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Education and Training

Twenty Years Medical Informatics Education at Heidelberg/ Heilbronn: Evolution of a Specialized Curriculum

Abstract: The medical informatics curriculum at University of Heidelberg/School of Technology Heilbronn started in 1972 as a specialized university curriculum. In this paper, we report on 20 years of experience and the evolution of this educational approach with respect to structure and content of the curriculum. We emphasize that this evolution parallels the development of medical informatics to a medical discipline in its own right, with distinct application domains and specific methodological approaches. Based on our experience and on recommendations from the national and international community, we describe and discuss the features of the curriculum.

Keywords: Medical Informatics, Education, Training

1. Introduction

Medical informatics deals with the systematic processing of information in medicine. Medical informatics:

- is concerned with the study of the principles of information processing in the field of medicine and with the provision of (general) solutions for information processing problems in medicine;
- uses appropriate (formal) methods and tools, especially from informatics, to model structure and mechanism of information processing systems in medicine in order to describe or analyze these systems, or in order to provide possibilities for their construction or their evaluation [1].

The aim of this paper is to highlight the consequences of the development of medical informatics for education in medical informatics. These consequences will be discussed with respect to the Heidelberg/Heilbronn curriculum on medical informatics.

2. Development of Medical Informatics

Looking at the development of medical informatics over the last decades (see e.g. [2,3]), we see that in the early stages of development there were mainly two kinds of approaches to the topic medical informatics: (1) applying the computer and (2) applying 'standard' methods of informatics and computer science to the field of medicine.

For both cases, in the beginning one could clearly distinguish between a medical part (the field of application) and an informatics part (with respect to methods and tools of informatics). Medical informatics at that time could be described as, and was mainly understood as 'informatics *and* medicine' (cf. title and contents of [2]). As is seen in section 3, this clear separation also reflected the recommendations and structures of medical informatics curricula.

However, in the continuing application of methods and tools of informatics we noticed that often the standard methods of informatics could not appropriately be applied to medi-

cal problems. Specific approaches in the development of methods for a systematic processing of information in medicine were often necessary. Medical informatics then no longer had the meaning of solely applying standard informatics methods in the field of medicine. Although still strongly related to informatics (and, obviously, using the informatics tool 'computer'), it developed into a separate medical discipline with specific methodological approaches and with distinct subjects, such as information systems in health care, biosignal processing, knowledge-based methods and systems in medicine, medical documentation, medical image processing or medical linguistics, which now also influence methodological development of informatics itself (see e.g. the examples in [4]). The 'informatics *and* medicine' paradigm for medical informatics was no longer adequate. This evolution of medical informatics necessarily led to changes in the medical informatics curricula.

For example, the 'standard' methodology of informatics for knowledge-based systems had to change considerably for medical problems. Excellent examples are presented in [4] with respect to problems of knowledge representation forms and inference mechanisms in the INTERNIST and CADUCEUS research projects. Furthermore, inference strategies for knowledge-based systems for clinical laboratories had to be redefined, especially with respect to less time-consuming explanation strategies. Another example is the problem of designing databases for medical use which require - besides standard database design methods - additional methodological effort to analyze medical data. Methods for casuistic documentation, for constructing clinical registers, and for classifying or indexing medical texts had to be developed in order to build up and use medical databases and in order to apply classifications like the ICD, or nomenclatures like SNOMED in medicine. Linguistic questions, e.g. the automated indexing of diagnoses, required newly developed methods, because standard methods of informatics or linguistics were unable to solve the specific information processing tasks concerning medical texts.

3. Development of Medical Informatics Education

Parallel to the development of medical informatics as a recognized discipline, the questions of teaching and education have received increasing attention, as reflected by special sessions at international conferences such as MEDINFO and Medical Informatics Europe, by the installation of the IMIA-Working Group Education and a series of international conferences organized by this group. This sequence of conferences reflects the international development of medical informatics education. The conference in Lyon 1974 [5] reported the basic responses to the increasing urgent need for education in medical informatics. These responses in several countries concentrated on introducing students and health care professionals to informatics. Still based on the 'informatics *and* medicine' paradigm, the conference in Chamonix 1983 [6] reviewed the achievements to date and reported the existence of several programs for the education of specialized professionals in medical informatics, and the introduction of medical informatics into medical curricula in medical schools. The conferences in Victoria 1989 [7] and in Prague 1990 [8] considered medical informatics as a discipline of its own, providing fundamental paradigms as well as essential tools for education at all professional levels [9].

In the Federal Republic of Germany, educational activities in the field of medical informatics date back more than 20 years and have different objectives and results (Fig. 1) [10,11].

