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

First Revision

J. Mantas; E. Ammenwerth; G. Demiris; A. Hasman; R. Haux; W. Hersh; E. Hovenga; K. C. Lun; H. Marin; F. Martin-Sanchez; G. Wright
(IMIA Recommendations on Education Task Force)

Keywords
Medical informatics, health informatics, biomedical informatics, education, recommendations, International Medical Informatics Association, IMIA

Summary

Objective: The International Medical Informatics Association (IMIA) agreed on revising the existing 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 biomedical and health informatics (BMHI), particularly international activities in educating BMHI specialists and the sharing of courseware.

Method: An IMIA task force, nominated in 2006, worked on updating the recommendations' first version. These updates have been broadly discussed and refined by members of IMIA's National Member Societies, IMIA's Academic Institutional Members and by members of IMIA's Working Group on Health and Medical Informatics Education.

Results and Conclusions: The IMIA recommendations center 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 (e.g. physicians, nurses, BMHI professionals), 2) type of specialization in BMHI (IT users, BMHI specialists), and 3) stage of career progression (bachelor, master, doctorate). 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 BMHI specialist. Recommendations are given for courses/course tracks in BMHI 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 BMHI (with bachelor, master or doctor degree).
To support education in BMHI, IMIA offers to award a certificate for high-quality BMHI education. It supports information exchange on programs and courses in BMHI through its Working Group on Health and Medical Informatics Education.

Correspondence to:
Professor John Mantas
Chair of Task Force
E-mail: jmantas@cc.uoa.gr

Methods Inf Med 2010; 49: 105–120
doi: 10.3414/ME5119
prepublished: January 7, 2010

1. Introduction

The first version of the "Recommendations of the International Medical Informatics Association (IMIA) on education in health and medical informatics" [1] has been widely used. Because of the tremendous progress in and the evolution of the field of health and biomedical informatics, the contents of those recommendations were, however, not fully up-to-date. As there is still a continuous need for such recommendations, a revision was necessary.

The revised version, presented here, is based on the original recommendations and the fundamental work following those recommendations ([2–9] and ▶Table 1 in Section 1.2).

There is increasing evidence that health information technology (HIT) improves health, health care, public health, and biomedical research. A number of recent systematic reviews have documented the evi-

Table of Contents

dence in favor of clinical decision support [10], information and communication technology (IT) interventions [11], and telemedicine [12]. This has led to widespread adoption of HIT around the world [13]. In addition to a growing range of research and application fields in biomedical and health informatics (BMHI) [14, 15], there is also growth in related areas of BMHI, such as clinical research informatics [16–18] and bioinformatics [19]. The growth of HIT has also led to the recognition of the need for educational programs to train professionals to develop, implement, and evaluate these systems. While this need has been recognized worldwide [20], there have been few international efforts with some notable exceptions [21, 22].

1.1 Why Do We Need Biomedical and Health Informatics Education?

Despite the documented benefits, there are still barriers to HIT in clinical settings, including a mismatch of return on investment between those who pay and those who benefit, challenges to ameliorate workflow in clinical settings, lack of standards and interoperability, and concerns about privacy and confidentiality [23–25]. Another barrier, lesser studied and quantified but increasingly recognized, is the lack of characterization of the workforce and its training needed to most effectively implement HIT systems [26, 27].

An additional challenge is that there are various definitions of the field of BMHI [26, 28, 29]. Furthermore, the field has difficulty agreeing on the adjective in front of the word informatics (i.e., medical, biomedical, and/or health) as well as whether a practitioner should be called an informaticist or informatician (this paper uses the latter). We also do not know where pure IT ends and informatics begins. For example, the individual who installs applications on a desktop computer in a hospital probably does not need formal training in informatics, although the CIO and his or her project leaders certainly do. This has led to calls for BMHI to become a professional discipline [30] and for it to acquire the attributes of a profession, such as a well-defined set of competencies, certification of fitness to practice, shared professional identity, life-long commitment, and a code of ethics [31].

A number of efforts to establish formal certification have been and are underway. For example, in Germany, medical informatics courses are mandatory for medical students since the 1970s [32]. In the US, certification in nursing informatics has been available for over a decade [33]. More recently, the American Medical Informatics Association (AMIA) has proposed a plan for a physician board sub-specialization,

Table 1 Some major publications on competencies in biomedical and health informatics

Organization (Reference)	Year	Discipline
University of Heidelberg and the University of Applied Sciences Heilbronn medical informatics program [36, 37]	1972	dedicated BMHI programs
German Association for Medical Informatics, Biometry and Epidemiology (gmds) and German Society for Computer Science (Reisensburg Conference) [38, 39]	1973	BMHI and computer science
Association for Computing Machinery [40]	1978	BMHI and computer science
Association of the Medical Colleges [41]	1984	BMHI and medicine
gmds [42]	1992	BMHI in general
Concerted Action on Education and Training in Health Care Informatics (EDUCTRA) [43]	1992	BMHI for health professionals
Council of Europe Committee of Ministers [44]	1995	BMHI for health professionals
NIGHTINGALE project [45, 46]	1996	nursing informatics
IT-EDUCTRA project [43]	1996	BMHI for health professionals
English National Board for Nursing, Midwifery and Health Visiting [47]	1996	BMHI for nurses, midwives and health visitors
National Advisory Council on Nurse Education and Practice [48]	1996	nursing informatics
Association of American Medical Colleges [49]	1999	BMHI and medicine
International Medical Informatics Association [1]	1999	BMHI in general
Schleyer [50]	1999	dental informatics
UK National Health Service [51]	2001	BMHI in general
Staggers et al. [52]	2001	nursing informatics
Covvey et al. [53]	2001	BMHI in general
Mantas and Hasman [54]	2001	nursing informatics
O'Caroll et al. [55]	2002	BMHI for public health (PH) professionals
Curran [56]	2003	nursing informatics
American College of Medical Informatics [57]	2004	bioinformatics
American Health Information Management Association (AHIMA) [58]	2004	health information management
Hovenga and Mantas [20]	2004	BMHI in general
Hovenga and Garde [59]	2006	health informatics
Ivanitskaya et al. [60]	2006	health information literacy
AHIMA [61]	2007	health information management
Canadian Health Informatics Association [62]	2007	health informatics
Medical Library Association [63]	2007	health science librarians
Pigott et al. [64]	2007	health informatics
Huang [65]	2008	BMHI in general
AMIA and AHIMA [66]	2008	EHR Clinical users
Gassert [67]	2008	Nursing informatics
Karras et al. [68]	2008	PH informatics
AMIA [69]	2009	clinical informatics
AMIA-OHSU 10x10 Course [70]	2009	BMHI in general
TIGER Nursing Informatics [71]	2009	Nursing Informatics
Office of the National Coordinator for Health IT [72]	2009	EHR adoption

which will be followed for other non-physician doctorally prepared individuals [34, 35].

Despite these challenges, a number of organizations have deemed competence in BMHI to be important. Competencies in the field have been developed for a variety of disciplines within BMHI. In ▶Table 1 some major publications on the development of such competencies are listed as examples.

1.2 IMIA Recommendations for Biomedical and Health Informatics Education

There are many opportunities worldwide for obtaining education in this field. In some countries, there are extensive educational components in BMHI at different levels of education and for the different health care professions. Increasingly dedicated BMHI programs exist (i.e. organized, structured sets of course offerings aimed at preparing participants for specific career paths and culminating in a BMHI degree, diploma or leaving certificate). 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. Lists of educational programs have been made available at a variety of websites, e.g.:

- BMHI programs world wide [73] (University of Freiburg, Germany),
- BMHI programs in [74] and outside [75] North America (AMIA).

