The new set-up of the medical informatics Master of Science program at the University of Amsterdam

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**ABSTRACT**

Objectives: To describe the new set-up of our Master of Science program in medical informatics that started in September 2006 at the University of Amsterdam-Academic Medical Center, The Netherlands.

Methods: To harmonize with the Bologna declaration, we transformed our former medical informatics program from a 4-year course into a 3-year bachelor and a 2-year (English) Master of Science Medical Informatics program. We describe the objectives, organizational structure and contents of this new medical informatics master program.

Results: The new master program now is aimed at (international) baccalaureates in medical informatics, computer science, medicine and other health-related studies and professionals from these disciplines. The master course comprises four study semesters of 30 EC each, equal to 120 EC in total. Central to the program is the context of hospital organization, encompassing medical practice and patient care, information and communication technologies and (logistic) structuring of health care and health care processes. The program comprises core education (60 EC), discipline-related in-depth-study (12 EC) and an academic work placement (48 EC). Students from a range of other disciplines will be admitted to the master program after successful completion of an individualized conversion program (a maximum of 30 EC).

Conclusions: With the new set-up of our master course and by offering individualized conversion programs, we hope to both accommodate the learning needs of our own medical informatics baccalaureates and to attract other (international) students and professionals to our new program. Our ultimate aim is to bring forth medical informatics specialists who can make significant contributions to the field.

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1. Introduction

It is widely recognized that the adequate management of medical information is crucial to the future of health care [1] and the potentials of ICT in this context are now generally acknowledged [2–5]. In fact, the Institute of Medicine regards the implementation of ICT as one of the principal ways to improve the quality of health care on a worldwide scale [6].

This likewise is the principal aim of medical informatics: To contribute to the enhancement of health care’s efficiency and quality by providing (automated) solutions for the capturing, storage, processing, retrieval and dissemination of medical and health care data, information and knowledge and to reveal underlying general principles in this respect. Medical informatics extends beyond the narrow focus of the design, application and implementation of medical and health care
opportunities for (international) students and professionals. In redesigning our medical informatics program, we felt that we should broaden the access and training for creating one common Europe-wide educational area. Due to the Bologna declaration, the University of Amsterdam-Academic Medical Center (UvA-AMC) a 4-year medical informatics university program was likewise introduced as an integrated bachelor and master course next to the medical science university program. During these 15 years, about 170 students graduated from this program [16]. Since 1990, our medical informatics program underwent some major modifications [17], of which we describe the last revision in this contribution.

In 1990, the Bologna declaration was signed by the European Ministers of Education of 29 countries binding them to standardize the structures of higher education systems by 2010 in a system of academic grades that are easy to understand and to compare [18]. The main goal of this standardization process is to enhance the employability and mobility of European students, teachers and researchers and to increase the international competitiveness of European higher education. So this whole process is meant to let the higher education systems in Europe converge towards a more transparent system whereby the different national systems use a common framework for bachelor, master and doctorate degree programs.

To accomplish these aims, besides this common framework, the European Ministers adopted the European Credit system (EC system), developed under the 1988–1995 Erasmus program [19]. This EC system enhances flexibility for student-exchange programs between institutes for higher education, curriculum transparency, and is helpful in reflecting about curriculum structures, student workload and learning outcomes [20]. So amongst the advantages of the EC system is a uniform description of the available study programs, bringing about a greater transparency and rendering it easier to compare what is on offer at European institutions. Besides, student exchanges take place along the lines of clearly set-out procedures, thus facilitating the recognition of studies abroad. Furthermore exchange students are given the guarantee that other European institutions and future European employers get a solid impression of the courses students have taken at a particular institution for higher education. As such, the EC system is to be considered a crucial and excellent instrument for creating one common Europe-wide educational area.

Due to the Bologna declaration, the University of Amsterdam had to restructure all her university programs, among which the medical informatics program, after which formal accreditation proposals for these university programs had to be submitted to the Accreditation organization of The Netherlands and Flanders (NVAO). To harmonize with the Bologna agreement, we transformed our former 4 years medical informatics curriculum into an individual bachelor and individual master program. In redesigning our medical informatics program, we felt that we should broaden the access and training opportunities for (international) students and professionals with different backgrounds (e.g. computer science, medicine, biomedical sciences and health care-related disciplines) willing to become expert in the field of medical informatics. We therefore decided to set up a conversion program to equip applicants with these backgrounds with the prerequisite medical informatics knowledge needed for entering our master program medical informatics. Moreover, in order to open our master program for international candidates and to further enhance the employability of all our master graduates on an international level, our master program is offered in English. In this contribution, we elaborate shortly on the history and international perspective of our university program in medical informatics. We more specifically elaborate on the mission, objectives, organizational structure and contents of this new master course in medical informatics.

