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Reflections Towards the Future of Medical Informatics

A Farewell Lecture after Almost Half a Century of Medical Informatics Activities

Reinhold Haux
Peter L. Reichertz Institute for Medical Informatics of TU Braunschweig and Hannover Medical School, Germany

Summary

Objective: To provide guidance on the future development and role of medical informatics, or biomedical and health informatics, in form of reflections.

Method: To report on the author's previous activities as a medical informatician, which spans almost half a century. It began in 1973 when he started to study medical informatics. In 1978, more than four decades ago, his professional work started. He retired at the end of summer semester 2021. This was the occasion to prepare this farewell lecture.

Results: In twenty reflections, thoughts are presented on professional careers (R1 – 'places'), on medical informatics as discipline (R2 – 'interdisciplinarity', R3 – 'focuses', R4 – 'affiliations'), on research (R5 – 'duality', R6 – 'confluences', R7 – 'correlations', R8 – 'collaboration'), on education (R9 – 'community', R10 – 'competencies', R11 – 'approaches'), on academic self-governance (R12 – 'autonomy'), on engagement (R13 – 'Sisyphos', R14 – 'professional societies', R15 – 'respect', R16 – 'tightrope walk'), and on good scientific practice (R17 – 'time invariants', R18 – 'Zeitgeist', R19 – 'knowledge gain', R20 – 'exercising').

Conclusions: It has been a pleasure for me to participate in medical informatics activities for almost fifty years. During that time, there have been significant advances, including in medicine and in informatics, and also in medical informatics itself. And now it is the turn of others. While keeping in mind that tradition is not preserving the ashes, but passing on the fire, this report with its reflections may be of some help.

Keywords

Medical Informatics; Biomedical and Health Informatics; Research; Eucation, Academic self-governance; Engagement; Good Scientific Practice

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1 Introduction

1.1 About this Manuscript

When the regular term of a professor ends, and the new professional life phase as a professor emeritus is about to begin, it is a tradition at German universities to give a so-called farewell lecture (in German: Abschiedsvorlesung). My farewell lecture was first presented on September 22, 2021, at TU Braunschweig in German [1]. In addition, I had the opportunity to give this lecture also in English on October 16, 2021, in Athens, Greece, during ICIMTH (International Conference on Informatics, Management, and Technology in Healthcare) 2021. This manuscript is an updated edited written version of the farewell lecture in English.

This English version started from the German version in [1], which I first translated and to some extent modified, supported by the DeepL program [2]. Then, Casimir Kulikowski kindly read the first version and suggested edits to my German-biased English, which developed into the present manuscript.

Please note that the German manuscript is more extensive, especially with the inclusion of a commented poem and nine appendices. Some details related to these appendices in [1] will occasionally be referred to here. As the German manuscript has been published in GMS MIBE, the official journal of the German Association of Medical Informatics, Biometry and Epidemiology (GMDS) - an Open Access journal - the German manuscript and its appendices can be easily accessed.

1.2 Objective(s) and Method

One objective of this farewell lecture is to reflect on future developments and on the role of medical informatics as a discipline. The manuscript contains twenty reflections, related primarily, but not exclusively, to medical informatics. These reflections may be of primary interest to readers.

In order to set the context for as well as to explain and elaborate on these reflections, it seemed necessary first to report about my work as a medical informatician. This part of the report might be of less interest to readers. Reporting about my work was both, method and another objective.

Please note that in this farewell lecture I will once again use the term medical informatics in its wide, comprehensive sense ([3], p. 256, and section 2.2 in this manuscript). Others may prefer to call this discipline biomedical informatics, or health informatics, or biomedical and health informatics or yet something else [4, 5-8].

My reflections on the future are presented after almost half a century of medical informatics activities, which I began studying almost fifty years ago in 1973. In 1978, more than four decades ago, my professional career started.

Do I really report on *my* activities? Actually, this is not possible, because I have always collaborated with others. Many people I have met during these almost five decades have shaped me. I have learned from them and I am still learning today. If I mention achievements here, then these people have helped to achieve them.

Unfortunately, many things can only be touched upon here and must be presented in a simplified manner.

1.3 But First . . .

But first: I would also like to use this farewell lecture to ask for apologies ...

- ... to all those whom I have offended,
- ... or whom I have treated inappropriately or unfairly, and possibly with unintentional arrogance or deprecation.

I do well remember such situations, where this was the case, and where there was no opportunity to ask the persons themselves for apologies. And besides, there will have been such situations, in which I would not have recognized this at all. At least I would like to now express that I have become aware of such situations, which I regret and for which I, humbly, wish to apologize.

1.4 Perspectives

To address reflections on the future of medical informatics, I will attempt to characterize my activities as a medical informatician from several different perspectives:
as major perspectives:

- research (subject, methods) and
- education (teaching, curricula)

and as further secondary perspectives

- academic self-governance,
- engagement and
- good scientific practice.

Before presenting the reflections from these perspectives, I will refer to my professional life phases. In addition, it made sense to characterize medical informatics as a discipline. Both these, and reflections on them, will be presented in section 2.

2 Reflections on My Professional Life Phases and on Medical Informatics as a Discipline

2.1 Professional Life Phases

My professional life phases are shown in Figure 1 as an annotated directed graph. A chronological tabular presentation can be found in Figure 2. The upper part of Figure 2, naming the universities where I have served at, is in all other figures. Both figures are simplifications. A more detailed list can be found in [1], appendix 2, a report, including the names of those who strongly influenced my professional development, in [10].