In 2007 IMIA, the International Medical Informatics Association [76], endorsed and published its strategic plan "Towards IMIA 2015" [77–80]. Education in BMHI was listed among its six core-subject-focused 'sectors'. Recognizing that the original version of the IMIA recommendations for education had become outdated, in 2006 a task force was established under the auspices of IMIA's Working Group on Health and Medical Informatics Education "to consider and undertake any necessary work to update the IMIA Recommendations on Education in Health and Medical Informatics" ([81]). These recommendations will continue to stimulate the further development of existing educational activities in the various nations and to support international initiatives concerning education in BMHI.

Because a variety of educational and health care systems exist all over the world, programs, courses and course tracks in BMHI may vary in different countries. In spite of this variability, basic similarities in BMHI 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, should be regarded as a framework for national initiatives in BMHI 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.

2. General Considerations

2.1 Key Principles of the IMIA Recommendations

In order to provide good-quality health care, training and education in biomedical and health medical informatics is needed:

H for various ***H***ealth care professions,
E in different modes of ***E***ducation,
A with different, ***A***lternate types of specialization in BMHI, and
L at various ***L***evels of education, corresponding to respective stages of career progression. There must be
T qualified ***T***eachers to provide BMHI courses, which lead to
H recognized qualifications for biomedical and ***H***ealth informatics positions.

In more detail, 'HEALTH' means:

H Practically all *professionals in health care* should, during their studies, be confronted with BMHI education: e.g. physicians, nurses, pharmacists, dentists, health care managers, health record administrators, and also health and medical informaticians who are graduates from specialized programs in BMHI. Computer scientists/informaticians and other scientists (e.g. engineers), who intend to work in the fields of medicine and health care, also need BMHI education.

E Various *education methodologies* are needed to provide the required theoretical knowledge, practical skills and mature attitudes. 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, videoconferencing, document sharing and social networking platforms and applications are additionally having great impacts on all educational methodologies, and in particular will favor flexible and distance learning including both synchronous and asynchronous communication between instructors and students. Inter-university collaborations might also facilitate curricular choice.

A *Alternate routes to different types of specialization* in BMHI 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 specialization in this field. They should, however, also be able to acquire an additional specialist qualification in BMHI as part of their chosen career development. BMHI specializations may be different to suit the various types of health care professionals. Finally, it should also be possible to acquire specialist qualifications in BMHI via specific BMHI programs leading to accreditation at different levels, e.g. master or PhD.

L Every profession in health care even at an early stage needs some core BMHI knowledge. Different *levels of education*, respectively stages of career progression, (bachelor, master, and doctor) have different BMHI education needs according to experience, professional role and responsibility. A junior professional uses information differently compared to a senior professional. There are specialized BMHI university programs but BMHI instruction could also be inte-

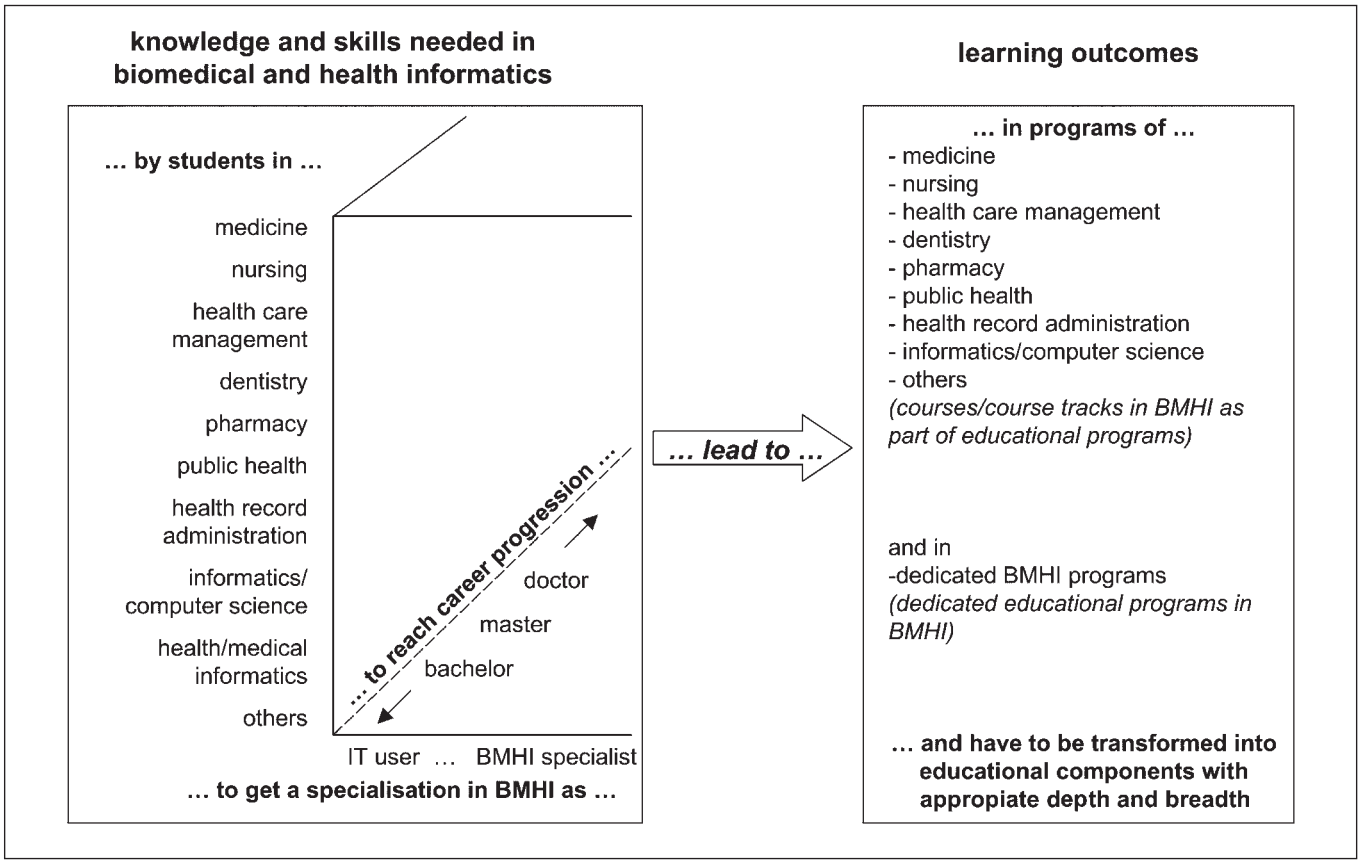

Fig. 1 Structural outline of the IMIA recommendations on education in biomedical and health informatics (BMHI): knowledge and skills needed in BMHI by students in health care, to get a specialization in BMHI and to reach a career progression lead to learning outcomes in programs, and have to be transformed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

grated 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 BMHI also need to be available.

T The content and delivery of BMHI courses and programs must be of good quality. *Teachers* of BMHI courses must have adequate and specific competence in this field.

H There must be recognized qualifications in *BMHI* for positions in this field. Accreditation of educational content and competence in BMHI is required, to eventually have recognition on an international basis.

2.2 Structural Outline of the IMIA Recommendations

The IMIA recommendations center 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 specialization in BMHI' and 'stage of career progression' (Fig. 1).

▶Figure 1 points 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 BMHI, so that they are able to efficiently use information and communication technology (IT users).

On the other side, candidates may want to prepare for careers as BMHI specialists. The study of BMHI for these specialists is somewhat different. Here we have to interpret Figure 1 in the sense that learning outcomes (also being given in ▶Table 2 and further explained in Sections 4 and 5) are defined to get a bachelor, master or doctor degree in BMHI. Per definition this predefines a BMHI specialist. There are obviously different ways to become a qualified BMHI specialist.

