

# An Abridged History of Medical Informatics Education in Europe

Arie Hasman<sup>1</sup>, John Mantas<sup>2</sup>, Tatyana Zarubina<sup>3</sup>

Department of Medical Informatics, Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands<sup>1</sup>

Health Informatics Laboratory, University of Athens, Greece<sup>2</sup>

Department of Medical Cybernetics and Informatics, Pirogov Russian National Research Medical University, Moscow, Russia<sup>3</sup>

## Review

### ABSTRACT

This contribution presents the development of medical informatics education in Europe. It does not discuss all developments that took place. Rather it discerns several themes that indicate the progress in the field, starting from the initiation phase to the final quality control phase.

**Key words:** Medical informatics, education, EFMI, WG1.

## 1. INTRODUCTION

The history of medical informatics is relatively short. The field started in the fifties of the last century. EFMI was established in 1976 and educational programs in medical informatics in Europe were not introduced much earlier. We were asked to sketch the history of medical informatics education in Europe. Different names with sometimes (slightly) different meanings have been suggested for our field of medical informatics. We will use the terms medical informatics, biomedical informatics and health informatics in this contribution interchangeably as umbrella terms.

When we started writing, we realized that we were not fully aware of all educational developments that took place in other European countries other than our own. That is why we called our contribution an abridged history with apologies that we probably do not refer to all important developments. On the other hand, we also realized that writing such a history does not mean that all developments have to be traced back and be mentioned. It is more important to look for trends that can be inferred from the various developments and to provide examples of those trends. That is what we have done in the following where we distinguish five different themes.

The questions whether medical informatics is a discipline separate from informatics or even whether it is a scientific discipline and whether it is necessary to develop specialized curricula for this field have often been posed. Especially in the beginning much of the research carried out by medical informaticians focused on the development of systems, like for example hospital information systems, departmental systems, database systems, signal and image processing systems and expert systems. These systems had as goal to support physicians and nurses in their work. Later on questions about the quality of the systems and the general design principles

on which they have to be based became more important. It was also realized that a technically perfect system does not warrant that such a system will be automatically accepted in practice. Since the implementation of an information system is a process of mutual transformation, the organization and the technology transform each other during the implementation process. Therefore, also sociological aspects play an important role and should be taken into account.

Medical informatics was considered by some as computer science applied to medicine, others were of the opinion that medical informatics was more than computer science and medicine together (because the body of knowledge in medical informatics also contained knowledge coming from a number of other disciplines like epidemiology, cognitive psychology, sociology, biostatistics, etc.) and therefore, they considered it as a medical discipline closely linked to but separate from informatics. However, in both views education in medical informatics would lead to graduates that were medical informatics professionals and not medical professionals (although some of these new professionals could initially have been educated as a medical specialist). Also, in order to be accepted by physicians, medical informatics specialists should be educated at an academic level.

Medical informatics is both an engineering discipline (design and development of information systems for example) and an applied science (aspects related to information science). Since medicine and healthcare are the domains of study of medical informatics, studies in medical informatics can lead to new knowledge that is pertinent to these domains. But the research outcomes are always about the computational and informational aspects of medicine and healthcare and therefore, also contribute to the field of medical informatics.

Research in medical informatics gradually changed. The development of information systems for example was increasingly left to industry.

We will not discuss the question about the scientific character of medical informatics further but refer to a panel discussion held during the IMIA working conference in Heidelberg/Heilbronn where it was concluded that medical informatics is a separate discipline with its own methodology (1).

Specialists in medical informatics were needed for a number of reasons. It was realized that because more and more medical knowledge was generated it would become very difficult for medical practitioners to stay well informed about new developments. In order to cope with the increasing knowledge base computers would be helpful. Also in medical research the use of computer systems became very important. In education computers would be needed to teach medical students how to access knowledge and to become independent life long learners. For computer-aided learning medical informatics specialists would be needed next to medical experts. Computer-aided instruction was used on a larger scale after PCs were introduced that were less costly than the mainframes used before (e.g. in the Plato (Programmed Logic for Automatic Teaching Operations) project of the University of Illinois (2)).

There was another reason that medical students should be taught medical informatics: only with such a background they would become proficient users of information systems.

In several medical faculties academic units for medical informatics were created. These units carried out research and also started education in medical informatics or medical information science as it was then often called, especially in the US. The name 'medical informatics' originated in Europe where it was first used by Francois Grémy and Peter Reichertz. The term informatics was used to distinguish the discipline from computer science as it was called in the US. The hardware was not the distinguishing aspect of this discipline, the processing of data into information was the aim. Later the terms health informatics and biomedical informatics came into use. The first theme we recognized in medical informatics we called the 'initiation stage' with a wink to Nolan's life cycle. In the next section we will discuss the characteristics of a number of early educational programs.

Almost simultaneously with the first endeavours of individual departments to design courses in medical informatics, leaders in the field began reflecting about how to design courses and curricula in medical informatics that would lead to graduates with similar capabilities. Questions about the functions these graduates would take and which subjects they therefore should be taught passed in review. We will present this theme of 'guiding stage' in section 3.

In EFMI and IMIA working groups on Education and Training were established. The Education working group of EFMI organized workshops during MIE conferences. The IMIA Education working group organized a

number of conferences. At a later stage, IMIA and EFMI working groups coordinated their activities in a more productive way by organising common workshops or by working together on the educational recommendations.