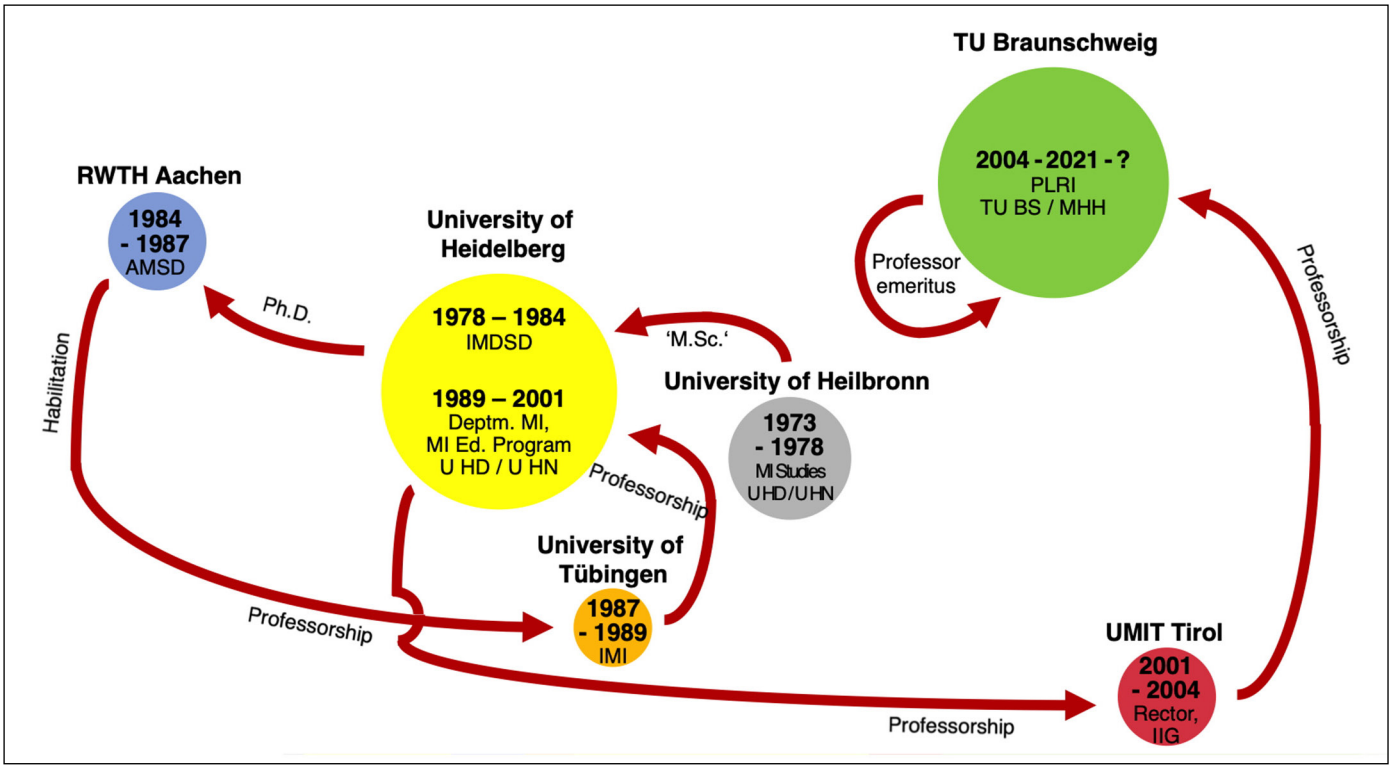

Fig. 1 My professional life phases presented as an annotated directed graph. Nodes: Size proportional to time periods, positions are relative to the universities' geographic locations.
AMSD: Department of Medical Statistics and Documentation, H HN: Heilbronn University of Applied Sciences, IMDSD: Institute for Medical Statistics, Documentation and Data Processing, IIG: Institute for Health Information Systems, IMI: Institute for Medical Information Processing, MHH: Hannover Medical School, MI: medical informatics, PLRI: Peter L. Reichertz Institute for Medical Informatics, RWTH Aachen: RWTH Aachen University, TU BS: TU Braunschweig, U HD: University of Heidelberg, UMIT Tirol: UMIT TIROL – Private University for Health Sciences and Health Technology.

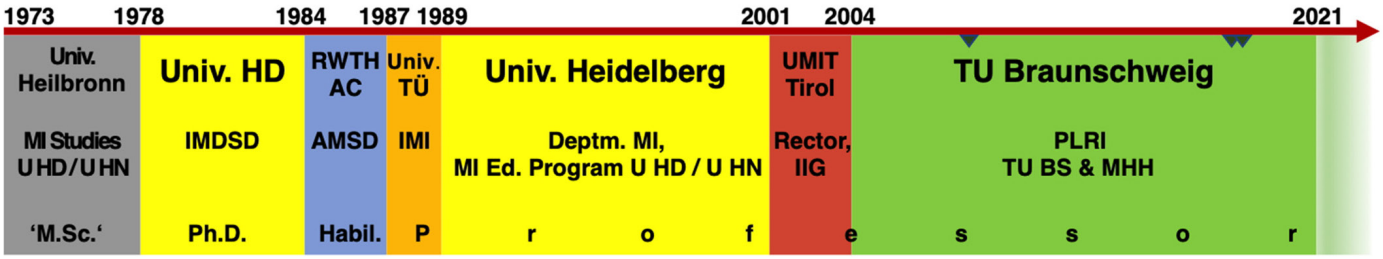

Fig. 2 My professional life phases presented in chronological order. Abbreviations same as explained in Figure 1. Left triangle under the time axis: foundation of PLRI, middle triangle: passing on the Braunschweig deputy directorship of PLRI to Professor Deserno, right triangle: passing on the executive directorship of PLRI to Professor Marschollek.

My professional life began in the 1970s. Both socially-politically and scientifically-technologically, these years were considerably different when contrasted to the 2020s of today. There existed a western and an eastern bloc, separating Europe by an iron curtain, and dividing Germany into two states. There were still no PCs, no Internet and no e-mail communication. Punch cards were a common medium of processing data. With the advent of computer tomography, there was considerable progress in medical imaging diagnostics; however, it would take more than another decade before magnetic resonance imaging came into clinical use. Life expectancy at birth was 71 years in Germany and 57 years worldwide; today it is significantly higher at 81 and 72 years, respectively [11].

During this period, a new discipline, computer science was established worldwide and also early in Germany. The German term for computer science is Informatik and for medical informatics Medizinische Informatik. So in this linguistic use there is a much closer relationship between the terms than in English. In this article I will use the terms computer science and informatics as synonyms. I was fortunate to be accepted into one of the first [12], if not the first, medical informatics programs in the world as student, the medical informatics program offered jointly by the University of Heidelberg and by the Heilbronn University of Applied Sciences, which begun in the winter semester of 1972/73 [13]. Those of us who were studying these new informatics methods and tools, literally felt we were at the beginning of a new age, an age which is now being called the digital age or the age of the information society, with its great potential contributions for medicine and health care.

Reflections

R_1 *– '**places**':* *Moving to different institutions turned out to have been good for me. Things that were taken for granted, be it in methodology or in the interactions with others, were put into perspective; one's own horizon became broader; together with a better appreciation of things that were previously simply taken as assumed. From this experience, I believe that changes in careers should be supported, or facilitated, also in an international context.*

2.2 Medical Informatics: the Discipline and its Objectives

Medical informatics, or biomedical and health informatics (as per the note in section 1.2), is concerned with the systematic organization, representation and analysis of data, information and knowledge in biomedicine and health care. Its objective is to contribute, across borders, to high-quality, efficient, as well as to affordable health care for all people worldwide, and to progress in the sciences [3]. I will comment on the insertion "across borders" in R_{15} (section 3.4). In terms of methods and tools, medical informatics can be considered closest to computer science. In terms of its objectives, it belongs to medicine; and, as with probably all medical disciplines, it is concerned with the health of people.

Reflections

R_2 *– '**interdisciplinarity**': Medical informatics is part of the medical/health sciences and of informatics/computer science. The field is highly interdisciplinary, which may include multi-disciplinarity and range to trans-disciplinarity (e.g., [9], [3], p. 258]). This requires interaction with other disciplines of medicine and the health sciences as well as of informatics/computer science, both in terms of methods and tools as well as in terms of the objectives to be achieved. In addition, there will often be further exchanges with other disciplines. People working in medical informatics must be able to work inter-disciplinarily and in teams. This interdisciplinarity, which is, as far as I can see, particularly evident in this field, should be taken into account and promoted in medical informatics education as well as in the work of medical informatics institutes.*

R_3 *– '**focuses**': A question that has arisen again and again, at least since my professional activity as a professor, is whether medical informatics at universities should be lived as an 'experimental and observing' discipline or also as a 'practicing' discipline. In other words, should medical informatics institutes at universities experimentally investigate and prototype new methods and tools and observe and evaluate their application in the practice of health care with scientific methods, but not participate in the practice themselves? In this case, medical informatics at universities would be an experimental and observing discipline, as most disciplines with their research institutes are at universities. Or should medical informatics at universities also contribute to the practice of health*

care, as is the case in some engineering sciences, for example, or as is the case for many clinical disciplines in which research, education and patient care are regarded together as a unity? Contributing to practice could mean that digital diagnostics and therapeutics are also offered through these institutes or that they are also responsible in managing information systems of university medical centers. Both variants have been tried and become established worldwide in a wide variety of forms, reflecting the wide range of professional and cultural practices involved. This question is a central one and should be revisited again and again in the future as societies, health care practices and technologies evolve.

***R_4 – 'affiliations'**: If medical informatics belongs to medicine and to informatics, to which faculty within a university should a medical informatics institute be assigned? I recommend an assignment to both faculties, medicine and informatics, as has been achieved, for example, with the establishment of the Peter L. Reichertz Institute at TU Braunschweig and Hannover Medical School. Other organizational solutions, up to an independent faculty in a university are plausible, too, and have also been implemented. Such affiliations are not self-evident. They have to be promoted in the sense of a well-practiced interdisciplinarity now and in the future.*

3 Reflections from Different Perspectives

3.1 Research

In order to characterize my activities from a research perspective, it made sense to describe them both in terms of subjects - the medical objective or the medical discipline - and in terms of methods. A summary is shown in Figure 3. The naming of larger research projects, in which I was involved (in different roles, at the beginning as a research assistant, later as a project leader or as principal investigator), attempts to illustrate the relationship of subjects and methods. These are only a few of many other research projects I have participated in, which unfortunately cannot be included here. In terms of subjects, I was involved in research in various medical disciplines, both in diagnostics and therapy, as well as in health information systems. Concerning methods, my work has mainly concentrated on the topics listed in Figure 3.

