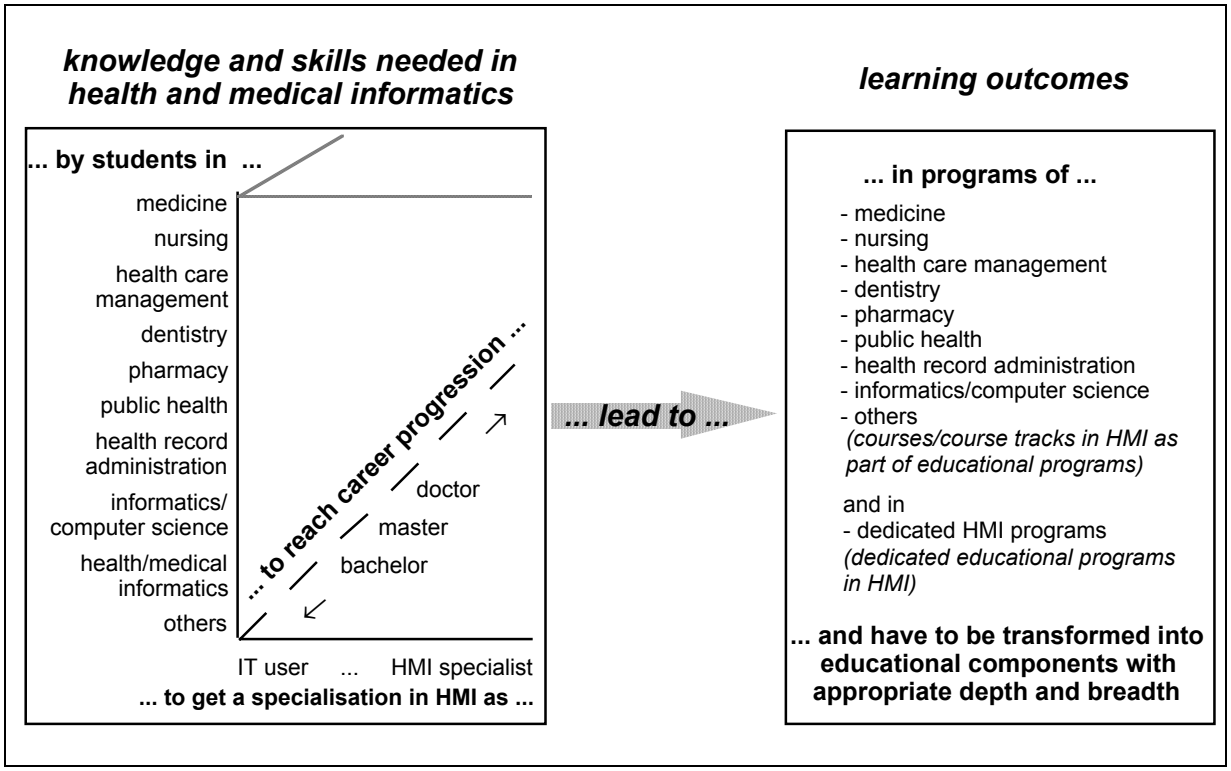

Figure 1: Structural outline of the IMIA recommendations on education in health and medical informatics (HMI): ***knowledge and skills needed in HMI*** by students in health care, to get a specialisation in HMI and to reach a career progression ***lead to learning outcomes*** in programs, and have to be transformed into educational components with appropriate depth and breadth.

Figure 1 shall point out, that if one is studying a certain discipline (e.g. medicine to receive a bachelor degree), then the IMIA recommendations suggest, that in their study all these students should get a minimum of education in health and medical informatics, so that they are able to efficiently use information and communication technology (IT users). This education will be formulated in table 1, section 3, in the form of learning outcomes. On the other side, candidates may want to prepare for careers in health and medical informatics (HMI specialists). Table 1 in section 3 will indicate, which education should be given to them to become an HMI specialist. The study of HMI is somewhat different. Here we have to interpret figure 1 in the sense, that learning outcomes (also being given in table 1 and further explained in sections 4 and 5) are defined to get a bachelor, master or doctor degree in HMI. Per definition this predefines an HMI specialist. There are obviously different ways to become a qualified HMI specialist.