In the late eighties the European Commission started with financially supporting research and development of ICT applications in medicine. It was soon realized that the products delivered by the funded programs would only be used when the potential users would have enough knowledge and skills with respect to ICT. Therefore, several projects to stimulate education of health professionals were funded. We shall discuss developments of this 'contagion stage' in section 4.

Over the years new medical informatics educational programs were established all over the world. Since not only the technology but also the character of applications was changing, education should take these developments into account. IMIA felt the need to initiate the development of recommendations about the content of curricula in medical informatics. These recommendations should help to establish education in the field, to further develop existing educational activities in the various nations and to support international initiatives concerning education in health informatics. In principle this was a continuation of the efforts described in section 3. The Recommendations were published in the year 2000. Because of new developments in the field an updated version of the Recommendations was published in 2010 (3). This trend of 'consolidation' will be discussed in section 5.

Having recommendations for designing curricula, the next question becomes: how can one monitor the quality of medical informatics programs? IMIA decided to start the process of accrediting medical informatics programs. This theme of 'quality control' will be discussed in section 6. Section 7 contains some conclusions.

## 2. THE INITIATION STAGE

Technical Committee Four (TC4) of IFIP was established by Francois Grémy. Under his leadership TC4 became independent from IFIP in 1977 and was then called IMIA. In 1974 for the first time medical informatics education was discussed at a meeting in Lyon organized by the international working group TC4.1. During this meeting the competences required by health professionals were identified. The meeting set the scene for application-oriented education at different levels of demand ranging from an orientation of users of information systems to the level of contributors to the advancement of system development (4).

At that time there were already some educational curricula in medical informatics. Francois Grémy for example already in 1969 initiated a curriculum in medical applications of computer techniques at Pitié-Salpêtrière. A second conference held in Chamonix followed in 1983. In the remaining part of this section we present some of the educational programs that were reported in Chamonix (5). In France and the United Kingdom some universities provided education and training to medical

students and/or physicians. John Anderson at King's College Hospital Medical School reported about his experience with research and education in medical informatics. Learning medical students and doctors to type was one example of a training that enabled them to enter data into the medical record part of the hospital information system. This course was given during six years. Also computer-aided learning programs in several areas of medicine were being developed. However, according to John Anderson, these learning programs were hardly shared between institutions, and the wheel was re-invented regularly (6).

Computer technology was changing very rapidly in those days. First only mainframes were available, restricting the introduction of computing considerably. Then relatively cheap mini-computers came on the market, resulting in systems that could be installed even in individual departments. This situation changed even more after the introduction of micro-computers in the eighties. Now individual physicians could afford to use them. Since computer technology was usually a subject in medical informatics courses, the courses had to be updated regularly. But it was increasingly realized that the principles of computer technology have to be taught only superficially to medical students. Instead the methodology behind applications was important and the benefits but also the limitations of the use of computers should be explained.

The establishment in the Soviet Union of medical informatics as a discipline (called medical cybernetics) began in the late fifties of the twentieth century. Like in other countries in Europe also in the Soviet Union the following questions were posed and discussed:

Is medical cybernetics a mere combination of medicine and cybernetics or something more—a separate scientific discipline and educational subject?

Should medical cybernetics education be a separate area of high-level specialty training?

Should all medical students be trained in medical informatics?

The first attempt in the Soviet Union to establish a medical informatics department in a medical school was undertaken in 1961 by the Leningrad Military Medical Academy. There was a small Medical statistics and cybernetics department led by professor L.E. Polyakov. A year later the department and its course were taken over by the larger Organization and tactics of medical service department.

In 1973 a new direction to produce medical cyberneticists (medical informaticians) was introduced at the Medicobiologic faculty of the Second Pirogov Moscow Medical Institute (now – Pirogov Russian National Research Medical University, PRNRMU, named after N.I. Pirogov) on the initiative of professor S.A. Gasparyan and the first students were admitted. As a result the department of Medical and Biological Cybernetics (now the department of Medical Cybernetics and Informatics) was established in 1974, headed by S.A. Gasparyan until 2002.

Salamon and Dusserre (7) reported that in the sev-

enties and half of the eighties medical informatics was not part of the usual medical curriculum in France. For students who wished to become medical informaticians medical schools offered an optional course (Biologie Humaine) leading to a Master of Science degree. Also a PhD in Medical Informatics could be obtained. The authors mention that relatively many students followed the Master course. They also indicated that there were enough opportunities for graduates to find a job.

In Belgium Roger France introduced a course for medical students in which medical information processing, using an informatics methodology was taught to facilitate decision making (8).

In the Netherlands at the Free University in Amsterdam in 1973 the department of Medical Informatics started under the chairmanship of Jan van Bommel. Apart from research the department became involved in education in Medical Informatics both for medical and informatics students.

To provide more insight in the character of applications and the way to implement them Jan van Bommel developed a comprehensive model for ordering computer applications in medicine. It consisted of six levels of complexity with the higher levels being more and more human dependent. He showed that there were many more applications at the lower levels of the model, due to the fact that at these levels the dependence on the human is relatively small and therefore the chance of being able to create a successful application relatively large. Applications on the higher levels are more difficult to develop because usually the processes that these applications have to support are not well understood. One can learn from the model that when human dependence is high interactive applications should be designed. The model was widely used for teaching (9).