The relationships of subjects and methods must be presented here in a simplified manner, and by example.

- In the Priority Program Viral Hepatitis Research, the primary objective was to develop a better understanding of viral liver diseases and their diagnostics, therapy and prevention. For this purpose, it was also necessary to develop data analysis methods that adequately modeled the structure and distribution of the data collected in the priority program's empirical studies [14,15]. For this purpose, linear rank tests had to be devel-

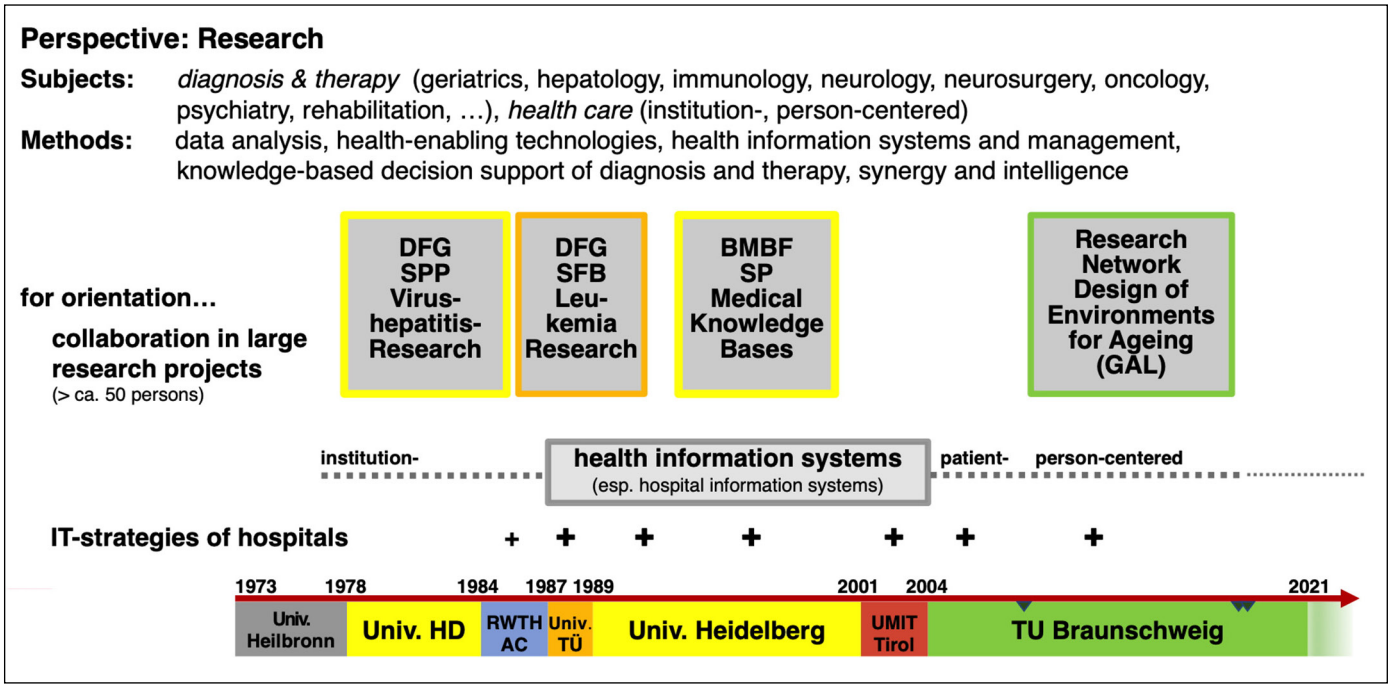

Fig. 3 Perspective: Research.
BMBF: Federal Ministry of Education and Research (in Germany), DFG: German Research Foundation, SFB: Collaborative Research Center, SP: Research Focus, SPP: Priority Program.

oped and examined with respect to their 'precision', which, among other factors, took into account the multicentricity of the studies as well as the special typing and distribution of the data [16, 17]. In the context of developing and implementing software for data analysis, proposals were made on how to construct statistical analysis systems, systems that were becoming established at that time [18]. In terms of its medical subject, the research project contributed to the fact that viral hepatitis diseases can now be treated in a much more differentiated and successful manner. In terms of methods, however, contributions were also made to improve the design of clinical studies and the analysis of data.

- In the Collaborative Research Center for Leukemia Research the primary focus was on differentiated diagnosis and therapy for patients suffering from leukemia. Of importance was a further differentiation of the typing of the human HLA system combined with a better understanding of the immune reaction in the transplantation of bone marrow. Concerning its methods, semantic data models were developed that could take into account these clinical as well as molecular data with their structural relationships in such a way that these representations would be useful for both diagnosis and (transplantation) therapy [19]. This research project has contributed to the fact that leukemia diseases can be treated much better today. It has also contributed to how biomedical data with their specific structural characteristics can be better represented and thus more adequately analyzed.
- The Research Focus Project on Medical Knowledge Bases concentrated on knowledge-based diagnosis and therapy support in clinical medicine, based, among others, on formally representing medical knowledge about diseases, combined with inference methods suitable for clinical practice. Concerning medical subjects, this research was related to a range of medical disciplines. Concerning methods, it concentrated, among others, on how to appropriately integrate knowledge-based decision support into computer-supported hospital information systems, and how to better integrate decision-support functionality into health care processes [20]. This also included access to medical knowledge at the clinical workplace [21]. Today, access to medical knowledge at the clinical workplace and knowledge-based diagnostic and therapeutic support have become a matter of course in probably all medical disciplines. This research project contributed to a better understanding of how clinical documentation and hospital information systems have to be designed in order to make good use of knowledge-based decision support, which is important for the quality of health care.
- The Research Network 'Design of Environments for Ageing' focused on investigating and providing answers on whether new information and communication technologies can contribute to supporting, or even improving the quality of life, health and self-sufficiency in ageing societies through new ways of living and new forms of care. Due to increasing life expectancy – which while very positive, is frequently related to increasing illness and chronic disease – the subject was about quality of life ('independent living') and about suitable, contemporary approaches for health care of geriatric patients or, more generally, senior citizens [22]. Concerning methods, questions arose as to how health-enabling technologies could be suitably constructed – for the persons themselves, for their relatives (family members or other close persons) or for professionals and institutions involved in health care (e.g., outpatient nursing staff, geriatric hospitals) and how personal environments, in particular homes (as 'diagnostic-therapeutic spaces') could be suitably included in care processes. Of particular importance were trans-institutional information system architectures and infrastructures, which can also use newly-available sensor technologies for tasks of prevention and diagnostics, while taking into account data protection and informational self-determination [23, 24]. This research should have contributed to a better understanding of how trans-institutional care processes should look like and how assistive technologies can be used and contribute to the quality of life and adequate care of senior citizens. This contribution refers to a better understanding for both persons from 'subject-related' disciplines such as geriatrics or gerontology and for 'methodological' disciplines such as informatics or engineering.
- Research on health information systems dealt with adequate architectures and infrastructures of information systems for supporting or enabling health care as well as on methods for their management. Especially at the beginning, in the 1980s and 1990s, the emerging use of connected computer systems with corresponding application software was in the foreground, related to hospitals, and mainly to university hospitals [25]. Gradually, research was added on patient-related care across institutions, up to the current level of person-related health care that includes prevention and everyday living [26].