[1] Program: An organised, structured set of course offerings aimed at preparing participants for specific career paths and culminating in a degree, diploma or leaving certificate, e.g. program in 'medicine', 'medical informatics' (as dedicated program).

3 Recommendations for Learning Outcomes

It is not possible today to refer to standard curricula, but rather interesting differences exist both within and between countries. A clear trend however in curriculum design is the coming together of competence requirements in information processing, information systems and technologies and competence requirements in information management, i.e. how to effectively use information and communication technology to support appropriate decision-making and evidence based practice. This trend also relates to the evolution of concepts of the multi-disciplinary information sharing that is needed for successful decision-making and quality management both in health care and in other domains.

For education in health and medical informatics two kinds of major learning outcomes can be identified. They specify the

1. Learning outcomes for all health care professionals in their role as IT users: Enabling health care professionals to efficiently and responsibly use information processing methodology and information and communication technology. These learning outcomes need to be included in all undergraduate curricula, leading to a health care professional qualification. On the other hand there are:
2. Learning outcomes for health and medical informatics specialists: Preparing graduates for careers in health and medical informatics in academic, health care (e.g. hospital) or industrial settings. These learning outcomes need to be included in all curricula, leading to a qualification as specialist in health and medical informatics.

Clearly for the health professional gaining knowledge and skills in health and medical informatics, various levels can exist concerning depth and breadth of educational components.

The learning outcomes define the levels of knowledge and practical skills needed. The desired outcomes determine the educational components either in courses/course tracks in health and medical informatics as part of educational programs or as dedicated programs in health and medical informatics.

Table 1 contains the list of learning outcomes, recommended by IMIA. These are specified as levels of knowledge and practical skills. There is a distinction between three levels of knowledge and skills: 1) introductory knowledge/skills, 2) intermediate knowledge/skills and 3) advanced knowledge/skills. Knowledge and skills which are described as optional are recommended if the research profile of the university/school offering a program includes these fields and if it fits well into a program. The knowledge and skill levels are classified into three domain areas of knowledge and skill:

1. Methodology and technology for the processing of data, information and knowledge in medicine and health care.
2. Medicine, health and biosciences, health system organisation.
3. Informatics/computer science, mathematics, biometry.

Knowledge/Skill - Domain	- Level IT User	 HMI Specialist
(1) Methodology and Technology for the Processing of Data, Information and Knowledge in Medicine and Health Care		
1.1a Reasons for the necessity of systematically processing data, information and knowledge in medicine and health care		
1.1b Benefits and current constraints of using information and communication technology in medicine and health care		
1.1c Value of high quality data for successful patient and institutional management.		
1.1d Need for an organisational information strategy and trained personnel		
1.2 Efficient and responsible use of information processing tools, to support health care professionals' practice and their decision making		
1.3a General characteristics of health information systems		
1.3b Management of information systems in health care		
1.3c Architectures and examples of health information systems, especially hospital information systems, office/practice information systems, to support health care professionals and managers of health care institutions		
1.3d Architectures and examples of information systems to support patients and the public		
1.3e Architectures and examples of information systems to support policy makers and managers of community/district/regional health care services		
1.4 Use of application software for documentation, personal communication including Internet access, for publication and basic statistics		
1.5 Information literacy: library classification and systematic health related terminologies and their coding, literature retrieval methods	HRA	
1.6a Appropriate documentation and health data management principles including ability to use health and medical coding systems	HRA HRA	
1.6b Construction of health and medical coding systems and their representation principles		
1.7 Structure, design and analysis principles of the health record including notions of data quality, minimum data sets, general applications of the electronic health record		
1.8a Appropriate decision making, using and constructing guidelines and critical paths		
1.8b Constructing tools for decision support and their application to patient management, acquisition, representation and engineering of medical knowledge		
1.9 Principles of practice evaluation and evidence based practice	HRA HRA	
...		