At the Free University medical students in the second year of their study followed lectures in medical informatics with a compulsory written examination. In addition elective courses could be followed in the third and fourth year. In the fifth year elective block courses were organized four times a year. The duration of the block course was five days and each day the student was confronted with topics from one of the complexity levels of the earlier mentioned model of van Bommel. Each topic was introduced by a lecture and then followed by practical work in which the ideas presented in the lectures were further elaborated.

In the following an example of one day of the block course devoted to the level 'recognition and diagnosis making' is presented. In a lecture the students were confronted with concepts like sensitivity, specificity, predictive value, decision trees, Bayes' rule, ROC, etc. In the practical part the student was among others introduced to the differential diagnosis between neonatal hepatitis, biliary atresia and normality. A pre-programmed decision tree was presented to the student. To each node a logical statement was connected, consisting of one or two conditions regarding one or two of four parameters (for example the results of laboratory tests). Each condition contained the name of one parameter followed by

one of the operators 'greater than', 'equal to' and 'smaller than' followed by unknown threshold values. In case there were two conditions they were combined with one of the logical operators AND, OR and NOT. The student had to determine the threshold values that optimized the classification performance of the decision tree. A database with patient data was available to determine the thresholds (10).

The student could also work with Bayes' rule to get familiar with the concepts sensitivity, specificity and predictive value by actually calculating them. In addition this rule was used to determine which of seven congenital heart diseases a patient was suffering from. A database was available with the necessary probabilities and the data of a number of patients. Also the students could construct ROC curves to better understand its meaning (11).

Informatics students could also specialize in medical informatics. During their study they had to spend a year specializing in medical informatics. Students had to study basic physiology and anatomy, biostatistics, pattern recognition, signal analysis and image processing, networks and communication and the structure of healthcare. In addition they were confronted with special medical informatics subjects. The informatics study was finished with a thesis in medical informatics (12).

At the University of Leiden students were offered the possibility of obtaining a degree in Medical Informatics. In the beginning of the nineties a separate four year program in Medical Informatics was established by the University of Amsterdam. This program is still in existence and is now the only bachelor/master program in medical informatics in the Netherlands (13).

In Germany a degree in medical informatics could be obtained in several ways: via an application subject Medicine in an informatics study or via a postgraduate course. Since 1974 several universities offered courses in informatics with application subject Medicine. In total 20-25% of the study was devoted to the application subject. A certificate in Medical Informatics (not issued by a university but by the German Informatics Society and the Association for Medical Documentation, Informatics and Statistics (GMDS)) could be obtained by graduates from different disciplines after 5 years of on-the-job training (comparable to the requirements for becoming a clinical chemist). The requirements for the certificate were specified. The five years of on the job experience for example needed to focus on either or all of the following fields in a medical environment: information management, (computer-aided) management of healthcare delivery and technical informatics and software production. Also, as was the case in The Netherlands, non-physicians could obtain a doctoral degree presented by the Medical Faculty when they completed work and a thesis within the medical environment and with relevance to the theory or practice of medicine. In 1978 medical informatics became compulsory for medical students. Moreover an additional qualification in medical informatics could be obtained by physicians. The qualification required a minimum of 2 years

of clinical work and a minimum of 1½ years of work in medical informatics, normally under the supervision and direction of a holder of the certificate for medical informatics (14).

Already in 1972 a medical informatics program was established. This program was a collaboration of the University of Heidelberg and the University of Applied Sciences Heilbronn. The names of Franz Leven, Jochen Möhr and, later, Reinhold Haux are associated with this program. Initially the idea was to create a curriculum at the polytechnical school level (equivalent to an undergraduate curriculum). But in order to guarantee that graduates from the program would be accepted in the medical professional world cooperation with the University of Heidelberg was sought and obtained and a university level program was made, leading to a University diploma, corresponding to an MSc degree (15).

The philosophy behind the curriculum was that informatics is a methods-oriented science concerned with applications of computer systems to solve concrete, existing problems rather than with research about and teaching the principles of computer systems. This meant that formalization and modelling of the problem field, selection and implementation of methods for solution and the application of methods in information processes should be part of the curriculum.

Conveyance of skills, attitudes and reliable judgment are of great importance in practical sciences, while knowledge and rational reasoning may suffice in a theoretical discipline. The incorporation of practical training before, during or after university education is a recurring characteristic of curricula for practical disciplines. Since the program was of the opinion that medical informatics was a practical science the practical training was deemed very important (16).

The education took 4.5 years and the program usually had an intake limited to 35 students per semester. Foundations of the natural sciences and technology covered 25% of the curriculum, informatics 40% and medical informatics 35% (15). Theoretical informatics was less emphasized; the focus was on practical informatics. The medical lectures provide the basic concepts of human biology, terminology and medical methodology so that the graduates were able to understand, to analyze and to solve application problems in the medical area. But medicine should not only be presented by the subset of human biology which tended to overload the student with irrelevant detail. Instead of these irrelevant details it should include the healthcare system: organizations and social structures and institutions and methods to analyse, model and modify them.

A key element was the practical course on "Systems engineering in the health care field". Fifteen hours per week in the beginning were allocated to this course which took place in the actual work environment of the healthcare field during the end of the second year.

Students developed scientific concepts via literature seminars and via lectures of invited experts. In 1983 20% of the students graduating from informatics curricula with medicine as application subject worked in



the healthcare field as compared to 60% of the graduates from Heidelberg/Heilbronn. The Heidelberg/Heilbronn program now exists for about forty years (17, 18, 19, 20). The curriculum was revised several times during its existence among others to keep up-to-date with the developments in the field (21).