Medical informatics at universities can be involved not only in research and education, but also in the practice of health care (recall R3). This involvement with practice took place in my case with health information systems, specifically with hospital information systems. In this context, for example, seven frame¬work concepts for information processing have been developed for the University Hospitals in Aachen, Tübingen, Heidelberg and Innsbruck as well as for the Braunschweig Medical Center, which were of importance for the architecture and infrastructure of their information systems as well as for the hospitals' investments. The framework concepts are listed in [1], appendix 5.

Can one illustrate the effort and scope of these research activities? It would probably be best to report about the results of each research project, including what was and was not achieved. This would be excessively lengthy, so not possible, but details can be found in the publications in which this research is reported [27]. By the time of the present farewell lecture, 684 such papers

had been published, in which I was either co-author or author. Of these, 423 were submitted to refereed journals and conference proceedings and accepted for publication. Fifty-two of the papers were books or monographs. About three quarters of these (502 of 684, and 330 of 423) were papers on research. As mentioned at the beginning, medical informatics is an interdisciplinary discipline, including teamwork. There were 865 co-authors from medicine, informatics and other disciplines involved in these 684 publications. For young scientists, such research projects are often associated with their doctoral thesis. For 56 of these dissertations I served as supervisor.

Reflections

R_5 – 'duality'*: The duality of medical objectives and informatics methodology, described here, is probably typical for most medical informatics research. Living this duality successfully is challenging and motivating at the same time. In future, 'real' medical informatics research will probably only exist as this duality. As already mentioned in R_2, it is important to give scientists the opportunity to practice this duality.*

R_6 – 'confluences'*: At least for me, but probably also for many other colleagues, topics as well as methods relevant for dealing with these topics were changing. Contents and methods are constantly in 'flow', so to speak, sometimes back and forth. A broad methodological as well as content-related basis was important for my research and must, in my opinion, be recommended. For example, skills in study design and data analysis acquired in the priority program on viral hepatitis research were very helpful for our research on long-term home monitoring of geriatric patients with mobility-impairing fractures using health-enabling technologies in the GAL research network – at first glance a completely different topic. Boundaries of disciplines were and are changing. They should always be reviewed and adjusted. For an adequate orientation, the definition of medical informatics as a field, given here, may serve as orientation.*

R_7 – 'correlations'*: For medical informatics research, it became important for me to realize that health care has to be seen as an integral part of life: Health care starts when people are born (or even earlier) and ends when people pass away. Sometimes, the relative share of health care in our lives is small, but sometimes it becomes greater. Health care includes life situations such as prevention, treatment of acute and chronic diseases, or care. It is provided by health care professionals, such as physicians or nurses. It is also provided by informal caregivers (relatives, such as family members or other close persons).* Last, but by no means least, the persons themselves, for which health care is provided, need to be considered, may they be healthy or may they be patients. *Settings where health care takes place are professional settings such as hospitals, medical offices or nursing homes, but often also settings such as the home or the workplace or other places of a person's daily life such as vehicles ([26], [28], chapter 1). Medical informatics research has focused primarily on health care delivered by physicians and nurses in professional care settings. This research remains important, both in diagnostics and therapy, and for information systems. The methodological and technical progress achieved in recent decades now also makes it possible to consider health care in other life situations, with other groups of people and in other settings in our research, and thus to take further into account that health care is an integral part of life. This applies both to research on the care processes themselves, and to research on gaining new insights into diseases and their diagnosis, therapy and prevention.*

R_8 – 'collaboration'*: The entities to be considered in medical informatics research that are involved in health care have also broadened over time in the context of scientific and technological progress. In R_7 health care professionals were mentioned as well as patients/persons and informal caregivers. In the future, I believe that functionally comprehensive, 'intelligent' machines as well as other living entities such as animals and plants should be increasingly included. Their collaboration, which could be described as collaboration of natural and artificial intelligence, can be of importance for the health care of people [29, 30].*

3.2 Education

3.2.1 Teaching

At universities, research and education are of equal importance for institutes such as the Peter L. Reichertz Institute for Medical Informatics. As my activities in medical informatics, comprising almost half a century, were always at universities, I was able to participate in the education of several thousand students, first as research assistant and later as professor. Still, it makes sense to report and reflect here first on research and afterwards on education, since good education at universities often correlates with corresponding research. This is by far not only true for courses in master programs, but also already starts with introductory courses in bachelor degree programs. Figure 4 summarizes the courses I was involved in during my professional life phases. A comparison with the research foci in Figure 3 will show that methods, used or developed in research projects, and the content of the courses overlap. For several courses textbooks were written. They are presented in Figure 4 and listed in more detail in [1], appendix 6. Three of these textbooks are available in several editions.

How can one illustrate efforts and the scope of these teaching activities? It would be best to report on the design and on the lessons learned for all these courses. This is again too extensive to be realistically possible. But let me briefly outline two events, as they may be somewhat unusual and as they were important educational activities to me.

- Since 2001, for 21 years, courses on strategic information management of health information systems were given in the summer semesters to informatics students from 4 countries, the so-called Frank-van-Swieten Lectures [31]. In Figure 4 the course is denoted as "Health Information Systems (M.Sc.)". During these two decades, the Universities of Amsterdam, Antalya, Braunschweig, Heidelberg and Leipzig as well as UMIT TIROL were involved. Our textbook on health information systems was used at all universities (latest edition: [28]). Exercises were the same, too. At the end of each course, the students met at one of these universities (since 2020 and until

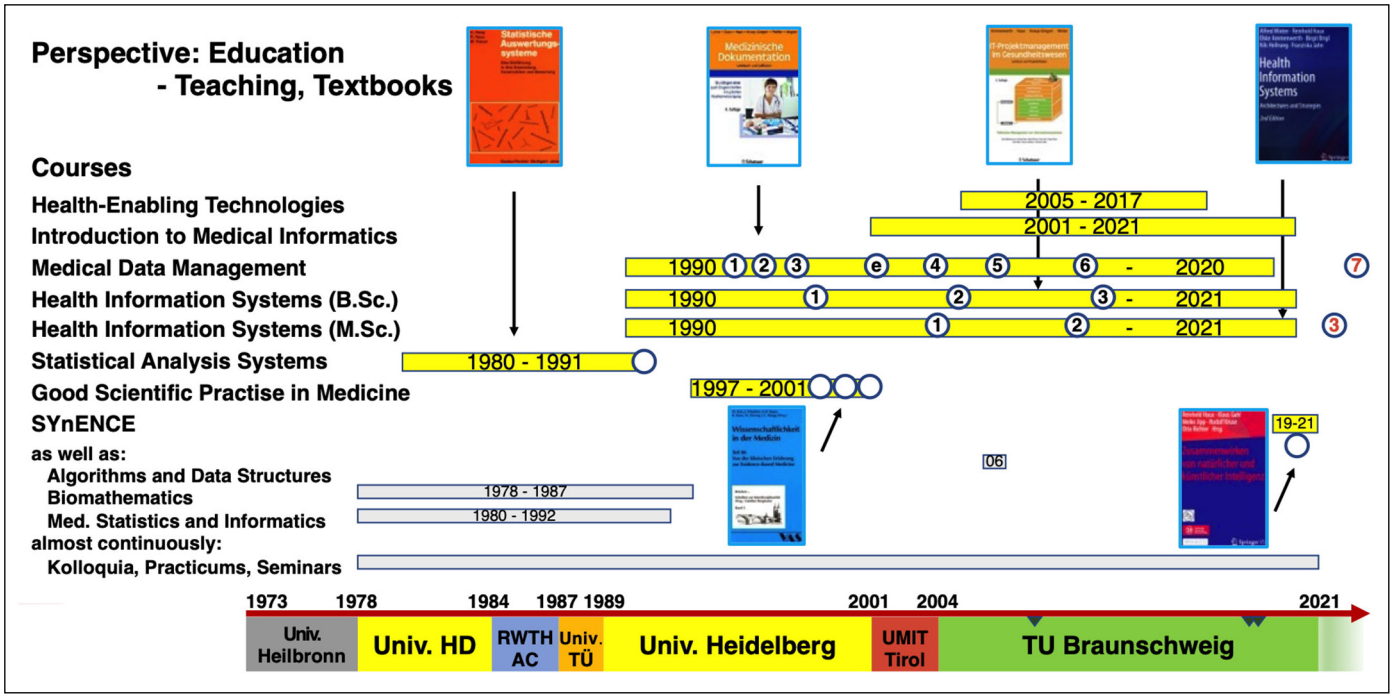

Fig. 4 Perspective: Education – teaching, textbooks. Timelines highlighted in yellow: 'core courses', timelines highlighted in gray: other courses. The circles show black numbers for published editions, red numbers for editions in planning or in progress, and e for an English-language edition of the German text book on medical data management.
SYnENCE: collaboration of natural and artificial intelligence.

now, unfortunately, only virtually due to the pandemic), shared their results on the respective information systems of the medical centers at their universities and reported on them. In my opinion, this exchange across national borders was of great importance.