Recommended ***level of knowledge***: : introductory : intermediate : advanced
Recommended ***level of skill***: : introductory : intermediate : advanced
, large size: recommended for *all* professionals in health care
, small size: recommended for *certain* professionals in health care

Table 1a: Recommended learning outcomes in terms of levels of knowledge and skills for professionals in health care either in their role as IT users or as health and medical informatics (HMI) specialist. Obviously, between the specialisation of a health care professional as IT users and a health care professional as a HMI specialist, various levels concerning depth and breadth of learning outcomes exist. Additional recommendations, specific for a certain educational program, will be added in sections 4 and 5.

Knowledge/Skill - Domain	- Level IT User	 HMI Specialist
...		
Methodology and Technology for ... (continued)		
1.10 Health telematics approaches, electronic commerce in health	✍ ✂	✍✍ ✂
1.11 Data analysis using primary and secondary data sources, analysis of business (operational) processes, biostatistics and epidemiology	✍	✍✍✍ ✂✂✂
1.12 Medical signal processing	✍P	✍✍✍P,SP ✂✂P,SP
1.13 Medical image processing	✍ P	✍✍✍P,SP ✂✂P,SP
1.14 Bioinformatics (optional)		✍✍✍ ✂✂
1.15 Medical physics, including radiotherapy (optional)		✍✍✍ ✂✂
1.16 Medical robotics (optional)		✍✍✍ ✂✂
1.17 Biomedical Modelling (optional)		✍✍✍ ✂✂
1.18 Ethical issues including accountability of health care providers and managers and HMI specialists and the confidentiality, privacy and security of patient data	✍ ✂	✍✍ ✂✂
1.19 Standards in health and medical informatics		✍✍
1.20 Informatics methods and tools to support education (incl. flexible and distance learning), use of relevant educational technologies, incl. Internet and World Wide Web	✍	✍✍
(2) Medicine, Health and Biosciences, Health System Organisation		
2.1 Fundamentals of human functioning and biosciences (anatomy, physiology, microbiology and clinical disciplines such as internal medicine, surgery etc.)	✍ ✂	✍✍ X ✂ X
2.2 Fundamentals of what constitutes health, from physiological, sociological, psychological, nutritional, emotional, environmental, cultural, spiritual perspectives and its assessment	✍ ✂	✍✍ X ✂ X
2.3 Diagnostic and therapeutic strategies	✍ ✂	✍✍ X ✂ X
2.4 Organisation of the health system	✍ ✂	✍✍ X ✂ X
2.5 Health administration, health economics, health quality and resource management, public health services and outcome measurement		✍✍ X ✍X
...		
Recommended ***level of knowledge***: ✍: introductory ✍✍: intermediate ✍✍✍: advanced Recommended ***level of skill***: ✂: introductory ✂✂: intermediate ✂✂✂: advanced ✍, ✂ large size: recommended for *all* professionals in health care ✍, ✂ small size: recommended for *certain* professionals in health care; see respective footnote		

Table 1b: Recommended learning outcomes in terms of levels of knowledge and skills for professionals in health care either in their role as IT users or as HMI specialist. Obviously, between the specialisation of a health care professional as IT users and a health care professional as a HMI specialist, various levels concerning depth and breadth of learning outcomes exist. Additional recommendations, specific for a certain educational program, will be added in sections 4 and 5.

P recommended for physicians

P,SP recommended for physicians and for HMI professionals

X *Minimum* knowledge and skills in medicine, health and biosciences, health system organisation, recommended e.g. for students of dedicated HMI programs, of health record administration programs and of computer science/informatics students at bachelor and master level.