In Greece in the late seventies only a few hospital based seminars and courses were taught on the principles of computer science to a healthcare professionals' audience as part of their continuing education, preparing them for the acceptance of the political decision of the early hospital information systems implementations. At that time no formal academic courses existed. Related formal courses were those included in the traditional Medical Physics courses already implemented a decade ago before that time in most Medical and Nursing Schools.

The programs mentioned in this section were usually not based on existing model curricula. Exception was the medical informatics program of Heidelberg/Heilbronn. During the years several model curricula were proposed in Germany. These model curricula influenced the Heidelberg/Heilbronn curriculum but also the other way around. This will be the subject of the next section.

### 3. THE GUIDING STAGE

In May 1969 in Germany a model curriculum for informatics was prepared with support of the then existing learned societies for mathematics and communication technology (the German Informatics Society was founded in the fall of 1969). Three types of informatics were defined: theoretical, technical and practical informatics. About 75% of the curriculum was devoted to these subjects. The remaining 25% was assigned to an application field, like engineering, commerce, mathematics or medicine (22).

In 1973 Peter Reichertz together with the Informatics Society and the GMDS organized a workshop to define a framework for education in medical informatics. This meeting was held at the Reisenburg in Ulm, Germany. Several types of education were defined for medical students, physicians, informatics students and informaticians: medicine as an application subject in an informatics study, informatics education for medical students, an additional qualification Medical Informatics for medical specialists and a certificate Medical Informatician for both informaticians and physicians were the suggested possibilities. From these educational variants it can be concluded that medical informatics was considered a combination of medicine and informatics. Yet a number of topics were included in the curriculum that were not regularly taught in either the core informatics or the core medical education: Methods critique of medical thought and decision processes, Man and environment, Hospital organization and management, Organizational structures in Healthcare and Legal issues. It was expected that these topics had to be taught by medical informaticians because these topics were rarely found in either informatics or medical curricula. Ac-

ording to Möhr the inclusion of these topics proved that medical informatics was more than the union of medicine and informatics and that one of the most important contributions of the conference was the creation of a vision of a new type of professional, the health informatician and the specification of an integrated curriculum which was more than a union of a subset of medicine and informatics. This provided a welcome framework for the Heidelberg/Heilbronn program.

Jochen Moehr reported about this meeting in the IMIA Yearbook of 2004 (23) and also discussed the effects of the Reisenburg meeting, especially for Germany (22).

The symmetry between medical informatics education for informaticians and physicians as expressed in the Reisenburg meeting was put into practice. From 1978 on medical informatics became a compulsory part of medical education. Immediately after the meeting several university programs in informatics started offering medicine as an application subject. The Certificate Medical Informatician was introduced in 1978. Also several institutions started offering courses leading to the additional qualification Medical Informatics.

In 1991 the Recommendations for Education and Training in Medical Informatics of the GMDS appeared (24). It elaborates the Reisenburg framework. The recommendations distinguish an informatics-related approach and a medicine-related approach to medical informatics. But contrary to the Reisenburg framework the recommendations considered medical informatics as a separate medical discipline with specific methodological approaches and with distinguished fields and not as just a combination of informatics and medicine. This shows that the Heidelberg/Heilbronn curriculum influenced the recommendations. Concerning the informatics-based approach the recommendations also mention medical informatics as an 'integrated' applied subject within informatics curricula. This referred among others to the informatics curriculum of the University of Hildesheim together with the medical school of Hannover: this informatics curriculum started in 1988 with medical informatics as a core part of the curriculum.

The recommendations also stated that an informatics study with an applied subject should be called applied subject medical informatics instead of medicine. A mere educational offering of medical fundamentals was not enough as an applied subject. Also it is stated that the number of hours devoted to medical informatics as recommended by the Informatics Society should be increased. The recommendations explicitly mention the subjects that were regarded as medical informatics subjects: structure of the healthcare system, medical documentation, information systems in healthcare, biosignal processing, image processing, medical linguistics, knowledge based methods and systems in medicine.

In 1981 a report about a model curriculum for doctoral-level programs in what was called health computing was published in the USA by the Association for Computing Machinery (ACM) (25). The health care industry in the United States was a \$220 billion a year in-

dustry (about 10% of the Gross National Product), with information handling accounting for about 30% of the health care dollar. Although computing could play a major role in facilitating health care information flow to reduce costs and improve the quality of care, the health care industry lagged behind most other major U.S. industries in its utilization of information technology. According to the report this was due to a great extent to the scarcity of adequately trained health computing professionals who can design and develop appropriate uses for the technology. The health computing profession's development and its ability to attract bright and creative young professionals, in turn, was hampered by the poorly specified and diverse career paths, the lack of a well organized peer structure for information exchange, and unspecified goals for the education of health computing professionals.

The authors noticed that there is a need for leadership and that in order to be accepted by the medical profession they should have a comparable preparation as MDs have. Therefore they proposed a model doctoral level curriculum. This acceptance problem was also the reason that in the Reisenburg framework a university level for the graduates was deemed necessary together with five years of on the job training for those who wanted to work as leaders in the healthcare sector.