- Since 1990, we have offered practicums, which could be taken after the health information systems course at the Bachelor's level [32]. Students had the opportunity to apply their knowledge, acquired in the course, in the practice of health care. This was typically done under intensive supervision in one of the medical centers and with the participation of our clinical partners. In total, as a professor, I was involved in 48 practicums, of which 27 were in Heidelberg, 3 in Innsbruck and 18 in Braunschweig. Hopefully, the students learned a lot through getting in touch early with the practice of health care. And, hopefully, they were also able to recognize the relevance of informatics for medicine and health care in these practicums.

For us as university professors, participating in education also means supervising theses and preparing, conducting and assessing examinations, in each case with considerable support from the research assistants working at the institutes. I was the first supervisor or first examiner for 264 theses, 70 of which were Bachelor, 60 Master and 134 Diploma theses. I have conducted 1,520 oral examinations. The number of students who were examined in writing for my courses is only recorded for TU Braunschweig, i.e. for a good half of my time as a professor, where there were 3,253. It should be emphasized once again that such examinations and also the holding of courses is always an institutes' achievement with many participants. Even in the 1,520 oral examinations, I conducted, there was nearly always one additional assessor.

Reflections

***R_9 – 'community'**: Even though this factor is not medical informatics specific, it is important for me to mention it in the reflections. University means a community of teachers and students, in their joint objective to search for new knowledge and for truth [33]. How can today's universities create good conditions for this community? It is a topic that must be considered and discussed over and over, again and again.*

***R_{10} – 'competencies'**: Education at universities has to be oriented towards the needs of our students and their future work, be it in practice, in research or whatever mix of the two. Which knowledge and which skills are to be taught in medical informatics? There are international recommendations on this for medical informatics [34]. Yet, in addition, this also needs to be reassessed and determined again and again. In the case of university education, medical informatics institutes should also be able to combine this teaching to a large extent with their current medical informatics research or with their activities in the practice of health care, of course in Master level courses, but, if possible, also already in Bachelor level courses. This is demanding and by no means easy to*

implement. On the other hand, at least in my opinion, medical informatics education at universities should have this ambition in the interest of our students.

3.2.2 Curricula

Education can also include planning and revising of educational programs with their contents and curricular concepts. In my professional life, such work was particularly intensive with the medical informatics program at Heidelberg/Heilbronn (in my second Heidelberg phase [35,36], but also already as a student) and with the establishment of the medical informatics programs at UMIT TIROL at that time [37]. Later on, the medical informatics curriculum at TU Braunschweig these curricula were further developed and revised [38]. In Figure 8 these activities are presented under "Curricula at Universities". During all these curricular developments I could learn from and contribute to national and international activities on recommendations for medical informatics education. This will be reported in section 3.4.

Reflections

***R_{11} – 'approaches'**: How can one become a medical informatician? There are two approaches to medical informatics worldwide: a so-called health care-based approach and a so-called informatics-based approach ([34], p. 111). In case of a health care-based approach, students often first study medicine or another program in the biomedical and health sciences, either with a focus on medical informatics or pursuing an additional degree, later achieved. The informatics-based approach is offered through dedicated medical informatics programs or within computer science programs with the respective specialization. Both approaches, the health care-based and the informatics-based approach, are important and should be offered and implemented.*

3.3 Academic Self-Governance

Academic self-governance is an important component for independence and for the quality of research and education. Figure 5 contains the most important tasks and responsibilities I have been assigned in this context.

Reflections

***R_{12} – 'autonomy'**: Even if work in research and education is central in all universities, participating in academic self-governance is an important 'secondary matter', which for some colleagues can also become the 'principal matter' at times. Independent universities form an important, though by no means always easy, component of our societies. Academic self-governance is not specific to medical informatics. As with all other disciplines, engagement of colleagues in self-governance should be expected and demanded.*

3.4 Engagement

"Tradition is not preserving the ashes, it is passing on the fire" [39]. In science, too, tradition is preserved and sustained, when it

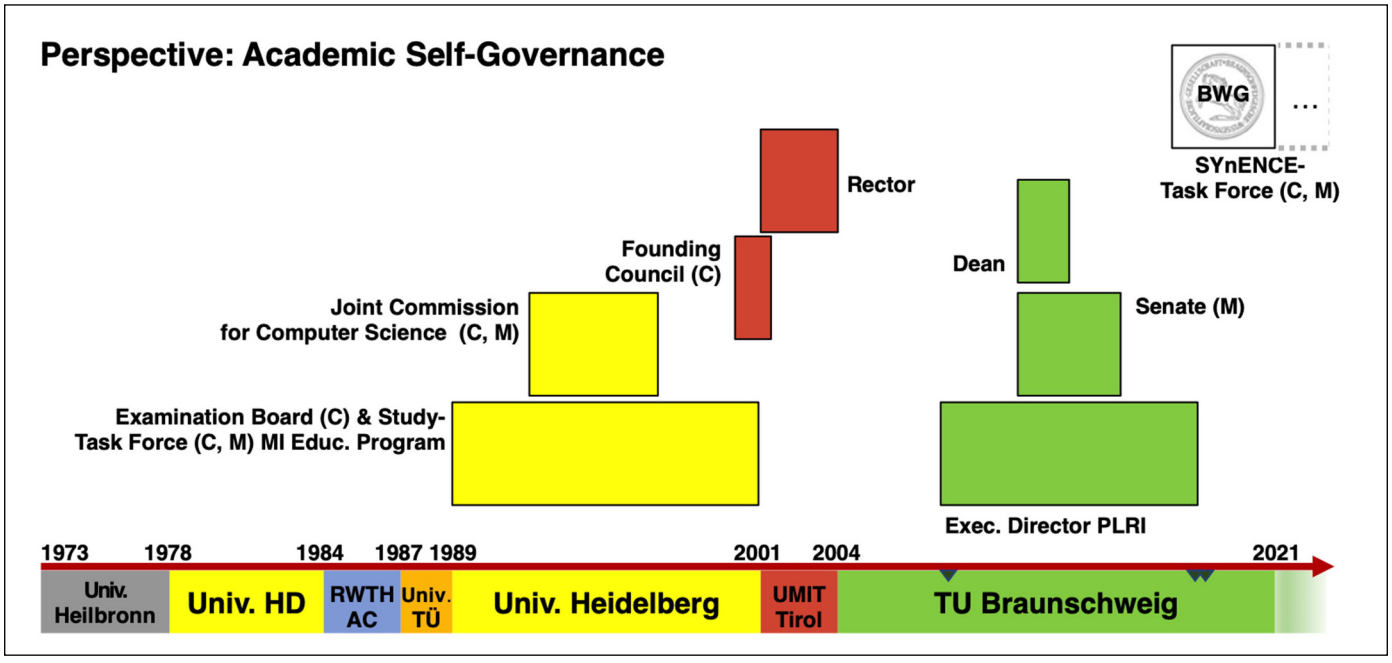

Fig. 5 Perspective: Academic self-governance.
The detailed name of the SYnENCE Task Force: task force on synergy and intelligence: technical, ethical and legal challenges of the collaboration of living and non-living entities in the age of digi¬talization (SYnENCE), BWG: Braunschweig Scientific Society, C: Chair, M: Member, MI: medical informatics, PLRI: Peter L. Reichertz Institute for Medical Informatics.

is possible to extend existing knowledge, and not to rest on its preservation or even idealization. And so I did not only want to learn existing knowledge in order to preserve it and to pass it on. I also wanted to create new knowledge and to apply both, existing and newly developed and acquired knowledge.