- foundation of schools for medical documentalists and medical record librarians at Ulm and Giessen in 1969 and 1970, and a related school in Hann over in 1980;
- establishment of the specialized university curriculum for education in medical informatics as a joint institution of the University of Heidelberg and the School of Technology Heilbronn in 1972, which is discussed in this paper;
- recommendations for teaching medicine in the context of teaching informatics, published in 1973 [13];
- inclusion of foundations in medical informatics as a compulsory part of the training of medical students in 1978 and as possible continuing education for physicians (see [12] for references);
- recommendations for granting a certificate to qualified professionals in medical informatics in 1978, now in its 3rd edition [14];
- recommendations for teaching in medical informatics on different educational levels issued by the German Association of Medical Informatics, Biometry and Epidemiology (GMDS) in 1991 [12].

The 1991 GMDS recommendations in [12] cover education at university level with specialized curricula covering the entire spectrum of medical informatics, such as informatics curricula with medical informatics as subsidiary subject. Besides these informatics-oriented approaches, medicine-oriented education in medical informatics is recommended, e.g. post-graduate education in medical informatics for physicians, based on medical informatics as part of their primary education in medicine. Compared with the recommendations of 1973 issued in [13], which clearly followed the 'informatics *and* medicine' paradigm, the 1991 GMDS rec-

ommendations now considered the evolution of medical informatics and embraced the view of medical informatics as a separate medical discipline with specific methodological approaches with distinct fields. In addition, the GMDS recommendations describe a 2-dimensional educational framework with different educational levels on the one hand and various types of educational needs and orientation on the other.

4. The Heidelberg/Heilbronn Medical Informatics Curriculum

Among the activities mentioned in section 3, the Heidelberg/Heilbronn curriculum deserves attention not only because of two decades of accumulated experience which has led the evolution of this approach to its current fourth revision, but also due to its type of specialization which is closely related to the independently formulated ACM proposals for a doctoral program in health care computing [15], which has had an international impact on new educational concepts in medical informatics [16].

The initial version of the Heidelberg/Heilbronn curriculum approach was oriented both at recommendations for informatics curricula in general [17] and the special recommendations [13] concerning medical informatics. However, other than conceiving medical informatics as a subsidiary subject in an informatics curriculum - an approach which has been adopted by about ten universities in Germany - the Heidelberg/Heilbronn curriculum has evolved as a specialized education for medical informatics and has strongly influenced the 1991 GMDS recommendations.

The development of education in medical informatics can further be illustrated by comparing the 3rd [18,19] and the current 4th revision [20] of the Heidelberg/Heilbronn curriculum with respect to structure and content (Fig. 2).

In its 3rd revision, the curriculum still reflects the 1973 recommendations and the pronunciation of informatics and medicine as the basic disciplines brought together in an integrated curriculum for medical informatics.

In the 4th revision, specific medical informatics subjects both in the introductory section and the mandatory part of the second section reflect the philosophy of medical informatics as a discipline of its own and cover its specific fields. Subjects within the curriculum are mainly:

- 1st section: introduction to medical informatics, electrophysiology, health care delivery systems, information systems planning in health care, medical methodology (including an introduction to medical documentation);
- 2nd section, mandatory: information systems in health care, especially hospital information systems, introduction to biosignal processing, knowledge-based methods and systems in medicine, medical documentation;
- 2nd section, elective: computer-supported therapy planning, informatical approaches for diagnostics and therapeutics in nuclear medicine, medical linguistics, molecular-biological information processing, development of software for health care institutions.

Furthermore, the importance of informatics education has been remarkably enhanced by offering a variety of electives. Finally, the structure of the curriculum now provides four - instead of three - major subjects for graduation in the second section in addition to the core of mandatory lectures:

1. organization of health care systems: analysis, planning and optimization of health care processes including legal and social considerations;
2. biosignal and medical image processing: advanced biosignal processing, biocybernetics, medical image processing, pattern recognition;
3. model building in medicine: biomathematical and statistical models, simulation of continuous systems, queuing theory;
4. information and knowledge processing in medicine: design, implementation of information systems, statistical analysis systems, epidemiology, artificial intelligence, medical decision making.

Besides the mandatory lectures the students have to choose one of these four blocks. In addition to the required courses and chosen electives, they have to pass additional electives taken from the other three blocks or from the set of free electives .

Education is application- and project-oriented with many courses run in a laboratory environment, e.g., information systems planning in medicine, software development, artificial intelligence, biosignal processing, process control, measurement techniques, technical informatics, and clinical chemistry. Figure 3 shows the current state of the curriculum.