In the report the subjects that all health computing specialists should master is specified: computer science, health sciences, integrative studies and contributing studies. The remaining part of the curriculum is divided in four tracks: health information systems, health research computing, health educational computing and health computing administration. They suggest that students will be attracted from a diversity of disciplines, ranging from computer science and mathematics to engineering to biology. According to Möhr and Leven a comparison of the Heidelberg/Heilbronn curriculum with the ACM curriculum shows that a large set of concepts is covered in both curricula.

In the Netherlands in 1987 recommendations for education and training in medical informatics education and training were formulated by the Subcommittee Medical Informatics of the Committee for Medicine of the Royal Netherlands Academy of Arts and Sciences under the chairmanship of Jan van Bommel. In the report 'Medical Informatics – Renewal in Medicine' it is noted that professionals in healthcare were increasingly confronted with computer systems (26, 27). Since the professional will always be responsible for the consequences of the use of the results of medical information processing, it is important that the student in medicine (or health sciences) will be taught both the fundamentals of medical information processing and the essentials of existing applications. Another reason to introduce students to the field of medical informatics was the fact that medical education requires the students to accumulate a multitude of facts. Because of the explosive growth of biomedical knowledge more and more of this knowledge was crammed into the curriculum. The report of the Panel on the General Professional Education

of the Physician and College Preparation for Medicine (GPEP) of the Association of American Medical Colleges entitled 'Physicians for the Twenty-First Century' was taken as starting point (28).

The perception that medical education too much emphasized the acquisition of knowledge was taken as one of the starting points of the GPEP report. The Panel recommended that in the general education of the physician medical faculties should emphasize the acquisition and development by students of skills, values and attitudes at least to the same extent that they do their acquisition of knowledge. Medical faculties should limit the amount of factual information that students are expected to memorize. The Panel realized that the acquired knowledge rapidly would become obsolete by the advances in biomedical knowledge and technology. Moreover students were passive recipients of information rather than active participants in their own intellectual growth. Medical faculties should encourage students to learn independently. The development of skills that support independent self-directed learning should therefore be emphasized. Students who learn independently develop abilities to seek out information and to analyze and apply it to the solution of problems. Computers are powerful tools for education, information management and analysis. The Panel concluded that basic research is needed on the use of electronic information systems in medical education. They therefore recommended that Medical Schools should designate an academic unit for institutional leadership in the application of information sciences and computer technology to the general professional education of physicians and promote their effective use. These latter recommendations were based on the Subgroup report on Medical Information Science Skills, chaired by Nina Matheson and Donald A. B. Lindberg (29). They observed that only a handful of American medical schools have the personnel and computer resources to provide education in the principles and operation of medical information systems.

The subgroup described seven levels of understanding of the principles of information handling: (1) Using basic information handling tools; (2) Independent learning about computers and information management; (3) Using computer systems and accessing databases; (4) Knowledgeably using systems and specialized databases; (5) Perceiving new applications; (6) Building systems for personal applications and (7) Tool building.

The Dutch report 'Medical Informatics, Renewal in medicine' proposed the content for the introductory education in Medical informatics, based on levels 1 to 4 of the GPEP report. Also it was stressed that the medical students should get practical experience so that they would understand the possibilities and limitations of information systems. Although the education of medical students was extensively elaborated, the report also mentions the need for educating medical informatics specialists via PhD studies and informatics graduates with a major in medical informatics. The recommendation that all medical faculties should designate an aca-

demic unit was taken over in the Dutch report.

The Information for Health programme (IfH) of the NHS had as purpose to put in place the people, resources, culture and processes necessary to ensure that the NHS clinicians and managers had the information needed to support the core purposes of the NHS in caring for individuals and improving public health. To successfully implement IfH at the local level the NHS Information Authority in 2001 developed competency profiles that identified skill and knowledge levels for NHS staff. The profiles provided guidance and baseline data for local staff training (30).

In Russia Medical Cybernetics is a full-blown health care specialty. Education is provided by the Siberian State Medical University, the Penza State University and the Voyno-Yasenetsky Krasnoyarsk State Medical University, in addition to the education provided by the Pirogov Russian National Research Medical University.

At present training is carried out in accordance with the third version of the Federal State Higher Educational Standards (FSHS), approved in 2010. It is a full-time program with a study load of 60 credits per year. One credit corresponds to 36 academic hours. The specialty training is carried out continuously during 6 years.

The medical cybernetics program at the university level comprises the study of several tracks: humanitarian, social and economical, mathematics and natural science, the professional, educational practice and practical training, research and the final state certification, with the main component being the preparation and defence of a diploma thesis. Each track has mandatory and elective parts.

The mathematics and natural science track includes the subjects: differential and integral calculus, mathematical statistics, computer science and medical informatics, morphology (anatomy, histology, and cytology), physiology, general pathology (pathological anatomy and pathological physiology), pharmacology, biochemistry, genetics and immunology.

The professional track consists of clinical and medical cybernetics subjects. The clinical subjects are internal medicine, clinical and experimental surgery, neurology and psychiatry, pediatrics, radiology, radiotherapy and clinical cybernetics. The subjects of medical cybernetics include the theory of cybernetics, medical electronics, physiological cybernetics, systems analysis and health system organization and health information systems.

Learning outcomes of the medical cybernetics program are: the mastery of knowledge of and skills in automation of data entry, physiological signal processing, methods of experimental design and statistical analysis of data, applications of mathematical and heuristic image analysis methods for solving problems of differential diagnosis and prediction of the patient state, methods of model construction and analysis (from the sub cellular level to health care systems), purpose and principles of the design and construction of automated health information systems, mathematical tools of systems analysis, etc. Graduate work is done during the last semester. It is a complete research or design project car-

ried out under the supervision of a medical cybernetics specialist. The knowledge and skills of medical cybernetics graduates are described in the FSHS.