Knowledge/Skill - Domain		- Level IT User	- Level HMI Specialist
...			
(3) Informatics/Computer Science, Mathematics, Biometry			
3.1	Basic informatics terminology like data, information, knowledge, hardware, software, computer, networks, information systems, information systems management	✍	✍✍✍ ✂✂✂
3.2	Using personal computers, text processing and spread sheet software, easy-to-use database management systems	✍✍ ✂✂✂	✍✍ ✂✂✂
3.3	Ability to communicate electronically, including electronic data exchange, with other health care professionals	✍✍ ✂✂✂	✍✍ ✂✂✂
3.4	Methods of practical informatics/computer science, especially on programming languages, software engineering, databases, database management systems, information and system modelling tools, information systems theory and practice, decision support, knowledge engineering, (concept) representation and acquisition, networking, telecommunications, general issues concerning the human-computer interface, cognitive aspects of information processing		✍✍✍ B/M ✂✂✂ B/M
3.5	Methods of informatics/computer science theories		✍✍✍ B/M ✂✂✂ B/M
3.6	Methods of informatics/computer science technologies including virtual reality, multimedia		✍✍✍ B/M ✂✂✂ B/M
3.7	Change management principles and terminology and methodology of project management	✍✍ ✂	✍✍✍ ✂✂
3.8	Mathematics: algebra, analysis, logic, numerical mathematics, probability theory and statistics		✍✍✍ B/M ✂✂✂ B/M
3.9	Biometry, including study design, evaluation methods	✍	✍✍ ✂
Recommended ***level of knowledge***: ✍: introductory ✍✍: intermediate ✍✍✍: advanced Recommended ***level of skill***: ✂: introductory ✂✂: intermediate ✂✂✂: advanced ✍, ✂ large size: recommended for *all* professionals in health care ✍, ✂ small size recommended for *certain* professionals in health care; see respective footnote			

Table 1c: Recommended learning outcomes in terms of levels of knowledge and skills for professionals in health care either in their role as IT users or as HMI specialist. Obviously, between the specialisation of a health care professional as IT users and a health care professional as a HMI specialist, various levels concerning depth and breadth of learning outcomes exist. Additional recommendations, specific for a certain educational program, will be added in sections 4 and 5.

All health care professional graduates should, in their role as *IT users*, have the levels of knowledge and skills mentioned for IT users. Analogously, those professionals in health care, being *health and medical informatics specialists*, should have the levels of knowledge and skills specified for them.

In order to achieve the learning outcomes mentioned above, their educational components should be considered for inclusion into the respective educational programs.

The levels of knowledge and skills mentioned may particularly work well for developed, industrialised countries, with high levels of access to, and use of, information technology, and which have highly developed health care infrastructures. Developing countries may at the beginning have the need to adapt them with regard to the level of technology. The principles of health and medical informatics, however, can still be taught, applied and developed in the absence of high levels of information and communication technology.

Recommendations, either specific for certain courses or course tracks in health and medical informatics as part of educational programs or specific for dedicated educational programs in health and medical informatics, are mentioned in sections 4 and 5.

B/M recommended for bachelor programs in HMI, based on an informatics-based approach to HMI (see section 5), necessary knowledge and skills for entering a master program in HMI, based on an informatics-based approach to HMI

4 Recommendations for Courses/Course Tracks in Health and Medical Informatics as Part of Educational Programs

4.1 General Remarks

Educational course components in health and medical informatics should be tailored to the student's advancement and where possible be made relevant for and used to support a given stage of student progression. For example, teaching about the patient record for students of medicine should be introduced after the student has gained some clinical experience, but not too late so that students can benefit from this knowledge in the latter stages of their clinical training.

Due to the afore-mentioned large variety, there exist different perspectives for health and medical informatics education. For health and medical informatics specialists we especially can distinguish between a more informatics-based and a more health care-based approach to health and medical informatics education, with a variety of combinations in-between.

The objective of an informatics-based approach to health and medical informatics is to focus on the processing of data, information and knowledge in health care and medicine with a strong emphasis on the need for advanced knowledge and skills of health and medical informatics, of mathematics, as well as of theoretical, practical and technical informatics/computer science. Health care problems, however, can be treated cooperatively with physicians and other health care professionals. In such an approach to health and medical informatics education knowledge and skills of informatics/computer science predominate.