3. Recommendations for Learning Outcomes in Biomedical and Health Informatics

Interesting differences exist both within and between countries and programs with

regard to structures of curricula and expected learning outcomes. Several initiatives have been launched in the last years to define some standardized content of BMHI curricula, aiming at developing sample informatics curricula.

A clear trend in curriculum design is the integration of disciplines closely related to the core field of BMHI, such as biomedical engineering, medical information sciences, molecular biology or nanosciences. Those fields share knowledge, methods and tools with BMHI. ▶Figure 2 highlights and describes the most important related disciplines. For further discussion of this issue, see e.g. also [82–84].

The learning outcomes, presented in Section 3, will integrate those overlapping areas as optional elements, depending on the focus of the respective program. This assures that graduates from BMHI programs know at least the basics of those related disciplines, and to give various programs the flexibility to focus on one or more of those overlapping areas, depending on the cultural, scientific and technical context of the institution.

For education in BMHI 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 and knowledge 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 BMHI specialists:* Preparing graduates for careers in BMHI in academic, health care (e.g. hospital, primary care), government or industrial settings. These learning outcomes need to be included in all curricula, leading to a qualification as specialist in BMHI.

Obviously, between the specialization of a health care professional as IT user and a health care professional as a BMHI specialist, *various levels concerning depth and breadth of learning outcomes exist*. Some programs may focus on either health care professionals or on health informatics specialists. Other programs may focus on a kind of intermediary level, where students are educated to communicate with physicians and nurses as IT users on one side and health informatics specialists on the other side.

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

▶Table 2 contains the list of learning outcomes, recommended by IMIA. The knowledge and skill levels are classified into the domain areas:

1. BMHI core knowledge and skills,
2. medicine, health and biosciences, health system organization,
3. informatics/computer science, mathematics, biometry,

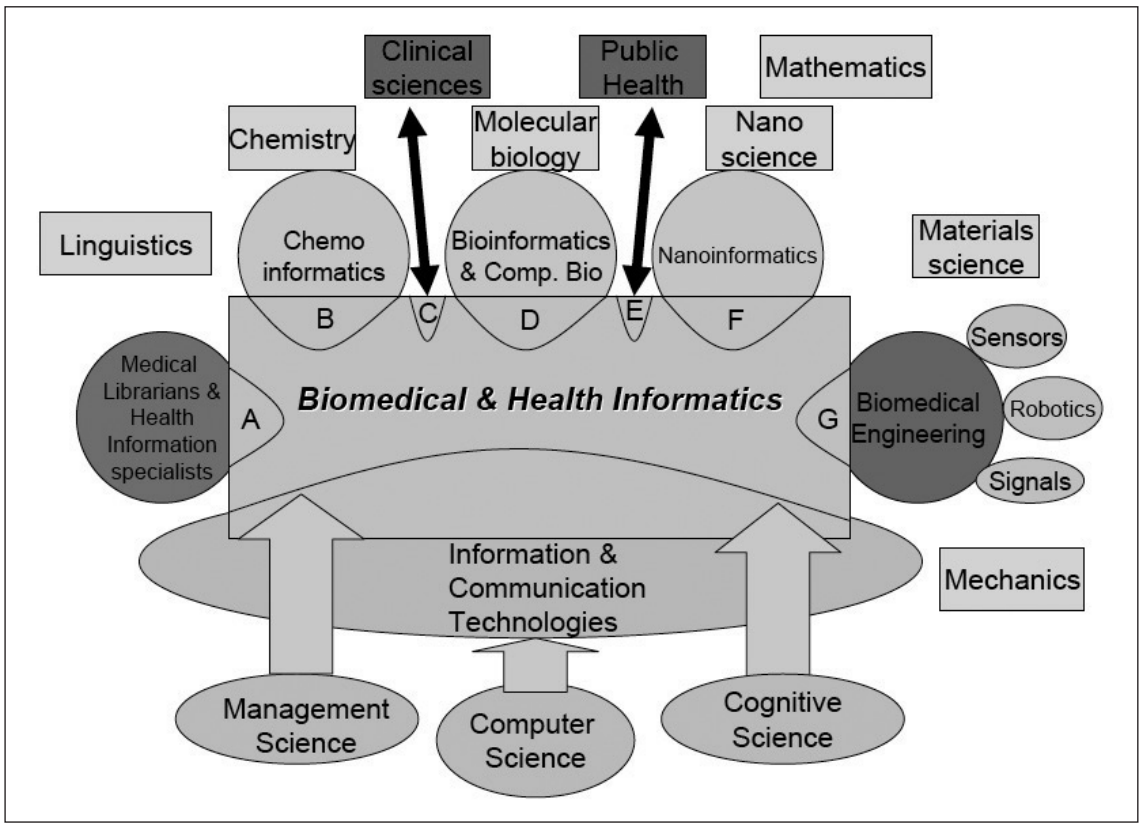

Fig. 2
Biomedical and health informatics and related fields. Overlapping areas: A – medical information science, B – medical chemo-informatics, C – clinical informatics, D – medical (translational) bioinformatics, E – public health informatics, F – medical nano-informatics, G – medical imaging and devices

4. optional modules in BMHI and from related fields.

In order to achieve the learning outcomes mentioned above, their educational components should be considered for inclusion into the respective educational programs. Knowledge and skills, which are described in part 4, are optional and are recommended, e.g. if the research profile of the university/school offering a program includes these fields and if it fits well into the program.

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 *BMHI specialists*, should have the levels of knowledge and skills specified for them.

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

Recommendations, either specific for certain courses or course tracks in BMHI as part of educational programs or specific for dedicated educational programs in BMHI are mentioned in Sections 4 and 5.

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

4.1 General Remarks

Educational course components in BMHI 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 aforementioned large variety, there exist different perspectives for BMHI education. For BMHI specialists we especially can distinguish between a more informatics-based and a more health care-based approach to BMHI education, with a variety of combinations in-between. It is important to recognize the need for teamwork as all health informatics projects require input from more than one person each with their own unique skill set, so that the team as whole is able to address all project aspects in a cohesive and coordinated manner.

The objective of an *informatics-based approach to BMHI* is to focus on the machine processing of data, information and knowledge in health care and medicine with a strong emphasis on the need for advanced knowledge and skills of BMHI, of workflow, people and organizational aspects, of mathematics, as well as of theoretical, practical and technical informatics/computer science, especially semantic interoperability, ontology-based software engineering and its relationship with effective and safe data, information and knowledge processing and representation. Health care problems, however, can be treated cooperatively with physicians and other health care professionals. In such an approach to BMHI education, knowledge and skills of informatics/computer science predominate, but must be applied with a sound knowledge of the business of providing healthcare services.

The objective of a *health care-based approach to BMHI* is again to focus on the machine processing of data, information and knowledge in health care and medicine requiring, apart from knowledge in BMHI, also knowledge in medicine or other health sciences to such an extent that can only be imparted within the scope of a medical or health science education. In such an approach to BMHI education, clinical knowledge and skills predominate but these must be applied within the BMHI context.

The recommendations given in Sections 4.2 and 4.3 for BMHI specialists are for health care-based approaches to BMHI. 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.

For specifying a student's workload, the European Credit Transfer and Accumulation System (ECTS) is used [85]. In ECTS a full academic year's student workload corresponds to 60 ECTS credits.

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

4.2.1 Courses/Course Tracks for IT Users

In order to achieve the levels of knowledge and skills in BMHI as recommended in Section 3 for IT users, the total student workload for educational components in BMHI should comprise at least four ECTS credits. Four ECTS credits can correspond, e.g., to approx. 40 hours of lectures, exercises and practical training at universities. A course, charged with four ECTS credits, may e.g. consist of a 3-hour/week lecture, given in one semester with 14 weeks of lecturing.