2. Historical overview of the Amsterdam medical informatics program

Fig. 1 provides a historical overview of our medical informatics program. In 1984, we started a specialized post master medical informatics course of 1 year aimed at graduate students in medical science with an interest for information and communication technologies’ developments in their field. This course, a typical health care-based approach to medical informatics education, gradually developed into a 3-year specialized master course on medical informatics for students with 1 year of medical training. The large enrollment in this course led to the introduction of a full fledged 4-year university program in medical information sciences in 1990. In 1994, this program underwent its first revision. In this version of the curriculum, we strived for a more interdisciplinary approach of medical informatics education [16]. In 1999, the curriculum underwent a second major revision providing more core courses in informatics and computer science. As explained, due to the Bologna declaration, we have restructured and redesigned this 4-year course into a 3-year bachelor, that started in September 2003 and a 2-year master course, which started in September 2006.

3. International perspective

Since 1998, the University of Amsterdam participates in the International Partnership for Health Informatics Education (IΦE [22,23]). IΦE aims to promote and improve medical and health informatics education through international collaboration of baccalaureate and graduate programs in medical and health informatics. This partnership now consists of six universities: Amsterdam [16], Heidelberg/Heilbronn [7], Minnesota [8], Utah [9], UMIT [10] and Washington [11]. IΦE realizes its aim by organizing international master classes [24], student and faculty exchanges and workshops on international conferences [23]. On the European level, we developed an international module on ‘strategic information management in hospitals’ [25,26] that is now fully integrated in the university programs of the European partner universities. From 2005 onwards, the University of Braunschweig [27] has become an important partner in organizing this European course.
4. The new medical informatics master program

In 2000, 1 year after the signing of the Bologna declaration, the International Medical Informatics Association (IMIA) endorsed international recommendations on health/medical informatics education [21]. In restructuring our 4-year medical informatics program into a 3-year bachelor and a 2-year master course, we followed the IMIA recommendations for dedicated programs medical informatics at the bachelor and master level [21]. IMIA recommends a (minimum) study load of 60 EC for medical informatics programs at the master level. For several reasons, we decided to offer a master program of 120 EC. First, in contrast to a bachelor level program focusing on a practice-oriented application of knowledge, for programs leading to a master degree, the objective is to provide an education of a scientific character, focussing on methodologies. Particularly at the master level, the aim is to bring forth graduates who can contribute to the scientific development of the medical and health informatics domain [28]. We therefore felt that in our renewed master program health informatics research and evaluation methodologies and advanced data analysis methods should be even more at the focus than in the older version of the program. Besides, the object of the master program is not only to educate students to a level where they have the skills necessary for the application of methods and techniques in scientific research but also to a level where they have an understanding of the way research results are used to develop advanced ideas. Particularly at the master level, the aim is to bring forth graduates who can contribute to the scientific development of the medical and health informatics domain [28].

Finally, we anticipated applicants for our master program to come from a wide variety of disciplines with insufficient knowledge in particular areas of medical informatics. The broadness of the medical informatics field, reflected in the many subjects to be covered in master level curricula according to the IMIA recommendations, required a master program accommodating the learning needs of all these candidates. We felt that all types of students would benefit from advancing their medical informatics knowledge in a broad sense as this would enhance their employability. Besides, a broad education would help them in deciding on the final specialization they want to achieve.

5. Objectives of the master program and exit qualifications

With our new set-up of the master program we aim to educate students to a level where they are able to contribute substantially to the development of scientific knowledge in the field of medical informatics. This knowledge should contribute to the diagnosis, treatment, prognosis and prevention of diseases and management of medical practice within the health care sector. Equally important, students learn to obtain, record and interpret research results in accordance with scientific norms.