In Russia the term medical cybernetics denotes the specialty, whereas the term medical informatics denotes the discipline that is taught to students majoring in the specialties Clinical Medicine, Pediatrics and Dentistry. Medical informatics education to medical students started in 2000 in Russia. In that year the Russian Ministry of Health approved a program for this discipline, prepared by the Second Pirogov Moscow Medical Institute (now PRNRMU). It was regarded as a separate discipline. The education in medical informatics covered 38 hours, 12 for lectures and 26 for workshops, and was given in the middle of the six years of the medical study. In all workshops the students had to work individually on the computer.

During the first five years of training the first experience with teaching medical informatics was obtained and weak points were detected. To improve the training of the medical informatics discipline the First All-Russian Training and Methodological Conference on Medical Informatics was organized in 2005 on the initiative of the PRNRMU. The main objectives of the conference were to present solutions to problems of teaching the discipline and to exchange experiences. During the preparation of the conference a special questionnaire for assessing the situation of medical informatics education in medical schools was developed and dispatched. In 2009, after repeated questioning, the Second All-Russian Training and Methodological Conference on Medical Informatics was held.

The most common suggestions and proposals mentioned in the returned questionnaires included the need for advanced training of teachers of the medical informatics course, the establishment of a model set of special software (computer programs that will help students to study how to develop medical models, to acquaint themselves with medical information systems in practice or to design, for example, expert systems for medical decision support), the availability of a database of test questions for students to test their knowledge and the necessity to increase of the number of classroom hours.

The third version of the Federal State Higher Educational Standards included the recommendations of the Russian medical information society. For instance, the training of the medical informatics course for students majoring in Clinical Medicine, Pediatrics and Dentistry now equals 3 credits, which corresponds to 72 and 36 academic hours of classroom and self-study, respectively.

Due to this significant increase in training time for the medical informatics course, the range of topics could be extended and the requirements could include skills and abilities that should be developed during the study. It allowed a transition from familiarizing students with the aims of the discipline to being able to pass on a notion of the medical informatics theory and of modern computer technology applications in medicine and health care. After a typical course a student needs to know:

- Types, structure and characteristics of medical information systems
- Principles of automated medical institution management, using modern information technologies
- Basic approaches to formalize and structure various medical data types used to find solutions during the diagnostic and treatment process.

A student has to be able to:

- Perform textual and graphical processing of medical data using standard software
- Use statistical and heuristic algorithms for diagnosis and treatment monitoring
- Use the modern internet resources to search for professional information as part of self-training and advanced training in specific topics of medical knowledge.
- A student has to master the basic skills of using medical information systems to efficiently carry out physician duties.

In Greece during the early 1980's formal courses started to appear in curricula in the Nursing School of the University of Athens. The lack of computer skills made it appropriate to introduce Introduction to Informatics as a first officially taught course combined with a laboratory practicum. At a later stage a separate course was introduced: that of medical informatics. As there was a strong objection by most of the conservative faculty members to accept new subjects as courses within the official curriculum of a traditional Nursing academic programme, it was difficult to have both above mentioned courses accepted as obligatory within the curriculum, so one course was accepted as obligatory and the other as optional. Due to the lack of computer skills among the fresh students in the first years of this initiation, the obligatory course was the Introduction to Informatics and the optional one was the Medical Informatics course later renamed as Health Informatics. Exactly the opposite occurred in early 1990's when the computer skills of the incoming students were at an appropriate level. Both Medical Schools of the University of Athens and the Aristotle University of Thessaloniki introduced Informatics courses as optional modules for a rather selected but limited audience of undergraduates in the late 1980's. This tendency improved after the late 1990's.

It is worth mentioning for historical reasons that in 1988 the taught course within the undergraduate curriculum of the Nursing School of the University of Athens changed from Medical Informatics to Health Informatics. It is the first time in the literature that we encounter in an official course the term, which was accepted very late at the end of the 1990's and beginning of the 2000's as the appropriate generic term reflecting our field.

#### 4. CONTAGION STAGE

In 1976 EFMI was established and in 1979 TC<sub>4</sub> of IFIP became an independent organization named IMIA. IFIP-TC<sub>4</sub> and later IMIA's working group on education organized a number of working conferences dedicated

to education in medical informatics. The first conference was held in 1974 in Lyon where it was discussed how to respond to the need for medical informatics education (4). In 1983 the second conference was held in Chamonix (5). Here several existing programs in medical informatics were discussed that were presented in section 2. Then next conferences were held in Victoria, Canada in 1989, in Prague, Czech Republic in 1990 (31), in Heidelberg/Heilbronn, Germany in 1992, in Newcastle, Australia in 1997, in Portland, USA in 2003, in Athens, Greece in 2005 and in Buenos Aires, Argentina in 2008.

Medical informatics education was also covered in EFMI meetings. The education working group organized a workshop at each MIE meeting. In 2005 an EFMI special topic conference on Education in Medical Informatics was held in Athens attracting more than 200 attendees. This conference was also an IMIA meeting as indicated above. These conferences showed the interest that existed in medical informatics education, both to educate specialized professionals but also to educate medical students in the field.