In many disciplines, engagement comprises not only one's own field, but also the sciences as a whole as well as society more broadly. Professional societies or associations, respectively, play a central role in the shaping of disciplines. The professional societies that are important to me are listed in Figure 6. In all these societies, I had the opportunity to exchange knowledge and to collaborate. In addition, I was elected for various responsibilities or was asked to take on certain tasks (see Figures 6 and 7). Please note that comments in Figure 6 here only refer to the part about professional societies. Comments on the other, more German-related parts can be found in [1].

Of particular importance in my case were GMDS [40] and IMIA [41]. GMDS, the German Association for Medical Informatics, Biometry and Epidemiology, was founded in 1955 and is probably the oldest medical informatics society worldwide. With its about 2,000 members, it is probably one of the five medical informatics societies with the largest number of members internationally. IMIA, the International Medical Informatics Association, is the world body for biomedical and health informatics and an association of medical informatics associations, such as GMDS. It was founded in 1967 and is an official non-governmental organization of the World Health Organization (WHO) for many years. Under the auspices of IMIA, an academy of science was established in 2017, the International Academy of Health Sciences Informatics (IAHSI) [42]). The Academy serves to share knowledge as well as to provide expert advice to organizations such as WHO, knowledge and advice that is not influenced by vested interests. Its members, appointed to the Academy after a rigorous selection process, often hold high academic positions in their respective countries. Quite a few belong to national academies of sciences. It was a special honor that I was allowed to serve IMIA from 2007 to 2010 and IAHSI from 2017 to 2020 as President [43-50].

Organizing conferences and editorships are other facets of engagement. As shown in Figure 7, this was closely associated with the above-mentioned professional societies. The most important editorships I was responsible for included the journal Methods of Information in Medicine (2001-2015, this journal is the official journal of IMIA, EFMI and official international journal of GMDS, [51]) and the IMIA Yearbook of Medical Informatics (2001-2007, [52]). Appendix 7 in [1] contains a detailed description of the conferences mentioned in Figure 7 and my respective roles there.

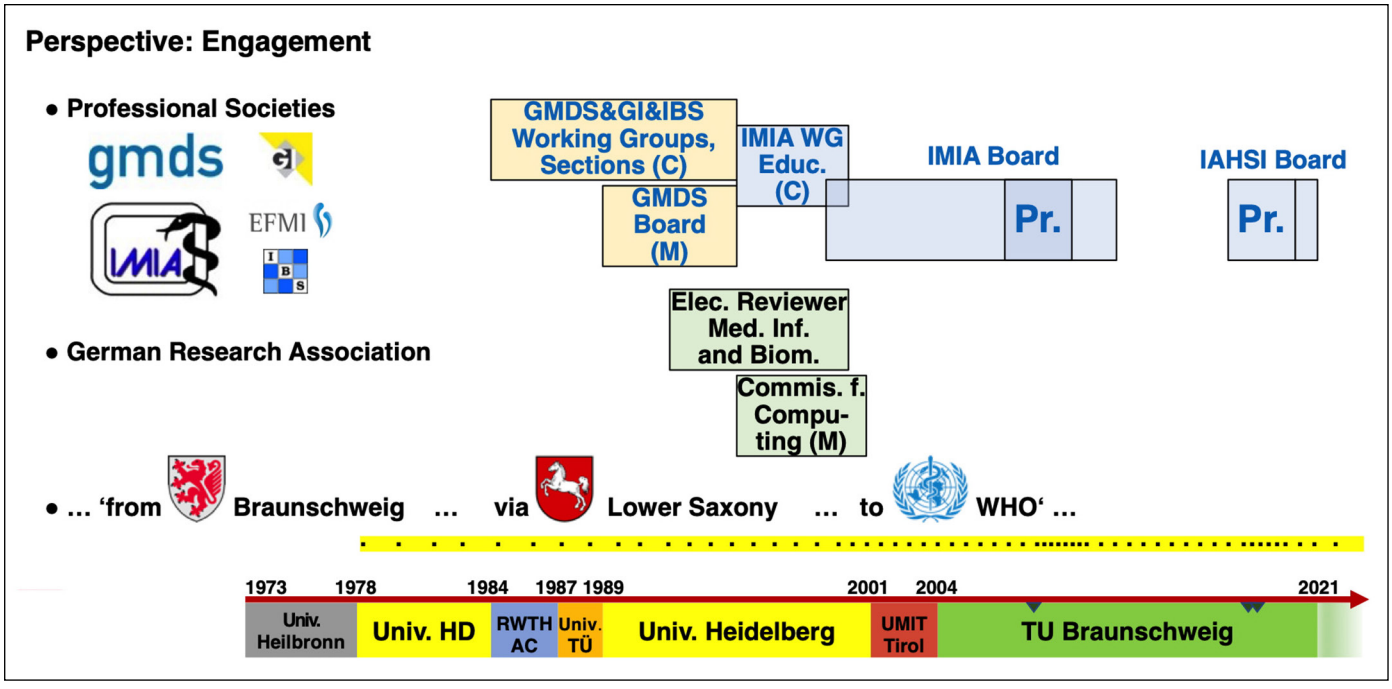

Fig. 6 Perspective: Engagement, part 1.
C: Chair, EFMI: European Federation for Medical Informatics, GI: German Informatics Society, GMDS: German Association for Medical Informatics, Biometry and Epidemiology, IBS: International Biometric Society, IAHSI: International Academy of Health Sciences Informatics, IMIA: International Medical Informatics Association, M: member, Pr.: president, WHO: World Health Organization.