Specific examples from the work of the respective health professionals should be used. Emphasis should particularly be given to practical and simulated training.

The additional recommendations of this Section 4 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 should be able to efficiently use methods and tools of information processing and information and communication technology.

Table 2 Recommended and optional learning outcomes in terms of levels of knowledge and skills for professionals in health care either in their role as IT users or as BMHI specialists. Additional recommendations, specific for a certain educational program, will be added in Sections 4 and 5. Recommended level of knowledge and skills: + = introductory. ++ = intermediate. +++ = advanced

Knowledge/Skill – Domain		– Level	
		IT user	BMHI specialist
(1) Biomedical and Health Informatics Core Knowledge and Skills			
1.1	**Evolution of informatics** as a discipline and as a profession	+	+
1.2	**Need for systematic information processing** in health care, benefits and constraints of information technology in health care	++	++
1.3	Efficient and responsible **use of information processing tools,** to support health care professionals' practice and their decision making	++	++
1.4	**Use of personal 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, research methods and research paradigms	++	++
1.6	Characteristics, functionalities and examples of **information systems in health care** (e.g. clinical information systems, primary care information systems, etc.)	+	+++
1.7	**Architectures of information systems** in health care; approaches and standards for communication and cooperation and for interfacing and integration of component, architectural paradigms (e.g. service-oriented architectures)		++
1.8	**Management of information systems** in health care (health information management, strategic and tactic information management, IT governance, IT service management, legal and regulatory issues)	+	+++
1.9	Characteristics, functionalities and examples of **information systems to support patients and the public** (e.g. patient-oriented information system architectures and applications, personal health records, sensor-enhanced information systems)	+	++
1.10	Methods and approaches to **regional networking and shared care** (eHealth, health telematics applications and inter-organizational information exchange)	+	++
1.11	Appropriate documentation and **health data management principles** including ability to use **health and medical coding systems,** construction of health and medical coding systems	+	+++
1.12	Structure, design and analysis principles of the **health record** including notions of data quality, minimum data sets, architecture and general applications of the electronic patient record/electronic health record	+	+++
1.13	**Socio-organizational and socio-technical issues,** including workflow/process modelling and reorganization	+	++
1.14	Principles of **data representation and data analysis** using primary and secondary data sources, principles of data mining, data warehouses, knowledge management	+	++
1.15	Biomedical **modelling and simulation**		+
1.16	**Ethical and security issues including** accountability of health care providers and managers and BMHI specialists and the confidentiality, privacy and security of patient data	+	++
1.17	**Nomenclatures, vocabularies,** terminologies, ontologies and taxonomies in BMHI	+	++
1.18	Informatics methods and tools to **support education** (incl. flexible and distance learning), use of relevant educational technologies, incl. Internet and World Wide Web		+
1.19	**Evaluation and assessment** of information systems, including study design, selection and triangulation of (quantitative and qualitative) methods, outcome and impact evaluation, economic evaluation, unintended consequences, systematic reviews and meta-analysis, evidence-based health informatics		++

to be continued

Table 2 Continued

Knowledge/Skill – Domain		– Level	
		IT user	BMHI specialist
(2) Medicine, Health and Biosciences, Health System Organization			
2.1	Fundamentals of **human functioning** and biosciences (anatomy, physiology, microbiology, genomics, and clinical disciplines such as internal medicine, surgery, etc.)	+	+
2.2	Fundamentals of **what constitutes health,** from physiological, sociological, psychological, nutritional, emotional, environmental, cultural, spiritual perspectives and its assessment	+	+
2.3	Principles of **clinical/medical decision making** and diagnostic and therapeutic strategies	+	++
2.4	**Organisation of health institutions** and of the overall health system, interorganizational aspects, shared care	+	+++
2.5	**Policy and regulatory frameworks** for information handling in health care		+
2.6	Principles of **evidence-based practice** (evidence-based medicine, evidence-based nursing, …)	+	+
2.7	**Health administration, health economics,** health quality management and resource management, patient safety initiatives, public health services and outcome measurement	+	++
(3) Informatics/Computer Science, Mathematics, Biometry (continued)			
3.1	**Basic informatics terminology** like data, information, knowledge, hardware, software, computer, networks, information systems, information systems management	+	+++
3.2	**Ability to use 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, internet/intranet use	++	+++
3.4	Methods of **practical informatics**/computer science, especially on programming languages, software engineering, data structures, database management systems, information and system modelling tools, information systems theory and practice, knowledge engineering, (concept) representation and acquisition, software architectures		+++
3.5	Methods of **theoretical informatics**/computer science, e.g. complexity theory, encryption/security		++
3.6	Methods of **technical informatics**/computer science, e.g. network architectures and topologies, telecommunications, wireless technology, virtual reality, multimedia		++
3.7	Methods of **interfacing and integration** of information system components in health care, interfacing standards, dealing with multiple patient identifiers		++
3.8	Handling of the **information system life cycle**: analysis, requirement specification, implementation and/or selection of information systems, risk management, user training	+	+++
3.9	Methods of **project management and change management** (i.e. project planning, resource management, team management, conflict management, collaboration and motivation, change theories, change strategies)	+	+++
3.10	**Mathematics:** algebra, analysis, logic, numerical mathematics, probability theory and statistics, cryptography		++
3.11	**Biometry, epidemiology,** and **health research methods**, including study design		++
3.12	Methods for **decision support** and their application to patient management, acquisition, representation and engineering of medical knowledge; construction and use of clinical pathways and guidelines	+	+++
3.13	Basic concepts and applications of **ubiquitous computing** (e.g. pervasive, sensor-based and ambient technologies in health care, health enabling technologies, ubiquitous health systems and ambient assisted-living)		+
3.14	Usability engineering, **human-computer interaction**, usability evaluation, cognitive aspects of information processing		++

to be continued

Table 2 Continued

Knowledge/Skill – Domain		– Level	
		IT user	BMHI specialist
(4) Optional Modules in BHMI and from Related Fields			
4.1	Biomedical imaging and signal processing		+ – +++
4.2	Clinical/Medical bioinformatics and computational biology		+ – +++
4.3	Health-enabling technologies, ubiquitous health systems and ambient-assisted living		+ – +++
4.4	Health information sciences		+ – +++
4.5	Medical chemoinformatics		+ – +++
4.6	Medical nanoinformatics		+ – +++
4.7	Medical robotics		+ – +++
4.8	Public health informatics		+ – +++

4.2.2 Courses/Course Tracks for BMHI Specialists

In order to achieve the levels of knowledge and skills in BMHI, as recommended in Section 3 for specialists, the student workload associated with these educational components in BMHI should be at least 60 ECTS credits, i.e. one year of full-time studies. This is similar to dedicated master programs in BMHI.

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 3.

For all health care professionals domain area (2) should focus on health system organization, area (3) on practical informatics and project management. For nurses it should be possible that specialization can be included in a postgraduate nursing curriculum. For health care managers, knowledge and practical skills of information systems architectures, incl. characteristics required to achieve semantic interoperability and information systems/network management should particularly comprise work and information flow supporting enterprise functions for administration, controlling, quality management and executive decision making.

4.3 Recommendations for Biomedical and Health 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 course of study at a college level resulting (e.g. in the U.S.) in an associate's degree. The focus for these students needs to be on data, meta-data, coding rules, classification systems and their relationship with health informatics.
- At a second level a deeper understanding of knowledge and more advanced terminology skills, problem solving and critical thinking skills in more depth is assumed. Students at this level take e.g. a three- or four-year course of study resulting in a bachelor degree where health information management skills and knowledge is integrated with more advanced informatics knowledge and skills. Further studies may follow.