The importance of information systems for healthcare was recognized by the European Community. Large amounts of money were funded to develop information systems of various kinds that could support professionals in their work. The AIM (Advanced Informatics in Medicine) initiative was a research and development activity of the European Community managed through Directorate General XIII of the European Commission. The programme focused on the possibilities of information and telecommunication technologies in the healthcare sector. It was realized that the developed systems would only be accepted and used when physicians and nurses had enough knowledge about and skills in the use of these new tools. The three year Concerted Action Education and training in health informatics (EDUCTRA) therefore started in 1992 as part of the AIM programme. Since the topic Education and Training in health informatics was considered too broad to be covered by one concerted action it was decided to focus on education and training in health informatics of professionals (including physicians, nurses, managers, etc.). The goal of EDUCTRA was to:

- obtain an overview of existing educational and training programmes in the area of health informatics
- identify potential gaps in the training and education of healthcare professionals and patient groups in the various countries
- propose, on the basis of this investigation, actions to remedy these gaps; and to
- investigate the potential of transferring existing training programmes to other countries.

Representatives of the member states surveyed the status of training and education in IT in their country. It appeared that in almost all countries health professionals lacked knowledge regarding the possibilities and limitations of information systems. It was concluded that the situation concerning health informatics at the universities was also far from ideal. Only some courses



in health informatics were provided in medical and nursing schools. The courses that were offered were frequently devoted to the technical use of computers. In a large number of countries medical faculties did not have health informatics departments. Graduate students entered professional life without having had an introduction to the possibilities and limitations of information systems. Post-graduate level courses in IT and health informatics were of variable content and quality, probably due to the limited number of health informatics teachers (32).

Since hardly any curricula in health informatics existed it was concluded that one of the tasks of EDUCTRA had to be to define guidelines for developing curricula for various groups of professionals. The objective of the guidelines was to provide trainers with a framework according to which they can design their courses. These guidelines were produced and published in 1995 (33, 34).

An Erasmus Inter-University Cooperation Programme (also a programme funded by the European Commission) had as target education in Health Informatics at the MSc level. The programme was funded (from 1989 to 1998) by Erasmus in two phases. The first phase developed a curriculum in the field of Health Informatics at an MSc level after an international workshop organised in Athens, and the second phase was the implementation of the programme by exchanging both professors and students among six European Universities in the beginning of the implementation to 20 European Universities at the mature stage of the programme. The first six European Universities/Institutions were: University of Athens, Polytechnical University of Madrid, University of Gent, City University London, University of Pavia, and the University of Manchester. The programme was coordinated by the University of Athens, was given at the Nursing School, and the overall evaluation merited it as a very successful coordinated effort despite the huge logistical overload and the very little funding support by Erasmus for a programme with no registration fees for the students. The MSc education was given until 1997/1998. The aim of this curriculum that started in 1990 was to give those working or intending to work in the health service a broad advanced postgraduate education in health informatics in order to develop the ability to understand and evaluate in detail the theoretical and practical requirements of informatics in medicine, nursing and healthcare. The course enrolled students from different European countries and also had lecturers from several European countries (35). It should be also mentioned that the official title of the Erasmus programme established in 1989 was MSc in Health Informatics. The term Health Informatics was for the first time used in an official academic programme and academic title to represent our field.

Another Erasmus programme funded the development of an educational self-learning software tool to study the application of the Bayes theorem. This program was developed initially as part of the block course at the Free University in Amsterdam mentioned above. The program was redesigned and translated also into

English, German and French in a cooperation of the University of Maastricht, Freiburg and Gent (36). The program consisted of two parts. An instruction part could be used by the student to repeat already learned concepts. With the second part the student can test his/her knowledge in an exploratory way. The computer-aided instruction program was used at several universities as well as at the above mentioned Erasmus MSc in Health Informatics in Athens.

In 1993 the joint European project EuroMISE (European Education in Medical Informatics, Statistics and Epidemiology) started under the umbrella of the European TEMPUS-PHARE programme. The idea was to teach the teachers in among others health informatics. Faculty from various European countries was involved in the programme. The students came from central and eastern European countries (37).

The results of European funded projects like EDUCTRA, the ERASMUS MSc Programme, the EuroMISE, etc. were the starting point of the IT EDUCTRA (Information Technologies EDUCation and TRAINing) project that was approved in the Fourth Framework programme of the EU in 1995 (38).

The main goal of the IT EDUCTRA program was to create a training program for healthcare professionals in the basics of information technology and IT medical applications. The final product was a CD-ROM containing the teaching materials and tools and used new information technologies for the dissemination of knowledge and skills required for new health care systems.

The NIGHTINGALE (Nursing Informatics Generic High-level Training in Informatics for Learning & Education) project, again an EU financed project, was also approved in 1995 (39). The project was considered essential for planning and implementing of a strategy to train the nursing profession in using and applying healthcare information systems. The project was based on previous experiences obtained in the Telenursing AIM project and on the EDUCTRA Concerted Action which partially touched the subject of education and training of the nursing profession. The main goal of the project was to bring to the surface, by means of a series of workshops, the user needs of the nursing profession with respect to telematics, to develop a nursing informatics curriculum for European nurses, and to develop educational tools and software assisting the educational process in nursing informatics. A number of European Conferences on Health Telematics education were also organized (40, 41, and 42) and a textbook in health informatics for nurses was compiled (43).