Since its start in 1972, admission to the program has been restricted to 35 students per term. Due to the large numbers of applicants, the selection process demands a high entrance qualifications. Due to the complexity of the curriculum, the length of the studies until the diploma ranges between 4.5 and 6 years, so that a total number of about 390 students are enrolled. Besides full time faculty members of the School of Technology Heilbronn and of the University of Heidelberg, teaching is done by part-time lecturers from the University of Heidelberg, neighboring teaching hospitals, scientific research centers, and the computer industry. The ratio of students to professors is about 25:1. Job opportunities as well as the professional experi-

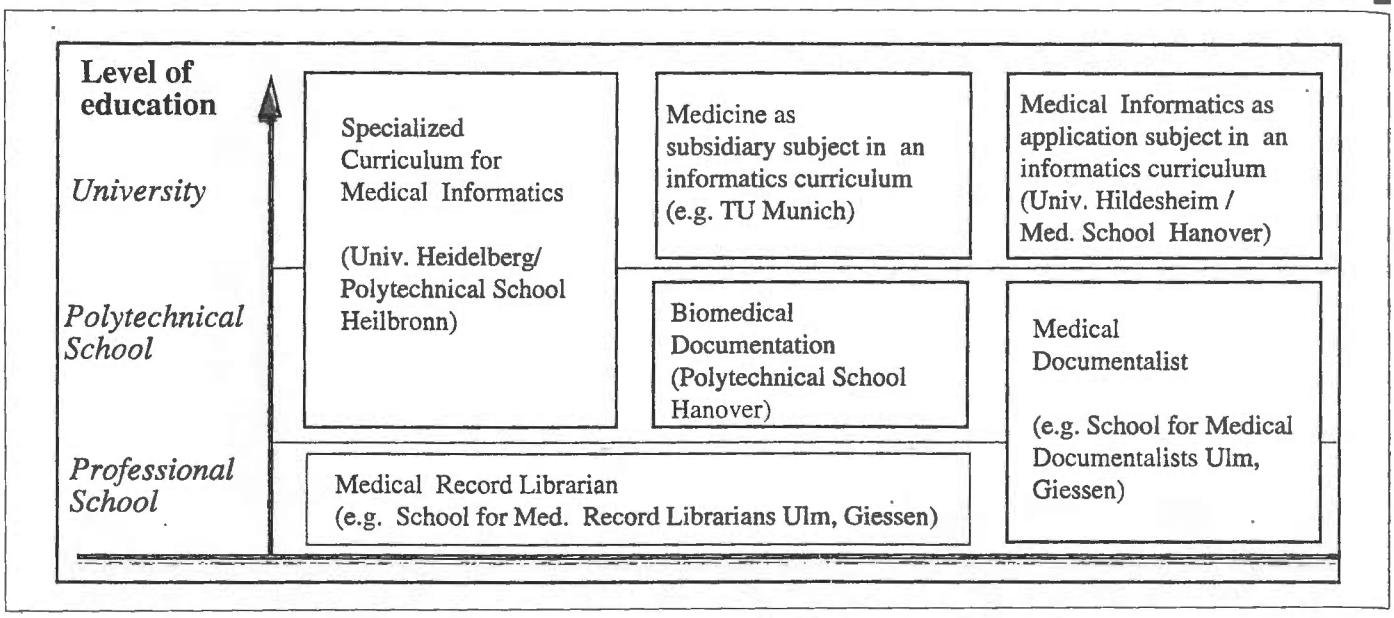

Fig. 1 Types of curricula in the field of medical informatics in the Federal Republic of Germany (status 1991, [12]).