To attain these aims, the students in the master program must satisfy predefined exit conditions, specific to the profile of a M.Sc. Medical Informatics graduate (see Table 1).
The Master of Science Medical Informatics graduate:

- Is capable of critical reflection concerning his own scientific activities.
- Is able to judge, from the viewpoint of the structuring of health care processes, how an ICT infrastructure can be optimally integrated into this process with the goal of improving the quality of care and the efficiency of health care processes.
- Has an overview of developments in health care and ICT and the implications thereof and can contribute to the prevailing views and decision-making regarding ICT issues in health care.
- Possesses knowledge of and insight into the reasoning and decision-making processes in medical practice and care provision and the possible consequences hereof for the structuring of management processes and information flows.
- Possesses knowledge of and insight into the most significant information processes connected with medical practice and care provision (prevention, diagnostics, prognosis, therapy).
- Possesses knowledge of and insight into the methods and thought processes in medical scientific research.
- Possesses knowledge of and insight into logistic aspects of health care processes, foundations for the restructuring of health care processes and the added value of ICT methods in the processes involved.
- Is able to approach medical informatics issues through architectural reasoning, whereby a relationship is established between the structuring of management processes, the information flows and the demands placed on health care information systems.
- Is able to independently acquire new scientific knowledge and insight in disciplines related to medical informatics, such as information studies, computer sciences, medicine, health matters, epidemiology and (bio)statistics and can use this knowledge to address issues in medical informatics.
- Has an overview of developments in medical informatics topics to which students are introduced during the master program.
- Possesses knowledge of and insight into logistic aspects of health care processes, foundations for the restructuring of health care processes and the added value of ICT methods in the processes involved.
- Is able to identify, describe and analyze, using information-science terms, information-science-related issues in medical practice and is able to formulate, select and implement appropriate solution strategies, thereby bridging theoretical insight and practical application.
- Can, through his knowledge of software engineering and advanced informatics methods and techniques, contribute to the design, development, implementation and impact evaluation of medical information and decision-support systems.
- Is familiar with the most significant international developments and relevant findings in the areas of medical informatics and computer science and is able to apply this insight to the optimization of information processing and decision-making as regards medical practice and health care processes.
- Is familiarization with various aspects of scientific research and an understanding of the way research results are used to develop advanced ideas or practical applications.
- Each semester ends with an internship, a multidisciplinary work placement. The idea is that links be formed during the internships between research and themes from modules by connecting these with existing lines of research in the AMC.

The aim of the master program is to allow the students to gain the skills necessary for the application of methods and techniques in scientific research and an understanding of the way research results are used to develop advanced ideas or practical applications. Each semester ends with an internship, a multidisciplinary work placement. The idea is that links be formed during the internships between research and themes from modules by connecting these with existing lines of research in the AMC. The aim of the first internship is integration of the knowledge and insights gained thus far into working practice in an AMC department that is directly or indirectly involved with patient care. The second internship is more directed towards organizational aspects of the AMC as health care organization.

In the second year, discipline-oriented elective courses are offered. These courses offer students the opportunity to concentrate on themes relevant to their chosen research project. The master program concludes with an academic work placement. The general aim of this academic work placement is familiarization with various aspects of scientific research by means of a student's own research project, typically being a component of a larger ongoing project. Departments of the AMC-UvA or other institutes and companies associated with medical or health care practice, both in The Netherlands and abroad provide traineeship positions, among which our IPHIE partner universities. The research project ends with a thesis by which students have to demonstrate...
their professionalism in scrutinizing and synthesizing their research results in a theoretically and methodologically sound way.

### 7. The contents of the master program

The study load of the master program is 120 EC, 1 EC equalizing 27 h of lecturing, exercises, practical training and independent hours of study. So the duration of the program is 2 years (full-time) in total. Each year is divided into two 20 weeks semesters according to an 8-8-4 weeks’ model.

Fig. 2 gives an overview of the modules, each with their respective study load.

The first year starts with a module **Current issues in medical informatics I**. This module serves two purposes. For baccalaureates in medical informatics, this module has the intention to deepen their knowledge with respect to particular medical informatics subjects, such as bio-informatics, signal and image processing, decision-support techniques, health information systems and to acquaint students with the scientific approach to research. Yet, for master students who completed a conversion program, the first module is used to further remedy these students’ gaps in knowledge and practical training in particular medical informatics domains. The second module **Knowledge representation and reasoning in medicine** deals with types and anatomy of medical knowledge, terminology systems, theory and practice of decision-support tools, formalization of medical guidelines and probabilistic reasoning. The module **Advanced data analysis in medicine** elaborates the biometry knowledge of the students. This module covers maximum likelihood theory, empirical Bayesian methods, multilevel analysis and advanced regression analyses methods, such as non-linear, mixed-effects regression and regression trees. The module **Biomedical systems engineering** elaborates on the bachelor module in software engineering.