The objective of a health care-based approach to health and medical informatics is to focus on the processing of data, information and knowledge in health care and medicine requiring, apart from knowledge in health and medical informatics, also knowledge in medicine or of other health sciences to such an extent, which can only be imparted within the scope of a medical or health science education. In such an approach to health and medical informatics education knowledge and skills of medicine and of other health sciences predominate.

The recommendations, given in section 4.2 and 4.3 for health and medical informatics specialists are recommendations for health care-based approaches to health and medical informatics. The recommendations in sections 4.4 and 5.2 are oriented towards an informatics-based approach. With respect to educational progression, especially for a bachelor, master, and doctoral degree, the general distinctions in depth and breadth should be considered as mentioned in section 5.

4.2 Recommendations for Health and Medical Informatics Courses as Part of Medical, Nursing, Health Care Management, Dentistry, Pharmacy, and Public Health Programs

Courses/Course Tracks for IT Users

In order to achieve the levels of knowledge and skills in health and medical informatics as recommended in section 3 for IT users, the total student workload for educational components in health and medical informatics should comprise at least 2 ECTS credits[1] (see [3]). Specific examples from the work of the respective health professionals should be used. Emphasis should particularly be given to practical training.

The additional recommendations of this section may also apply to the programs of other professions in health care such as medical laboratory technicians, medical librarians, radiology technicians, dieticians, occupational therapists etc. or for the programs allied health/clinical researchers studied. These people also need to know about the potentials and the risks of information processing in health care and be able to efficiently use methods and tools of information processing and information and communication technology.

Courses/Course Tracks for Health and Medical Informatics Specialists

In order to achieve the levels of knowledge and skills in health and medical informatics, as recommended in section 3 for specialists, the student workload associated with these educational

[1] In the European Credit Transfer System (ECTS, [3]) a full academic year's student workload is 60 credits. Two ECTS credits can correspond, e.g., to approx. 40 hours of lectures, exercises and practical training at universities. A course, charged with two ECTS credits, may e.g. consist of a 3 hours/week lecture given in one semester with 14 weeks of lecturing.

components in health and medical informatics should be at least 60 ECTS credits, i.e. one year of full time studies. This is similar to dedicated master programs in health and medical informatics.

In addition to the 'core' knowledge and skills obtained in each program, the relative amount of student workload for the three knowledge and skills areas inside the health/medical informatics course track should approximately be as indicated in table 2.

Knowledge/Skill Area		Program: Medicine, Nursing, Health Care Management, Dentistry, Pharmacy, Public Health
(1)	methodology and technology for the processing of data, information and knowledge in medicine and health care	40
(2)	medicine, health and biosciences, health system organisation	5
(3)	informatics/computer science, mathematics, biometry	15
Σ		60

Table 2: Recommended student workload in ECTS credits for the three knowledge and skill areas of health/medical informatics course tracks inside programs of medicine and other health sciences.

For all health care professionals area (2) should focus on health system organisation, area (3) on practical informatics and project management. For nurses it should be possible that specialisation can be included in a post registration nursing curriculum. For health care managers knowledge and practical skills of information systems architectures and information systems management should particularly comprise enterprise functions for administration, controlling, quality management and executive decision making.

4.3 Recommendations for Health and Medical Informatics Courses as Part of Health Record Administration Programs

Within the past decade the discipline of health record administration (also denoted as health information management) has often enhanced its scope from document handling to managing health care information. Also the scope of practice has changed considerably.

For educating health record administrators, two different levels of education are recommended:

- A first level should cover introductory concepts and principles and assumes an introductory skill level. Students at this level take e.g. a two- or three year prescribed course of study at a college level resulting (e.g. in the U.S.) in an associate's degree.
- At a second level a deeper understanding of knowledge and more advancedskills, developing problem solving and critical thinking skills in more depth is assumed. Students at this level take e.g. a three- or four-year prescribed course of study resulting in a bachelor degree. Further studies may follow.

Courses/Course Tracks for IT Users

Health record administration students at the mentioned first level can be regarded as IT users. The recommendations on levels of knowledge and skills are the same as for IT users, mentioned in section 4.2. Particular emphasis should be given to information literacy, health terminology, coding systems, the electronic health record, and evaluation methodology. There should be introductory knowledge and skills in the knowledge/skill-domain medicine, health and biosciences, health systems organisation.