Knowledge/Skill Area		Program Medicine, Nursing, Health Care Management, Dentistry, Pharmacy, Public Health
(1)	BMHI core knowledge and skills	40
(2)	Medicine, health and biosciences, health system organisation	5
(3)	Informatics/computer science, mathematics, biometry	15
Σ		60

Table 3 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.

4.3.1 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 and classification 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 organization.

4.3.2 Courses/Course Tracks for Biomedical and Health Informatics Specialists

Students of health record administration programs, respectively health information management programs, which lead to bachelor and master degrees should have the knowledge and skills of BMHI specialists, as mentioned in Section 4.2. Again, special emphasis should be given to information literacy, meta-data, health terminology, coding and classification systems, the electronic health record, and evaluation methodology and to the relationship between these concepts and the use of various informatics technologies.

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

4.4.1 Courses/Course Tracks for Biomedical and Health Informatics Specialists

In order to achieve the levels of knowledge and skills in BMHI, recommended in Section 3 for specialists, the length of studies for educational components in BMHI 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 BMHI course track should approximately be as indicated in ▶Table 4.

The student workload in (3) comprises knowledge and skills in biometry, semantic interoperability 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 emphasized. It is essential to include ontology-based software engineering and the need to separate knowledge from system configuration, as these concepts are fundamental to achieving semantic interoperability and safe clinical decision support systems. This assists informatics or computer science students to gain more knowledge about the health care environment. 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.

Table 4 Recommended student workload in ECTS credits for the three knowledge and skill areas of a BMHI course track inside informatics/computer science programs.

Knowledge/Skill Area		Program Informatics/ Computer Science
(1)	BMHI core knowledge and skills	40
(2)	Medicine, health and biosciences, health system organisation	15
(3)	Informatics/computer science, mathematics, biometry	5
Σ		60

5. Recommendations for Dedicated Educational Programs in Biomedical and Health Informatics

The aim of all dedicated programs in BMHI is to prepare graduates for careers in academic/research settings, health care facilities or organizations, governmental or international public health entities or industrial settings.

5.1 Recommendations for Bachelor Programs in Biomedical and Health Informatics

The curriculum of a program leading to a bachelor degree in BMHI should be application-related aiming to prepare students for a professional career in the field. In addition, the curriculum should offer the background and theoretical foundation necessary to pursue advanced graduate studies in this or related fields.

The objective of this undergraduate education is to equip students with specialized knowledge in the field of BMHI and the skills to apply the acquired knowledge in a variety of practical situations. The intention is to provide a deep understanding of the state-of-the-art of the discipline and the ability to translate expertise gained in the field into practical application of tools and concepts. Compared to the comprehensive formal methodological foundation of a master program, it is the practice-oriented application that predominates the undergraduate curriculum. Given the diversity of the discipline, students at the bachelor program level need to understand the breadth of the field and become familiar with the spectrum of BMHI (capturing all sub-domains such as bioinformatics, clinical informatics, public health informatics, etc.). The challenge herein is to provide knowledge and skills that students can apply in practice while recognizing that areas of interest could be explored further and in more-depth at the graduate educational level.

In order to achieve the levels of knowledge and skills recommended in Section 3, and to achieve a broad depth and breadth of all educational components, the length of study for the instructional component of a bachelor program in BMHI should be at least three years. This corresponds to a student workload of 180 ECTS credits.

For an informatics-based approach to BMHI, the relative amount of student workload for the four knowledge and skills areas for the bachelor program should be

Knowledge/Skill Area		Program BMHI (bachelor)
(1)	BMHI core knowledge and skills	50
(2)	Medicine, health and biosciences, health system organisation	20
(3)	Informatics/computer science, mathematics, biometry	110
Σ		180

Table 5 Recommended student workload in ECTS credits for the knowledge and skill areas of a biomedical and health informatics bachelor program.

Knowledge/Skill Area		Program BMHI (master)
(1)	BMHI core knowledge and skills	80 (40)
(2)	Medicine, health and biosciences, health system organisation	20 (10)
(3)	Informatics/computer science, mathematics, biometry	20 (10)
Σ		120 (60)

Table 6 Recommended student workload in ECTS credits for the knowledge and skill areas of a two year (one year) biomedical and health informatics master program.

approximately as indicated in ▶Table 5. 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.

5.2 Recommendations for Master and Doctoral Programs in Biomedical and Health Informatics

For programs leading to a master or doctoral degree, it is the comprehensive formal methodological foundation for BMHI that dominates the instructional component of the program.

The objective is to provide scientific education that captures the theoretical foundations of the field, provides specialized knowledge and equips students with both practical skills and analytical approaches that will allow them to further the knowledge base of the discipline. Graduates will be able to master both the practical methods and tools and the leadership of independent research.

Unlike undergraduate bachelor programs, these graduate and post-graduate programs emphasize a formal penetration into the knowledge and foundation of the discipline and promote methodological expertise and independent analysis. Graduates are expected to contribute to the field and lead its scientific advancement.

In order to achieve the levels of knowledge and skills in BMHI as recommended in Section 3, and in order to achieve the desired broad depth and breadth of the educational components, the length of study should be at least one year full time for a master degree, corresponding to at least 60 ECTS credits. Two years of study, corresponding to 120 ECTS credits, should be preferred. Ph.D. studies or Ph.D. work should usually last three to four 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 6.

It is expected that master students have successfully finished either a) a bachelor program in BMHI, b) a bachelor or master program in medicine, biology, public health, health administration or another health science, or c) in computer science/information science. For cases b and c additional complementary courses (for b in informatics/computer science and for c in health and biosciences, health systems) should be offered.

For programs leading to a doctoral degree, independent comprehensive research should be carried out by the student in addition to the instructional requirements already mentioned. Knowledge and skills should also have additional depth and breadth and students may choose to gain additional insight into elective fields that are at the core of their research.

6. Recommendations for Continuing Education

6.1 Continuing Education in Biomedical and Health Informatics

A certificate of 'Health Informatics', 'Medical Informatics' and/or 'Biomedical Informatics' should be offered in recognition of having acquired sufficient competence in BMHI from an academic, educational and/or practical perspective relative to specific tasks or roles within the health industry. 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 'Health Informatics', 'Medical Informatics' and/or 'Biomedical Informatics'. This additional qualification can be issued by any national medical or health professional association or university. The same holds true for nurses, for whom various forms of continuing education are very well-established in many countries.

In order to offer courses in BMHI for continuing education, it is recommended that specific entities are established to provide such courses. These entities might be inside universities or, as academies of health/medical informatics established by any national association in BMHI or provided by an independent private entity, provided that in all cases the people responsible for course curriculum, content and educational delivery are suitably qualified (see also [89]).

6.2 Life-long Learning

Working in the field of BMHI and even using information and communication technology requires life-long learning. Therefore opportunities for continuing education should be offered for BMHI

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 Biomedical and Health Informatics Education

BMHI affects all health care professionals. To commence education in this field, IMIA recommends that education in BMHI for all types of health care professionals, including the different types of specialization and levels of education, is considered. The first step is to consider the level of practice of the individual. As noted in ▶Table 7, work in informatics depends upon whether someone has a technical/informatics or clinical background. Within informatics, one may practice more at the applied level in operational settings or may be an academic who teaches and/or performs research. For countries without formal informatics educational programs, additional steps are necessary. In this instance, teachers have to be educated ('teach the teachers') first, or, e.g., retiring BMHI faculty in developed countries could also perform this service. Next, courseware has to be prepared (or adapted) and institutes for health informatics or medical informatics must be established within universities, usually inside medical or health sciences faculties.