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<td><strong>Current issues in medical informatics I</strong></td>
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<td>- bio-informatics, signal and image processing, decision support techniques, health information systems</td>
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<td><strong>Knowledge representation &amp; reasoning in medicine</strong></td>
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<td>- medical knowledge types, terminology systems, (guideline-based) decision support tools, probabilistic medical reasoning</td>
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<td><strong>Advanced data analysis in medicine</strong></td>
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<td>- maximum likelihood theory, Bayes methods, multilevel analysis, modern regression analyses</td>
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<td><strong>Biomedical information systems engineering</strong></td>
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<td>- system design, software architectures, complex software systems, quality control</td>
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<td><strong>Biomedical research &amp; evaluation methodology</strong></td>
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<td>- formative/summative evaluation, quantitative/qualitative evaluation, objectivist/subjectivist evaluation, usability evaluation, health technology assessment</td>
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<td><strong>Organizational settings of healthcare</strong></td>
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<td>- organization structure and design, hospital organization, organizational dynamics, IT organization</td>
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<td><strong>Healthcare logistics &amp; information systems</strong></td>
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<td>- logistics, logistics for redesign care processes, IT support and tools</td>
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<td><strong>Information &amp; process modeling in healthcare</strong></td>
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<td>- information management, architectures, security</td>
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<td><strong>Internship II</strong></td>
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<td>- multidisciplinary work placement</td>
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<td><strong>Current issues in medical informatics II</strong></td>
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<td><strong>Total number of EC of the MSc program</strong> 120</td>
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Fig. 2 – The curriculum of the Master of Science Medical Informatics program.
The focus is on advanced concepts, methods and techniques of systems engineering to be used in various phases of system design, software architectures for complex software systems and on quality control.

The second semester of the first year starts with Biomedical research and evaluation methodology presenting a broad range of sophisticated research designs to evaluate the effects of medical or ICT interventions. A variety of methods from health technology assessment are covered and their similarities and differences discussed: formative/summative, subjectivist/objectivist, quantitative/qualitative and usability evaluation methods, outcome measures to evaluate effectiveness, efficiency and usability of interventions and health technology assessment and cost study designs. The module Organizational settings of health care focuses on health care organization structures, designs and strategies, organizational dynamics and IT organization. Logistical concepts for (re)designing health care processes and clinical paths, patient logistics, work flow management and IT support in this context are covered in the module Health care logistics and information systems. The last module of the first year Information and process modeling in health care's focus is on health information management, health care IT strategies and architectures and on IT-related security aspects in health care. After a theoretical introduction, students apply the concepts learned to particular situations presented in case exercises. The main aim of these exercises is to have students understand the complexity of information management in hospitals and acknowledge the need of an appropriate theoretical background. The last part of the module covers the European I4E inter-university course on 'strategic information management', during which students and faculty of each of the 3 participating programs meet. After an additional lecture series, students work in international groups to jointly finalize their exercises and present their outcomes during a 1-day seminar.

The second year of the M.Sc. course starts with two elective modules. Students choose two out of three modules to specialize themselves in a specific medical informatics domain, preferably the domain of the student's master research thesis. Students thus obtain in-depth knowledge in the research area of their interest. Current issues in medical informatics, health and medicine, computerized medical records, health care registries and public health informatics are at the focus of these electives.