Courses/Course Tracks for Health and Medical Informatics Specialists

Students of health record administration programs, respectively health information management programs, who lead to bachelor and master degrees should have the knowledge and skills of HMI

specialists, as mentioned in section 4.2. Again, special emphasis should be given to information literacy, health terminology, coding systems, the electronic health record, and evaluation methodology.

4.4 Recommendations for Health and Medical Informatics Courses as Part of Informatics/Computer Science Programs

Courses/Course Tracks for Health and Medical Informatics Specialists

In order to achieve the levels of knowledge and skills in health and medical informatics, recommended in section 3 for specialists, the length of studies for educational components in health and medical informatics should be at least 60 ECTS credits, i.e. one year of full time studies.

In addition to the 'core' knowledge and skills of informatics/computer science, the relative amount of student workload for the three knowledge and skills areas inside the health/medical informatics course track should approximately be as indicated in table 3.

Knowledge/Skill Area		Program
		Informatics/ Computer Science
(1)	methodology and technology for the processing of data, information and knowledge in medicine and health care	40
(2)	medicine, health and biosciences, health system organisation	15
(3)	informatics/computer science, mathematics, biometry	5
Σ		60

Table 3: Recommended student workload in ECTS credits for the three knowledge and skill areas of a health/medical informatics course track inside informatics/computer science programs.

The student workload in (3) comprises knowledge and skills in biometry and evaluation methods. Applying methods and tools of informatics in health care institutions and for concrete problems in diagnosis, therapy, nursing and health care management should be emphasised. This helps to learn to know the health care environment as informatics or computer science student. Health information systems management should include the development and implementation of software and hardware components of health information systems. In medical signal and image processing technical and informatics aspects should particularly be considered.

5 Recommendations for Dedicated Educational Programs in Health and Medical Informatics

5.1 General Remark

The aim of all dedicated programs in health and medical informatics is to prepare graduates for careers in health and medical informatics in academic, health care (e.g. hospital) or industrial settings.

5.2 Recommendations for Bachelor Programs in Health and Medical Informatics

For programs leading to a bachelor degree in health informatics or medical informatics, curricula should be application-related, serving the purpose of a direct preparation for the future professional activity. In addition they should offer a good foundation for studying in a master program in this field or in related ones.

The objective of such a type of education is to impart specialised knowledge in the field of health and medical informatics as well as skills in a practice-oriented application of the acquired knowledge. The intention is to provide a practice-related education to qualify for translating expertise gained in the field of health and medical informatics into practical activity, in conformity with the state of knowledge. As compared with the comprehensive formal methodological foundation of a master program, it is the practice-oriented application that predominates.

In order to achieve the levels of knowledge and skills in health and medical informatics as recommended in section 3, and in order to achieve a broad depth and breadth of all educational components, the length of study for educational components in health and medical informatics should be at least three years. This corresponds to a student workload of at least 180 ECTS credits.

For an informatics based approach to health and medical informatics, the relative amount of student workload for the three knowledge and skills areas for the bachelor program should be approximately as indicated in table 4. This composition can be varied from very strong technical IT skill acquisition to less IT skill and a stronger health application focus, depending on the desired learning outcomes.

Knowledge/Skill Area		Program: Informatics/ Computer Science
(1)	methodology and technology for the processing of data, information and knowledge in medicine and health care	50
(2)	medicine, health and biosciences, health system organisation	20
(3)	informatics/computer science, mathematics, biometry	110
Σ		180

Table 4: Recommended student workload in ECTS credits for the three knowledge and skill areas of a health/medical informatics bachelor program.

5.3 Recommendations for Master and Doctoral Programs in Health and Medical Informatics

For programs leading to a master or doctoral degree (e.g. Ph.D.), it is the comprehensive formal methodological foundation for health and medical informatics that predominates, at a formal level.