Table 7 Categories of informatics practice, adapted from [53]

Level of Practice	Type of Work	Example Job Titles
Academic	Individual who does research and/or teaching in an academic center	Professor Scientist or Researcher
Applied	Individual who works in an operational informatics setting for a majority of his or her working time	Chief Information Officer Chief Medical or Nursing Information Officer Project Manager Developer Trainer
Clinical	Clinicians and others who apply informatics in their work	Physician Nurse Health administrator

7.2 Modes of Education

The next consideration for informatics educational programs is (are) the mode(s) of education to be chosen, considering the specific profile and possibilities of the respective universities. Besides lectures it is of importance that practical experience within health care institutions (e.g., in hospitals) is offered. Besides 'traditional' lectures and exercises within universities, different models of flexible, distance and supported open learning should be actively pursued. Problem-oriented learning might particularly support the relevance of BMHI as it requires integration of information and a cross-disciplinary understanding [86].

7.3 Qualified Teachers

Courses and programs in BMHI must be of high quality. Teachers of courses in BMHI must have adequate and specific qualifications in this field. It must be possible to obtain such qualifications for lecturing in BMHI from universities or other institutions of higher education.

7.4 Recognized Qualifications

Education of students in BMHI, 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 BMHI graduates must be recognized and we are recommending that health care organizations realize the need of positions as specialists in BMHI.

8. IMIA Support for Programs and Courses in Biomedical and Health Informatics

8.1 IMIA Certification

To support education of high quality in the field of BMHI, 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. IMIA is also currently establishing services for the accreditation of such educational programs.

BMHI courses inside programs and specialized 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 organizational integration and resources, has been assessed by IMIA-appointed experts. Single courses cannot 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 four members of IMIA's Working Group on Health and Medical Informatics Education or other persons, experienced in BMHI education, and will be approved by the IMIA President and the Chairperson of IMIA's Working Group on education.

After approval, a written certificate, signed by the IMIA President, the Chairperson of IMIA's Working Group on Health and Medical Informatics Education, will be given to the respective organization.

Requests should be submitted to the Executive Director of IMIA.

8.2 International Programs, International Exchange of Students and Teachers

IMIA encourages and recommends international activities in educating BMHI 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 European Credit Transfer and Accumulation System (ECTS [85]) should be used in the respective national programs to support these international perspectives.

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

IMIA's Working Group on Health and Medical Informatics Education is a group devoted to BMHI education. Its activities include to disseminate and exchange information on BMHI programs and courses and to support BMHI courses and exchange of students and teachers. The Working Group intends to advance the knowledge of 1) how informatics is taught in the education of health care professionals around the world, 2) how in particular BMHI is taught to students of computer science/informatics, and 3) how it is taught within dedicated curricula in BMHI. Working Group members contribute to various Web-based catalogues of BMHI programs, including those mentioned in Section 1.2.

In addition, IMIA's Working Group on Health and Medical Informatics Education operates a mailing list to facilitate communication between all persons interested in BMHI education worldwide. For subscription, instructions on the Working Group's website should be followed. IMIA encourages the development and sharing of courseware of high quality for courses in BMHI. This will help to further establish courses in this field. It also encourages the use of its IMIA Working Group on education's website and list server for the dissemination of information about such courseware.

10. Concluding Remarks

These recommendations provide a 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. A new professional activity needs to be officially recognized in the form of a well-established title linked to a specific salary scale. Such recognition appears to be a natural complement to a university degree. For example, in Belgium, a Ministerial Decree established in 2001 criteria for the certification of physician specialists in health data management. This official recognition by one of the member countries of the European Union opens the way to equivalence of this particular competence in all other member countries for the content of the teaching programs as well as for employment conditions [87]. Furthermore, the UK has done much work on professionalism and competencies which is published mostly as UK Council for Health Informatics Professions [88, 89]. Such national efforts are expected to influence future reviews of these guidelines.

IMIA, understanding its role as a leader in the scientific progress of the expanding field of BMHI, is also developing as part of its strategic plan [77] a knowledge base [90], which can be of real significance for educators in the field as well as to healthcare professionals.

IMIA's Working Group on Health and Medical Informatics Education may in the near future develop teaching credentialing criteria to serve as a guide for teachers wishing to participate in BMHI education.

Acknowledgments

These revised recommendations are the result of the task force team established by the IMIA Working Group on Health and Medical Informatics Education in 2006 [81]. The draft document is being communicated and discussed by the working group members during its Working Conference 2008 at Buenos Aires. The recommendations have finally been approved by the IMIA General Assembly on November 25, 2009, in Hiroshima, Japan.

Significant contributions to the recommendations came from Elske Ammenwerth (Austria), George Demiris (USA), Arie Hasman (The Netherlands), Reinhold Haux (Germany), William Hersh (USA), Evelyn Hovenga (Australia), K. C. Lun (Singapore), John Mantas (Greece), Heimar Marin (Brazil), Fernando Martin-Sanchez (Spain), Graham Wright (UK). The team would like to thank Professor Dr. Reinhold Haux, President of IMIA, for his continued support in developing the revised version of the Educational Recommendations. We also thank Dr. Peter Murray, Executive Director of IMIA, for monitoring and supporting the team's efforts.

We would like to thank all contributors of the original recommendations for their pioneering work as mentioned in [1].

The recommendations have been edited by John Mantas (co-chairman of the IMIA Working Group on Health and Medical Informatics Education) chairing the task force team.

References

1. Recommendations of the International Medical Informatics Association (IMIA) on education in health and medical informatics. Methods Inf Med 2000; 39: 267–277. http://www.imia.org/pubdocs/rec_english.pdf. Last access: August 29, 2009.
2. IMIA Yearbooks of Medical Informatics. http://www.imiapubs.org and http://www.schattauer.de/index.php?id=imia. Last access: August 29, 2009.
3. Haux R, Swinkels W, Ball MJ, Knaup P, Lun KC, editors. Special Issue on health and medical informatics education: transformation of healthcare through innovative use of information technology. Proceedings of the 1997 IMIA Working Group on Education Meeting. Int J Med Inform 1998; 50: 1–300.
4. Hersh WR, Gorman P, editors. Teach Globally, Learn Locally. Proceedings of the 2003 IMIA Working Group on Education Meeting. Int J Med Inform 2004; 73: 95–213.
5. Mantas J, editor. Health and medical informatics education. Proceedings of the 2005 IMIA Working Group on Education Meeting. Methods Inf Med 2007; 46: 50–92.
6. Hersh WR, Otero P, Bernaldo de Quirós FG, editors. Building Worldwide Capacity for the Health In-