8. The conversion program

As described earlier, in redesigning our master program, one of our aims was to create opportunities for students with backgrounds in informatics/computer science and health care-related disciplines to specialize in medical informatics. So besides our own baccalaureates that may prolong their training by following our master program, other types of baccalaureates and professionals may now apply for our new Medical Informatics master course. Candidates who join the master program may come from a range of other first-degree courses including medicine, health or biomedical sciences and computer science. These candidates may have profound knowledge and skills in their area of expertise but may lack sufficient knowledge and skills in specific areas of the medical informatics field. We therefore constructed a conversion program for these baccalaureates and professionals. The aim of this conversion program is to remedy their knowledge deficiencies and practical skills in medical informatics so as to qualify them for our 2 years master program. The goal of the conversion program is to impart the required knowledge of medicine, health and biosciences, health system organization and biometry to baccalaureates or professionals with an informatics-oriented background. The necessary mathematics-, computer science-/informatics- and biometry knowledge and skills are imparted to baccalaureates or professionals with a health care-oriented background. The conversion program takes at the most 30 EC to complete. The applicant's background knowledge and experience determine which courses of this conversion program the candidate has to take. To enable candidates to follow the main part of the conversion program by distance-learning, courseware has been developed for the Blackboard virtual learning environment. This learning environment has been introduced at the University of Amsterdam in 2001, and has proven to be a very efficient in enhancing communication between students and faculty and students mutually. But at present, Blackboard is mainly used as a tool for distributing the course materials and exercises of the conversion program to students and to enable students to contact faculty by e-mail when they need teacher support in comprehending certain materials. Other Blackboard facilities, such as discussion boards will be implemented in the near future. Successful completion of a dedicated conversion program gives access to our master program.

9. Status of the master program

The accreditation of this 120 EC M.Sc. program by the Accreditation Organization of The Netherlands and Flanders for university programs was achieved in December 2005, after 20 months of preparation. Five candidates successfully completed the conversion program and are now students within our master program, while four students presently are following an individualized conversion program. Since we yearly have approximately 25 students in the third year of our bachelor program, we expect about 25–40 students to enter our master program in the years to come. Dutch candidates for our M.Sc. program are (partly) funded by the Dutch Government for a maximum period of 60 months. Applicants from the European Union may apply for a student performance-related scholarship (maximum of 48 months) of the Dutch government.

The implementation of the master program requires an equivalent of six full-time faculty positions. Yet, approximately 30 faculty members with backgrounds in medical informatics, computer science, medicine, public health, epidemiology, biostatistics, health care management, contribute to the program on a part-time basis. The department of medical informatics, holding one professor, two associate professors and eight assistant professors, takes responsibility for a major part of the master course.
10. The Ph.D. program in medical informatics

After graduation, a selected group of students may start a paid Ph.D. project, which is mainly research-based. Ph.D. courses are offered by the AMC Graduate School. Ph.D. students have to spend about 25% of their time on teaching and learning. The basic module ‘the AMC world of science’ is to be taken by all Ph.D. students. The remainder of the program consists of 22 advanced courses. At enrolment, the other elements of a training plan that matches a Ph.D. student’s specific needs are defined. This plan stipulates the courses to be attended. The average length of a Ph.D. project is 4 years. At the end of the Ph.D., the student must have developed the ability to conduct, construct and present his research and acquire funding for new research projects. In stimulating master graduates to prolong their education by a Ph.D. trajectory, 4-year stipends for talented students are offered.

11. Discussion and conclusions

Our medical informatics program is still the only one offered at the university level in The Netherlands. We believe that we established a master course which is unique in both its contents and foreseen audience. The focus of the master course is on the broad range of research methodologies applied in medical informatics and on health care information (system) management. In building upon our experiences with medical informatics education, we enlarged the scope and prospects of our medical informatics course by overcoming (language) obstacles for (international) students who now have access to our master course that from 2006 onwards is offered in English. The target audience is no longer our own medical informatics baccalaureates but also baccalaureates with backgrounds in informatics, computer science and health care-related studies. Even professionals in computer science or health care may apply for our master program.

Strong links to medical informatics research projects exist within the course due to the involvement of the department of medical informatics that performs applied and theoretical research on a national and international level. Besides, our medical informatics course has from the outset been offered in a collaborative effort by the AMC—an academic hospital and the University of Amsterdam. This means that our medical informatics course is embedded in an environment offering great opportunities to link research projects with the practice of health care so that new insights can be shared among both faculty and students.

Societies become more and more competitive and dynamic, and more and more take part in international communities and economies. To meet the challenges of a global economy, graduates should learn skills in an increasingly international and multicultural society. International experiences also provide a different perspective on the learning process itself and the possibility to share good practice with foreign colleague students and teachers and to learn from each other. By combining our own expertise and efforts with our IDeE partner universities, we have achieved the participation of internationally acknowledged medical informatics experts in our master program, learning experiences of students across institutions and a continuous exchange of experiences with medical informatics education among our partner universities.

The challenge will continue to be bringing forth medical informatics specialists who can make significant contributions to the field.

References