The objective is to provide an education of scientific character that includes theory, specialised knowledge and practical skills. Graduates shall, apart from a practice-oriented application of methods and tools from health and medical informatics, be enabled to independently participate in research and in the methodical advancement within the field of health and medical informatics. In contrast to bachelor programs, these higher degrees include formal penetration and abstraction as well as the afore-mentioned qualification of graduates independently contributing to the methodical and scientific advancement that predominates.

In order to achieve the levels of knowledge and skills in health and medical informatics as recommended in section 3, and in order to achieve the desired broad depth and breadth of the educational components previously defined, the length of study should be at least one year full time for a master degree, corresponding to at least 60 ECTS credits. Ph.D. studies or Ph.D. work should usually last three years.

The relative amount of study time for the three knowledge and skills areas for the master program should approximately be as indicated in table 5.

Knowledge/Skill Area		Program: Informatics/ Computer Science
(1)	methodology and technology for the processing of data, information and knowledge in medicine and health care	40
(2)	medicine, health and biosciences, health system organisation	10
(3)	informatics/computer science, mathematics, biometry	10
Σ		60

Table 5: Recommended student workload in ECTS credits for the three knowledge and skill areas of a health/medical informatics master program.

It is expected that master students have successfully finished either (a) a bachelor program in health and medical informatics, (b) a bachelor or master program in medicine or another health science, or (c) in computer science. For cases (b) and (c) additional complementary courses in informatics/computer science (for case (b)) or medicine, health and biosciences, health system organisation (for case (c)) should be offered.

For programs leading to a doctoral degree, comprehensive own research should be carried out independently by the student in addition to the requirements previously mentioned. Knowledge and skills should also have additional depth or breadth. This should also be considered for the learning outcomes of sections 3 for depth and breadth of educational components when transforming them to educational components in doctoral programs.

6 Recommendations for Continuing Education

6.1 Continuing Education in Health and Medical Informatics

To prove sufficient qualification in health/medical informatics both in relation to the academic education or continuing education in health and medical informatics and in relation to a successful at least four-year professional activity (operational qualification), a certificate of 'Health Informatics' or 'Medical Informatics' should be offered.

Furthermore, for physicians, who usually have well established forms of continuing education, there should be offered the possibility of receiving, in addition to their medical degree, the supplementary qualification of 'Medical Informatics' or 'Health Informatics'. This additional qualification can be issued by the national medical associations. The same holds for nurses, for whom in many countries also forms of continuing education are very well-established.

In order to offer courses in health and medical informatics for continuing education, it is recommended that institutions are established to provide such courses. These institutions might be inside universities or, e.g. as academies of health/medical informatics established by associations in health and medical informatics.

6.2 Life Long Learning

Working in the field of health and medical informatics and even using information and communication technology requires life long learning. Therefore opportunities for continuing education should be offered for HMI specialists as well as IT users of the various health professions. The ability of 'learning to learn' will become of particular importance.

7 Other Recommendations

7.1 How to Commence with Health and Medical Informatics Education

Health and medical informatics affects all health care professionals. To commence education in this field IMIA recommends that education in health and medical informatics for all types of health care professionals, including the different types of specialisation and levels of education is considered. In countries, where no education in health and medical informatics exists, the following steps are recommended.

First of all teachers have to be educated ('teach the teachers'), courseware has to be prepared and institutes for health informatics or medical informatics have to be established within universities, usually inside medical or health sciences faculties. A broad education in the use of information processing and information and communication technology for health care professionals, especially physicians and nurses, should have the first priority. Thus, introductory courses especially for medical and nursing students should be offered first. Other types of education, as mentioned above, should then follow.

7.2 Modes of Education

Certain modes of education should be chosen, considering the specific profile and possibilities of the respective universities. Besides lectures it is of importance that practical exercises within health care institutions (e.g. in hospitals) are offered. Besides 'traditional' lectures and exercises within universities, and given the explosive growth of the Internet and World Wide Web, different models of flexible, distance and supported open learning should be actively pursued. Problem-oriented learning

might particularly support the relevance of health and medical informatics as it requires integration of information and a cross-disciplinary understanding.