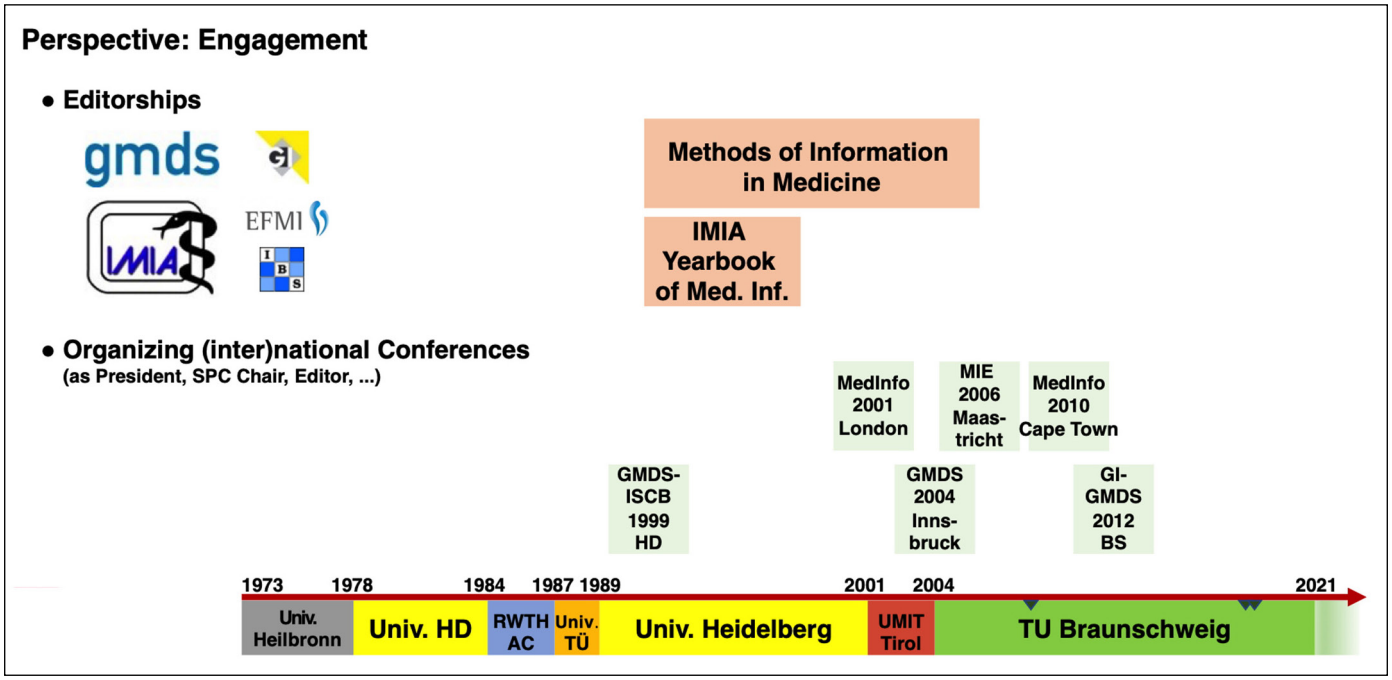

Fig. 7 Perspective: Engagement, part 2. Explanations of abbreviations in Figure 6.

Another task assigned to me included leading (1991 and 1999) and contributing (2009) to the development of national (1991 [53]) and international (1999 [54], and 2009 [34]) recommendations on medical informatics education. The international recommendations, translated into several languages, have been an important guide for many countries in the introduction or further development of their medical informatics curricula. Figure 8 lists these recommendations together with the curricular tasks described in section 3.2.2. Both tasks could benefit from the other.

Reflections

R_{13} – 'Sisyphos'*: Something that is especially true in research and in engagement: Not everything is successful. Not everything is positively received and supported, no matter how well justified and prepared it may be. This can be very disappointing. In addition, an important characteristic in research is doubt. We, who are in research, have to question results and conclusions and have to try to verify and/or reproduce them. This doubt is necessary and also concerns our own research. What could have been done better? Shouldn't I have achieved more? Why was it not possible to achieve a goal that would have made an important contribution to methodology or to good health care? Why was I not able to convince decision-makers involved and motivate them to act, despite good arguments and good preparation? As I said, this doubt is a necessary prerequisite for science. What have I learned over time? What can I recommend? Live with doubt and accept that not only successes, but also failures are perhaps sometimes necessary to make further steps in life. If you are convinced about your methodological or subject-related goals, do not give up and try again.*

R_{14} – 'professional societies'*: Independent professional societies, such as GMDS, EFMI, and IMIA in my case, represent an important component at the national and international level, both in scientific exchange and in scientific advice not driven by interests, such as the recommendations on education mentioned above. Another field of activity for such societies could be the 'fair' communication of knowledge of its members, possibly together with university libraries and publishers. Fair means, among other things, that copyrights and rights of using knowledge remain as far as possible with the scientists who have developed this knowledge. Fair can also mean that this knowledge, which is often publicly funded, is then freely available to the public in Open Access [55]. Professional societies are successful when the scientists of the disciplines are engaged in them. This commitment, be it in working groups, in task forces or whatever else, will continue to be of great importance in the future.*

R_{15} – 'respect'*: Again, regarding the objective of medical informatics stated at the beginning: "Its objective is to contribute, across borders, to high-quality, efficient, as well as to affordable health care for the people in our world and to the progress of sciences". Why was it important for me to include "across borders"? IMIA's statutes state: "In order to achieve IMIA's objectives to contribute to the health and quality of life of the people in our world through dissemination and use of informatics for high-qual-*

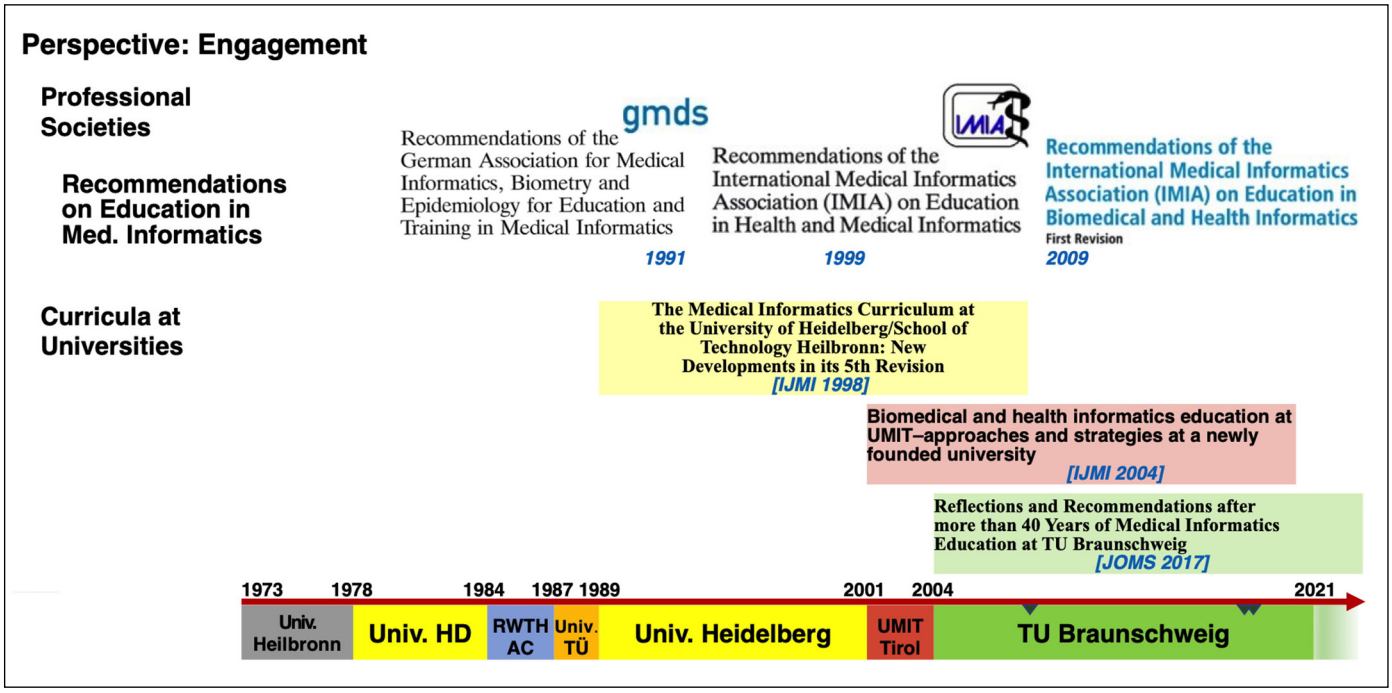

Fig. 8 Perspective: Engagement, part 3 and education: curricula.
The publications visualized in the figure (from left): recommendations [34,53,54]; curricula: [35-38].

ity, efficient health care and public health and for high-quality research in biomedicine and in the health, information and computer sciences, IMIA's members collaborate in a tolerant and peaceful way, transcending nations, cultures, and political or social structures" [56]. When these statutes were approved in 2010, I felt this statement was self-evident. During the last few years, national egoisms and hate-filled speeches, even from leading politicians, have increased. And 'fake news' – an unacceptably trivializing term for nothing but lies – became an accepted way to push interests for some persons. Since then, I have become aware again that respect is by no means self-evident and that one must continue to be committed to it, especially in a field with the ultimate goal of improving human health, as in medical informatics. And maybe it is easier to live this jointly with supporting our discipline's values like health, dignity, participation and informational self-determination, a discipline, which is, perhaps, comparatively less driven by national politics and interests as it is about the health of the people for all our world.