formatics Workforce. Proceedings of the 2008 IMIA Working Group on Education Meeting. Methods Inf Med (to appear).
7. Hasman A, Albert A, Wainwright P, Klar R, Sosa M, editors. Education and training in health informatics in Europe. Amsterdam: IOS Press; 1995.
8. Mantas J. Health and nursing informatics education. Stud Health Technol Inform 1998; 56: 146–152.
9. Mantas J. Future trends in health informatics – theoretical and practical. Stud Health Technol Inform 2004; 109: 114–127.
10. Garg AX, Adhikari NK, McDonald H, Rosas-Arellano MP, Devereaux PJ, Beyene J, Sam J, Haynes RB. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review. JAMA 2005; 293: 1223–1238.
11. Chaudhry B, Wang J, Wu S, Maglione M, Mojica W, Roth E, Morton SC, Shekelle PG. Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. Ann Intern Med 2006; 144: 742–752.
12. Hersh WR, Hickam DH, Severance SM, Dana TL, Pyle Krages K, Helfand M. Diagnosis, access and outcomes: Update of a systematic review of telemedicine services. J Telemed Telecare 2006; 12 Suppl 2: S3–31.
13. Lorenzi NM. E-health strategies worldwide. In: Haux R, Kulikowski C, editors. IMIA Yearbook of Medical Informatics 2005. Stuttgart: Schattauer; 2005. pp 157–164.
14. Hasman A, Haux R. Modeling in biomedical informatics – an exploratory analysis (part 1). Methods Inf Med 2006; 45: 638–642.
15. Hasman A, Haux R. Modeling in biomedical informatics: an exploratory analysis (part 2). Int J Med Inform 2007; 76: 96–102.
16. Kuhn KA, Knoll A, Mewes HW, Schwaiger M, Bode A, et al. Informatics and medicine – from molecules to populations. Methods Inf Med 2008; 47: 283–295
17. Payne PR, Johnson SB, Starren JB, Tilson HH, Dowdy D. Breaking the translational barriers: the value of integrating biomedical informatics and translational research. J Investig Med 2005; 53: 192–200.
18. Zerhouni EA. Translational research: moving discovery to practice. Clin Pharmacol Ther 2007; 81: 126–128.
19. Baxevanis AD, Ouellette BFF. Bioinformatics: a practical guide to the analysis of genes and proteins. Third Edition. Hoboken, NJ: Wiley-Interscience; 2005.
20. Hovenga EJS, Mantas J. Global Health Informatics Education. Amsterdam: IOS Press; 2004.
21. Jaspers MW, Gardner RM, Gatewood LC, Haux R, Schmidt D, Wetter T. The International Partnership for Health Informatics Education: lessons learned from six years of experience. Methods Inf Med 2005; 44: 25–31.
22. Otero P, Hersh W, et al. Translation, implementation and evaluation of a medical informatics distance learning course for Latin America. MEDINFO 2007 – Proceedings of the Twelfth World Congress on Health (Medical) Informatics. Brisbane, Australia: IOS Press; 2007. CD-ROM P421.
23. Ball MJ, Silva JS, Bierstock S, Douglas JV, Norcio AF, Chakraborty J, Srini J. Failure to provide clinicians useful IT systems: opportunities to leapfrog current technologies. Methods Inf Med 2008; 47: 4–7.
24. Hersh W. Health care information technology: progress and barriers. JAMA 2004; 292: 2273–2274.
25. Poon EG, Blumenthal D, Jaggi T, Honour MM, Bates DW, Kaushal R. Overcoming barriers to adopting and implementing computerized physician order entry systems in U.S. hospitals. Health Aff (Millwood) 2004; 23: 184–190.
26. Hersh W. Who are the informaticians? What we know and should know. J Am Med Inform Assoc 2006; 13: 166–170.
27. Hersh W. Health and biomedical informatics: opportunities and challenges for a twenty-first century profession and its education. Yearb Med Inform 2008. pp 157–164.
28. Hersh W. A stimulus to define informatics and health information technology. BMC Med Inform Decis Mak 2009; 9: 24.
29. Schuemie MJ, Talmon JL, Moorman PW, Kors JA. Mapping the domain of medical informatics. Methods Inf Med 2009; 48: 76–83.
30. Roberts J. Developing health informatics as a recognised professional domain supporting clinical and health management activity. World Hosp Health Serv 2006; 42: 38–40.
31. Joyub R. The professionalisation of health informatics in the United Kingdom. UK Health Informatics Today 2004; 42 (Spring): 1–4.
32. Klar R. Official catalogue of subject matters in medical informatics for German medical students. In: [7], pp 145–152.
33. Scope and Standards of Nursing Informatics Practice. Washington, DC: American Nurses Association; 2008.
34. Detmer DE, Lumpkin JR, Williamson JJ. Defining the medical subspecialty of clinical informatics. J Am Med Inform Assoc 2009; 16: 167–168.
35. Safran C, Shabot MM, Munger BS, Holmes JH, Steen EB, Lumpkin JR, et al. Program requirements for fellowship education in the subspecialty of clinical informatics. J Am Med Inform Assoc 2009; 16: 158–166. Erratum in: J Am Med Inform Assoc 2009; 16: 605.
36. Leven FJ, Curriculum for medical informatics at the University of Heidelberg/School of Technology Heilbronn. Methods Inf Med 1994; 33: 262–267.
37. Knaup P, Haag M, Leven FJ, Dickhaus H. Challenges in the evolution of the medical informatics program at Heidelberg/Heilbronn (Germany). Methods Inf Med 2009; 48: 66–75.
38. Moehr JR. English Translation of the Minutes of the Invitational Workshop Goals, Contents and Methods for Education in Medical Informatics. Haux R, Kulikowski C, editors. IMIA Yearbook of Medical Informatics 2004. Stuttgart: Schattauer; 2004. pp 210–219.
39. Moehr JR. The Quest for Identity of Health Informatics and for Guidance to Education in it – The German Reisensburg Conference of 1973 Revisited. Haux R, Kulikowski C, editors. IMIA Yearbook of Medical Informatics 2004. Stuttgart: Schattauer; 2004. pp 201–210.
40. Duncan KA Austing RH, Katz S, Pengov RE, Pogue RE, Wasserman AIl. Health Computing: Curriculum for an emerging profession – report of the ACM curriculum committee on health computing education. Proceedings of the 1978 ACM Annual Conference/Annual Meeting. Washington, DC: ACM Press; 1978. pp 277–285. http://portal.acm.org/ft_gateway.cfm?id=804112&type=pdf&coll=GUIDE&dl=GUIDE&CFID=47975758&CFTOKEN=19987037. Last access: August 29, 2009.
41. Physicians for the twenty-first century (The GPEP Report). Washington: Association of the American Medical Colleges; 1984.
42. Haux R, Dudeck J, Gaus W, Leven FJ, Kunath H, Michaelis J et al. Recommendations of the German Association for Medical Informatics, Biometry and Epidemiology for education and training in medical informatics. Methods Inf Med 1992; 31: 60–70.
43. Hasman A, Albert A. Education and training in health informatics: guidelines for European curricula. Int J Med Inform 1997; 45: 91–110.
44. Council of Europe Committee of Ministers (1995): Recommendations No. R (90) 21 of the Committee of Ministers to Member States on training strategies for health information systems. In: [7], pp 3–6.
45. Mantas J. Developing curriculum in nursing informatics in Europe. Int J Med Inform 1998; 50: 123–132.
46. Mantas J. NIGHTINGALE – a new perspective in nursing informatics education in Europe. Stud Health Technol Inform 1998; 51: 102–113.
47. Enabling People Programme & English National Board for Nursing, Midwifery and Health Visiting. Information for caring: integrating informatics into learning programmes for nurses, midwives and health visitors. Birmingham: Institute of Health and Care Development; 1997.
48. National Advisory Council on Nurse Education and Practice (NACNEP): A national informatics agenda for nursing education and practice. Washington DC: US Department of Health and Human Services, Division of Nursing: 1997. http://www.eric.ed.gov:80/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/16/d3/da.pdf. Last access: August 29, 2009.
49. Medical School Objectives Project. Medical Informatics Objectives. Washington, DC: Association of American Medical Colleges; 1999. http://www.aamc.org/meded/msop/start.htm. Last access: August 29, 2009.
50. Schleyer T. Competencies for Dental Informatics V 1.0. Pittsburgh, PA: University of Pittsburgh Center for Dental Informatics: 1999. http://www.dental.pitt.edu/informatics/competencies.php. Last access: August 29, 2009.
51. Health Informatics Competency Profiles for the NHS. London: National Health Service Information Authority; 2001.
52. Staggers N, Gassert CA, Curran C. A Delphi study to determine informatics competencies at four levels of practice. Nursing Res 2002; 51: 383–390.
53. Covvey HD, Zitner D, Bernstein R. Pointing the way: competencies and curricula in health informatics. Waterloo, Ontario: University of Waterloo; 2001. http://www.cs.uwaterloo.ca/health_info/health_docs/CurriculaMASTERDocument Version1Final.zip. Last access: August 29, 2009.
54. Mantas J Hasman A, editors. Textbook in health informatics – a nursing perspective. Amsterdam: IOS Press; 2001.
55. O'Carroll PW; Public Health Informatics Competencies Working Group. Informatics competencies for public health professionals., Seattle, Wa: Northwest Center for Public Health Practice; 2002.