## 5. CONSOLIDATION STAGE

Over the years the number of programs in Health Informatics increased steadily. Beginning in 1990 the University of Maryland at Baltimore began to enter information collected on health/medical informatics programs worldwide into a database (44). IMIA's Working Group 1 on Education and Training in Medical Informatics provided guidance on critical issues of policy and purpose. In 1993 the database was revised to improve

the quality and quantity of information accessible by remote users. The database was accessible through Gopher. A few years later it was reported that the data were outdated or replaced by links to the Gopher sites of the respective programs. It was then decided to establish a website at the University of Heidelberg. The main goal was to give potential students easy access to a new version of the database (45).

Although there were different opportunities worldwide for obtaining education in health informatics many countries had not, or at least not sufficiently, established such opportunities. Therefore IMIA felt the need to develop international recommendations for health informatics education. The IMIA recommendations that resulted took into account the various existing, mainly national recommendations of which some were mentioned in section 3. The IMIA recommendations were published in 1999 and centred on educational needs for healthcare professionals to acquire knowledge and skills in information processing and information and communication technology as needed and used in medicine and healthcare (3). The educational needs are described as a three-dimensional framework with dimensions 'professional in healthcare', 'type of specialization in health informatics' and 'stage of career progression'. For the various educational needs learning outcomes were suggested. Two types of learning outcomes were documented: learning outcomes for all healthcare professionals in their role as IT users and learning outcomes for health informatics specialists. Three levels of knowledge and skills were distinguished: introductory, intermediate and advanced. The knowledge and skill levels were classified into three domain areas: (1) Methodology and technology for the processing of data, information and knowledge in medicine and healthcare; (2) Medicine, health and biosciences, health system organization; (3) Informatics/computer science, mathematics, biometry.

The programs that prepare graduates for careers in health informatics were divided into two types: health informatics courses as part of informatics/computer science programs and dedicated educational programs in health informatics.

The recommendations were received positively as can be concluded from the many references to them. Because of the tremendous progress in and the evolution of our field of health informatics, the contents of those recommendations were not fully up-to-date. Therefore a first revision of the Recommendations was published in 2010 (46). The name of the first domain area was changed into Biomedical and Health Informatics Core Knowledge and Skills, doing much more justice to our field than the earlier name: Methodology and technology for the processing of data, information and knowledge in medicine and healthcare.

## 6. QUALITY CONTROL

There is an increasing need for health informaticians and an increasing number of health informatics programs deliver health informaticians with different

kinds of expertise. The IMIA recommendations define the knowledge and skills necessary for these different types of health informaticians.

In many countries the quality of educational programs is monitored via an accreditation procedure. As a first step the program writes a self-assessment report that serves as a reference for a site visit committee. The site visit committee visits the premises of a program and checks the contents of the curriculum, the adequacy of examinations, lecture rooms, computer facilities, the library, etc. In some countries there are no accreditation requirements for individual graduate programs, only for universities. In this case the university determines the quality of programs that it offers, once it is accredited.

In order to attract the best students, institutions with health informatics programs, be it vocational, bachelor or master programs, may want to convince potential students of the international level of their program. A program may also want to show to their university board that they indeed provide excellent education. The results of national accreditations are not always convincing since not always do the members of national site visit committees have a clear understanding of the level of international health informatics programs or of the international level of health informatics itself. This is especially true when the university itself determines the quality of the program.

IMIA developed an accreditation procedure as a support for institutions that want to prove that their program in health informatics is of an international level (47). Institutions interested in IMIA accreditation have to write a self-assessment report. In the self-assessment report an answer should be given to the following six main questions:

1. What are the goals of the program for which the institute asks for accreditation?
2. How are the goals implemented in a curriculum?
3. What is the size and quality of the staff?
4. Which facilities for teaching are available?
5. How does the institute guarantee the quality of the program?
6. Are the goals routinely achieved?

The self-assessment report will, in addition to a site visit, provide the members of the site visit committee enough information to judge the program.

The accreditation protocol is now tried out. In the mean time three programs have been accredited and another three are in the process of writing a self-assessment report.

## 7. DISCUSSION

In this contribution we have sketched the development of education in Health Informatics in Europe. We recognized a number of themes. Education in health informatics started in several European countries at the end of the sixties, beginning of the seventies. This education concerned health professionals, medical students and also students that wanted to become medical informaticians. In that same period also model curricula were defined as a guide for programs. A change can be

observed from a focus on computer science to a focus on informatics.

In this contribution we did not mention the medical informatics educational literature. Several different textbooks on health informatics are available and several scientific journals in medical informatics also cover educational aspects.

The question whether health informatics is a separate discipline should, according to de Vries (philosopher at the University of Amsterdam; personal communication), be answered positively. In the first place in order to be a discipline institutional facilities are required. A discipline should at least have educational programs using its own textbooks. Furthermore, a discipline should consist of a population of researchers whose work has a larger chance to influence the work of others in the discipline than the work of researchers outside the discipline. According to de Vries the term discipline refers more to how education is organized than how the research is organized. Given the above survey of the history of health informatics we conclude that we can at least say that health informatics is a discipline. And in our opinion we can add that it is also an applied science.

Our contribution shows that the field of medical informatics has grown enormously. Medical informatics in itself is a very broad field and this means that there is a need for specialization. Because of the broadness of the field, medical informatics can be considered as an interdisciplinary field. The field is becoming mature as is evident from the last theme of this contribution.

**CONFLICT OF INTEREST: NONE DECLARED.**

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