***R_{16} – 'tightrope walk'**: With digitization, we are on a path that has brought a lot of good, but which also has considerable 'side effects' living together. Like almost every discipline, medical informatics can bring about positive things but also cause harm. This has always been and must continue to be considered. Especially when, as in the case of health-enabling technologies, we find ourselves to a considerable extent in the most private areas of people. Even if, for example, it is the clear wish of senior citizens, suffering from frailty, to be supported by 'intelligent homes' so that they can continue to live in their familiar home and social environment, the extent to which informational self-determination is still possible must be considered and weighed. Questions on appropriate information and communication architectures as well as ethical and legal issues play a role here. Medical informatics research and practice must take into account this balancing act and draw attention to it. These are questions about how societies – that is, we – should approach them, how laws should be adapted, and how new ways of living and care can be implemented.*

3.5 Good Scientific Practice

Good research and good education are closely related to good scientific practice. It is important for me to mention this as a perspective. What good scientific practice means is by no means easy to define [57]. This was also shown by the series of lectures on good scientific practice in medicine mentioned in section 3.2.1. Moreover, it can vary from discipline to discipline.

Reflections

***R_{17} – 'time invariants'**: What are important time-invariant criteria for good medical informatics research? As in many other disciplines, medical informatics research can be evaluated according to whether it is relevant in terms of its objectives, and original or novel in terms of the methods and tools developed or applied. If research projects meet both criteria - originality and relevance - then it is medical informatics research. If research projects meet only one of these characteristics, then one should reflect, on whether it is really medical informatics*

research. It could also be research in another field of medicine or informatics. If projects do not fulfill any of these properties, then one must reflect on whether it is research at all ([3], p. 260).

***R_{18} – 'Zeitgeist'**: During these nearly five decades in medical informatics, the priorities for research, education, or practice that were considered important by politics, scientific organizations, or university leadership have changed and varied considerably, as have the indicators or criteria used for evaluation. What was considered of little importance or even criticized at some times could be seen as particularly important at other times and gain public recognition. In contrast, the objectives of medical informatics and the principles of good scientific practice have remained essentially invariant [57]. They formed, so to speak, time-invariant cornerstones for good research and education as well as for adequately contributing to the practice of health care. Of course, there were and are other time-variant indicators for research. At present, these are, for example, the impact factors or H-indices for publication achievements of scientists or their acquired third-party funds ([3], p. 262). It makes little sense to ignore the respective time-variant indicators completely, especially since they can characterize research performance, although in a limited way, as in the case of the indicators mentioned. Moreover, at least in my experience, a primary focus on the important, time-invariant criteria of originality and relevance is positively correlated to such time-variant criteria.*

***R_{19} – 'knowledge gain'**: How should research projects in medical informatics be designed in order to achieve the best possible gains in knowledge? This question is difficult and there is probably no simple and unique answer. During my professional career, I have noticed that the approaches to this question differ both within the various fields of medicine and informatics/computer science and, in particular, between medicine/health sciences and informatics/computer science themselves. While in computer science, for example, experimentation is frequently used to test findings under various conditions, in medicine empirical studies are often necessary for this purpose, where it is essential that findings are obtained on a sufficiently large number of entities. This is related to variability. For medical informatics research, it seems important to me to conduct more well-designed empirical studies in the future. This could be the case, for example, in the evaluation of health-enabling technologies or other digital diagnostics and therapeutics. An assessment of diagnostic relevance or therapeutic efficacy based primarily on technical feasibility or on individual case studies would not do justice to this complex issue in medicine and health care. A knowledge gain based on comparative intervention through controlled studies, preferably by means of randomized trials, should also be further used as an important method in medical informatics.*

***R_{20} – 'exercising'**: How can good scientific practice in medical informatics be exercised? How do original and relevant research questions emerge? Unfortunately, these questions are extremely difficult to answer. They concern curricula of medical informatics programs and then especially how medical informatics research is practiced in our university institutes and in professional societies. In this respect, institutes and professional societies are likely to play an essential role in exercising good scientific practice. Their focus and organization must be continuously reviewed and adapted.*

4 Meta Reflections and Related Work

This kind of farewell lecture – a report on activities with one's reflections on a discipline – may be rather unusual. Why did I want to give a farewell lecture? And, to give it and write it down in such a way? Couldn't I have used the energy and time, invested in this farewell lecture, in a different, better way? I have no good answer to these questions. And indeed, I had long thought about whether I should give it and write it down like this. But the urge to do so was so clear that I had to do it, so to speak.

At the beginning I had mentioned that this report does not only cover my previous activities as a medical informatician, but also those of many other people. Perhaps in this farewell lecture I am reporting on behalf of others. And perhaps this report and the reflections can stimulate a debate and initiate further discussions.

Related work, at least from my point of view and of which I am aware, has been published by Alexa McCray [58], Casimir Kulikowski [59], François Grémy [60], Jan van Bemmel [8, 61, 58], and Peter Reichertz [6] as well as in [62], where many personal stories of medical informatics colleagues have been documented. Further reflections from my perspective can be found in [3], [63] and [64].

Also, while I have presented general reflections on the future of medical informatics here, I have not proposed priorities in medical informatics research. On the one hand, I had already done this elsewhere [63]. On the other hand, I believe that such priorities should now be elaborated by colleagues from subsequent generations of medical informaticians, especially as they are the ones who will be able to implement them.

5 Final Remarks

Since I am giving the farewell lecture as a professor at PLRI, I feel it is important to mention five professorial colleagues. The first three: Peter Leo Reichertz (1930-1987), the institute's namesake, Dietrich-Peter Pretschner (1938-2007), my predecessor, and Herbert Matthies (1949-2021), my colleague on the MHH side when PLRI was founded. How wonderful it would have been if they could have attended. I think they would be very pleased with how the Peter L. Reichertz Institute stands today, under the leadership of the two new directors of the PLRI sites in TU Braunschweig and Hannover Medical School: Professor Thomas Deserno and Professor Michael Marschollek (more details in [1]).

It has been a pleasure for me to participate in medical informatics activities for almost fifty years. During that time, there have been significant advances, including in medicine and in informatics, and also in medical informatics itself. And now it is the turn of others. To those who are responsible

today, I want to suggest: Do not try to copy your role models. Based on what you have experienced and learned, and in considering relevance and originality, you, too, should preserve and sustain tradition by letting new things emerge. Do not be fully complacent in preserving some ashes, no matter how beautiful they may look like in some Zeitgeist! Remain thirsty for new knowledge! Have the will to pass on the fire, in being aware of existing knowledge, in improving it and in gaining new knowledge. Before me, there was a very long line of persons, passing on the fire in this way. Then I had, and still have, the opportunity to participate. And now there is again a long line of committed persons. To see this continuity is good and also helps one to remain humble.

Acknowledgements

I would like to thank all those who have accompanied me in my life phases, described in this farewell lecture, and who will continue to do so, whether professionally or privately or both. There are too many to mention here by name, as important as it would be to me. Some persons who have influenced my professional development in a special way are mentioned in [10]. And in my personal life I would like to mention my family and, especially, my wife Katharina.

I would also like to thank all those who helped in making this farewell lecture happen during difficult pandemic times, in Braunschweig as well as in Athens, and for the publication opportunity of the manuscript in major venues.

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Correspondence to:
Prof. Dr. Reinhold Haux
Peter L. Reichertz Institute for Medical Informatics of
TU Braunschweig and Hannover Medical School
Muehlenpfordtstr. 23,
38106 Braunschweig, Germany
E-mail: Reinhold.Haux@plri.de
www.plri.de