7.3 Qualified Teachers

Courses and programs in health and medical informatics must be of good quality. Teachers of courses in health and medical informatics must have adequate and specific qualifications in this field. It must be possible to obtain such qualifications for lecturing in health and medical informatics, usually from universities.

7.4 Recognised Qualifications

Education of students in health and medical informatics, which goes beyond introductory courses in the use of information and communication technology, only makes sense if positions for these graduates exist or are created. The qualifications of such health and medical informatics graduates must be recognised and there should be positions as specialists in health and medical informatics.

8 IMIA Support for Programs and Courses in Health and Medical Informatics

8.1 IMIA Certification

To support education of high quality in the field of health and medical informatics, IMIA offers help by providing expert advice to persons and institutions in this field, as far as the resources of IMIA allow. This might especially be needed when commencing with educational activities and when national institutions are not yet established to do this.

Health and medical informatics courses inside programs and in specialised programs in this field can upon request add to the description of their course track or program the phrase ‘endorsed by the International Medical Informatics Association’ and can use the IMIA logo in this context.

This is conditional to the IMIA recommendations being fulfilled and once the quality of the program, including organisational integration and resources, has been assessed by IMIA appointed experts. Single courses can not be considered, only course tracks or programs.

The fulfilment of the recommendations and the assessment of the quality of the program will be examined by a committee usually consisting of 4 IMIA WG1 members or other persons, experienced in HMI education, and will be approved by the IMIA president and the chairperson of IMIA WG1. The members of this committee will be nominated jointly by the IMIA president and by the chairperson of IMIA WG1.

After approval, a written certificate, signed by the IMIA president, the chairperson of IMIA Working Group 1 on Health and Medical Informatics Education, and by the committee members, will be given to the respective organisation.

Requests should be submitted to the chairperson of IMIA Working Group 1.

8.2 International Programs, International Exchange of Students and Teachers

IMIA encourages and recommends international activities in educating health and medical informatics specialists. IMIA also recommends the international exchange of students and of teachers in this field. It encourages the establishment of international programs to support this and to exchange courseware. Programs should be built up in a modular way, and international credit transfer systems such as the ECTS ([3]) should be used in the respective national programs to support these international perspectives.

9 Information Exchange on Programs and Courses in Health and Medical Informatics Supported by IMIA

9.1 IMIA WG1 Database on Programs and Courses in Health and Medical Informatics

IMIA’s Working Group 1 on Health and Medical Informatics Education (IMIA WG1) has established a WWW site to provide up-to-date information about its work ([10]). The main feature of the site is a

database providing information on health and medical informatics programs and courses world-wide ([7]). To be able to have a database of high quality and value IMIA encourages all teachers and institutions to submit information about courses and programs on HMI education offered and to set pointers to their own WWW sites.

9.2 IMIA WG1 Mailing List

In addition, IMIA WG1 operates a mailing list to facilitate communication between all persons interested in health and medical informatics education world-wide. For subscription, a message has to be sent to 'listserv@urz.uni-heidelberg.de'. The body of the message should read 'SUBSCRIBE IMIA-WG1'. Messages to the IMIA WG1 list have to be sent to 'imia-wg1@urz.uni-heidelberg.de'.

9.3 Developing and Sharing Courseware

IMIA encourages the development and sharing of courseware of high quality for courses in health and medical informatics. This will help to further establish courses in this field. Examples for such initiatives are the IT Eductra project of the European Union ([11]) or the WWW sites of the Handbook of Medical Informatics ([16]). IMIA encourages the use of its IMIA WG1 WWW server and list server for the dissemination of information about such courseware.

10 Concluding Remarks

These recommendations provide a beginning framework for individual curriculum development. Individual countries may wish to develop more detailed or better defined curricula guidelines to suit their specific needs and educational system. This could include specific minimum level competencies required for each level and knowledge/skill domain. Such national efforts are expected to inform future reviews of these guidelines. The IMIA WG1 may in the near future develop teaching credentialling criteria to serve as a guide for teachers wishing to participate in health and medical informatics education.

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