http://www.nwcphp.org/docs/phi/comps/phi_print.pdf. Last access: August 29, 2009.
56. Curran CR. Informatics competencies for nurse practitioners. AACN Clin Issues 2003; 14: 320–330.
57. Friedman CP, Altman RB, Kohane IS, McCormick KA, Miller PL, Ozbolt JG, et al.; American College of Medical Informatics. Training the next generation of informaticians: the impact of "BISTI" and bioinformatics – a report from the American College of Medical Informatics. J Am Med Inform Assoc 2004; 11: 167–172.
58. HIM Baccalaureate Degree Entry-Level Competencies. Chicago, IL: American Health Information Management Association; 2004. http://library.ahima.org/xpedio/groups/public/documents/ahima/bok1_025415.pdf. Last access: October 2, 2009.
59. Garde S, Hovenga E. Australian health informatics educational framework. Brunswick East, Australia: Australian College of Health Informatics; 2006. http://www.achi.org.au/sites/default/files/Health_Informatics_Educational_Framework_20060326.pdf. Last access: October 2, 2009.
60. Ivanitskaya L, O'Boyle I, Casey AM. Health information literacy and competencies of information age students: results from the interactive online Research Readiness Self-Assessment (RRSA). J Med Internet Res 2006; 8: e6.
61. VISION 2016: A Blueprint for quality education in health information management. Chicago, Il: American Health Information Management Association (AHIMA); 2007. http://www.ahima.org/emerging_issues/Vision2016BlueprintforEduc.pdf. Last access: August 29, 2009.
62. Health informatics professional core competencies. Toronto, Ontario: Canadian Health Informatics Association (COACH); 2007. https://secure.coachorg.com/opendoc.asp?docID=1062 Last access: August 29, 2009.
63. Health information science knowledge and skills. Chicago, IL: Medical Library Association; 2007. http://www.mlanet.org/education/platform/skills.html. Last access: August 29, 2009.
64. Pigott K, de Lusignan S, Rapley A, Robinson J, Pritchard-Copley A. An informatics benchmarking statement. Methods Inf Med 2007; 46: 394–398.
65. Huang Q. Competencies for graduate curricula in health, medical and biomedical informatics: a framework. Health Informatics Journal 2007; 13: 89–103.
66. Joint Workforce Task Force. Health information management and informatics core competencies for individuals working with electronic health records. Chicago, IL, and Bethesda, MD: American Health Information Management Association and American Medical Informatics Association: 2008. http://www.ahima.org/infocenter/whitepapers/workforce_2008.pdf. Last access: August 29, 2009.
67. Gassert C. Technology and informatics competencies. Nursing Clinics of North America 2008: 43: 507–521.
68. Karras BT, Davies J, Koo D; Working Group on Competencies for Public Health Informatics Competencies. Competencies for public health informaticians, Public Health Informatics Competencies. 2007, Seattle, WA: Center for Public Health Informatics; 2008. http://cphi.washington.edu/competencies. Last access: August 29, 2009.
69. Gardner RM, Overhage JM, Steen EB, Munger BS, Holmes JH, Williamson JJ, et al.; AMIA Board of Directors. Core content for the subspecialty of clinical informatics. J Am Med Inform Assoc 2009; 16: 153–157.
70. Hersh W. AMIA-OHSU 10×10 Program – Logistics, Accessing Demo, Detailed Curriculum, Learning Objectives, and Additional Information. Portland, OR, Oregon Health & Science University, 2009. http://www.billhersh.info/10x10.html. Last access: November 25, 2009.
71. Gugerty B, Delaney C. TIGER Informatics Competencies Collaborative (TICC) Final Report, Technology Informatics Guiding Educational Reform (TIGER) Initiative, 2009. http://tigercompetencies.pbworks.com/f/TICC_Final.pdf. Last access: November 25, 2009.
72. HIT Workforce Competencies by Role. Washington, DC, Office of the National Coordinator for Health IT, 2009. http://healthit.hhs.gov/portal/server.pt?open=18&objID=888534&parentname=CommunityPage&parentid=15&mode=2&in_hi_userid=11113&cached=true. Last access: November 25, 2009.
73. http://www.hiww.org/. Last access: August 29, 2009.
74. http://www.amia.org/informatics/acad%2526training/index.asp. Last access: August 29, 2009.
75. http://www.amia.org/informatics/acad%2526training/international.asp. Last access: August 29, 2009.
76. http://www.imia.org. Last access: August 29, 2009.
77. The IMIA strategic plan: towards IMIA 2015. http://www.imia.org/images/IMIA_Strategic_Plan.pdf. Last access: August 29, 2009.
78. Lorenzi NM. Towards IMIA 2015 – the IMIA strategic plan. Yearb Med Inform 2007. pp 1–5.
79. Murray P, et al. Let a thousand flowers bloom: transition towards implementation of the IMIA strategic plan. Methods Inf Med 2007; 46: 625–628.
80. Murray PJ. The IMIA strategic plan – towards IMIA 2015. Yearb Med Inform 2008. pp 7–15.
81. Minutes of the IMIA General Assembly, August 2007, Brisbane, Australia. Report of the Vice-President for Working Groups.
82. Knaup P, Dickhaus H. Perspectives of medical informatics: advancing health care requires interdisciplinarity and interoperability. Methods Inf Med 2009; 48: 1–3.
83. Kulikowski CA. The micro-macro spectrum of medical informatics challenges: from molecular medicine to transforming health care in a globalizing society. Methods Inf Med 2002; 41: 20–24.
84. van Bemmel JH. Medical informatics is interdisciplinary avant la lettre. Methods Inf Med 2008; 47: 318–321.
85. European Credit Transfer and Accumulation System: http://ec.europa.eu/education/lifelong-learning-policy/doc48_en.htm. Last access: August 29, 2009
86. Hasman A, Boshuizen HP. Medical informatics and problem-based learning. Methods Inf Med 2001; 40: 78–82.
87. Moniteur Belge du 13 12 2001: Arrêté Ministériel du 15 octobre 2001 fixant les critères d'agrément des médecins spécialistes en gestion de données de santé N 2001–3555; C-2001/22760; pp 43044–43046.
88. Roberts J. Developing the Health Informatics Professional. In: Hayes, G, Barnett D, editors. UK Health Computing: Recollections and reflections. BCS, May 2008.
89. UK Council for Health Informatics Professions, http://www.ukchip.org. Last access: November 25, 2009.
90. Wright G, et al. IMIA knowledge base. Report submitted to IMIA, June 2008.

International Medical Informatics Association (IMIA) Working Group on Health and Medical Informatics Education
http://www.imia.org

Chair:
Professor William Hersh
Chairman, Department of Medical Informatics and Clinical Epidemiology
Oregon Health and Science University
Portland, OR
USA
E-mail: hersh@ohsu.edu

Co-Chair:
Professor John Mantas
Director, Health Informatics Laboratory
University of Athens
Athens
Greece
E-mail: jmantas@cc.uoa.gr