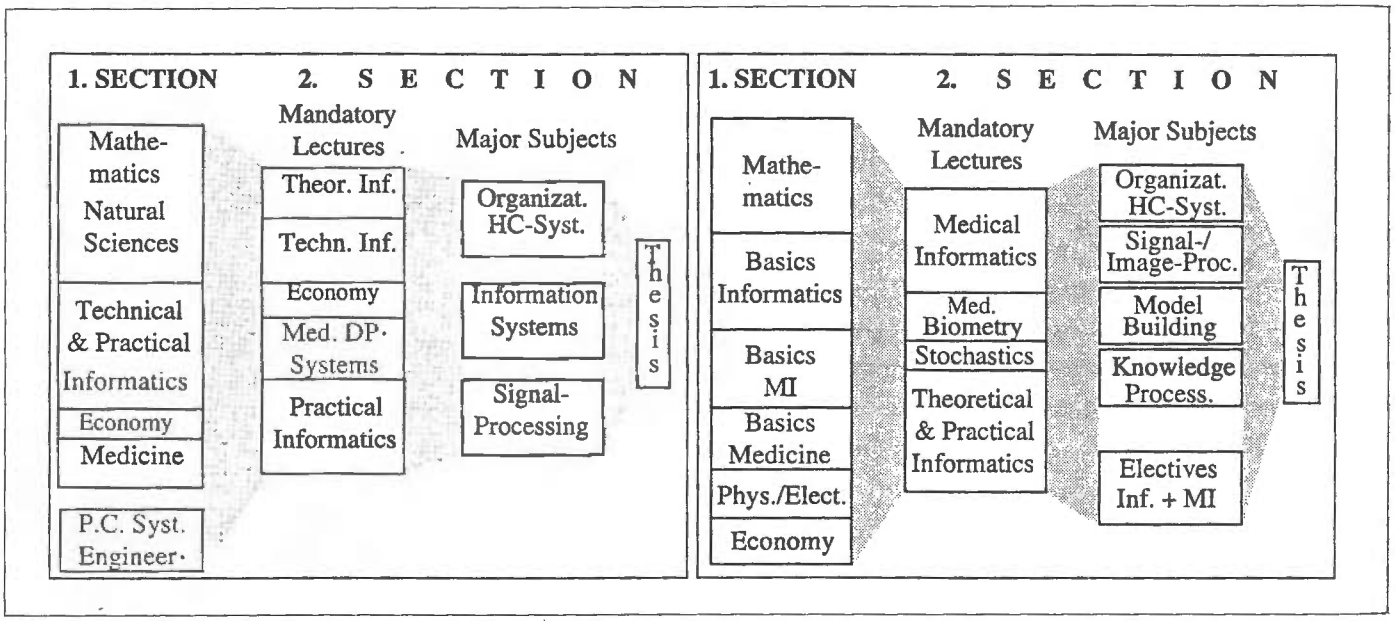

Fig. 2 Curriculum medical informatics Heidelberg/Heilbronn: a. 3rd revision 1982, b. current 4th revison.

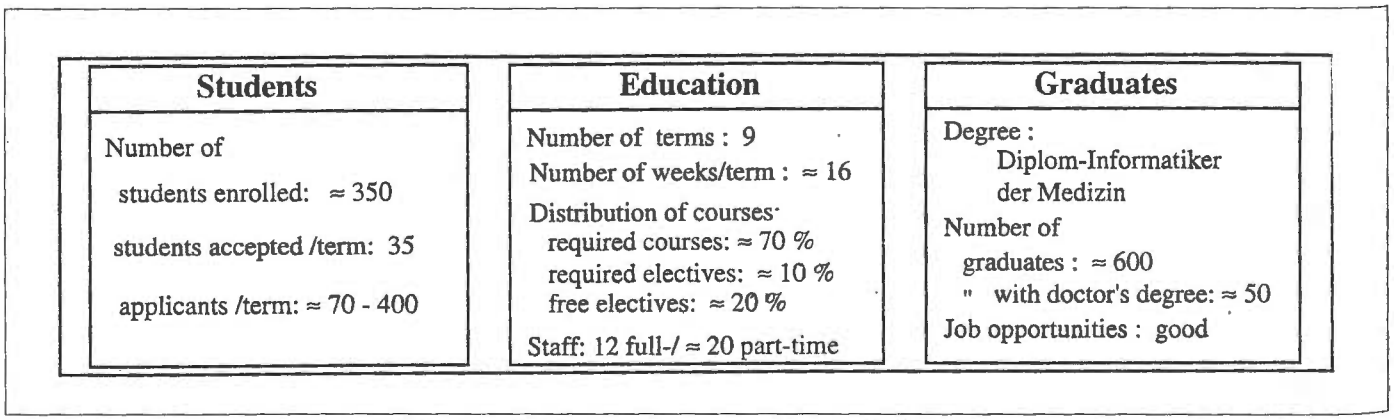

Fig. 3 Characteristics of the Heidelberg/Heilbronn curriculum for medical informatics.

ence of about 600 graduates are good. However, for various reasons about 50% of the graduates work in non-medical application fields [21].

5. Discussion

The evaluation of medical informatics and its curricula has mainly been discussed with respect to international and German approaches. Other national approaches, such as e.g. outlined in [22] can not be addressed here extensively.

In our opinion, the development of the Heidelberg/Heilbronn medical informatics curriculum reflects the evolution of medical informatics to a discipline of its own. Taking into consideration 20 years of experience with our curriculum, we feel that we are progressing in the right direction (although this is not the only one) in educating for medical informatics. Based on several investigations (e.g. [21]) and our experience, we can see the benefits for medicine and health care of having dedicated trained medical informatics specialists at university level. We agree with Shortliffe and Perreault: "....schools are beginning to realize the need for professionals trained specifically at the interfaces among medicine, computer science, and related disciplines such as statistics, cognitive science, health economics, and medical ethics. .... It is exciting to be working in a field that is gradually maturing and that is having a beneficial effect on society...: medical informatics" [23].

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