Healthcare Transformation with Informatics and Artificial Intelligence
J. Mantas et al. (Eds.)

doi:10.3233/SHTI230512

Is Medical Informatics a Scientific Discipline or Just Applied Computer Science?

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Abstract. The aim of this paper is to investigate whether and how medical informatics can claim to have a sound scientific basis. Why is such clarification fruitful? First, it provides a common ground for the core principles, theories and methods used to gain knowledge and to guide the practice. Without such a ground, medical informatics might be subsumed to medical engineering at one institution and to life sciences at another institution or might be just regarded as an application domain within computer science. We will provide a succinct outline of the philosophy of science, after which we provide an application of the related notions in order to decide the scientific status of medical informatics. We justify viewing medical informatics as an interdisciplinary field with a paradigm that can be formulated as "user-centered process-orientation in the healthcare setting". Even if MI is not merely applied computer science, it still remains uncertain whether it will attain the status of a mature science, especially without comprehensive theories.

Keywords. Kuhn; paradigm; philosophy of science; design & process orientation

1. Introduction

Scientific publications in medical informatics (MI) journals portray several major topics, such as care coordination, clinical documentation, artificial intelligence, clinical decision support, implementation of health information technology, mobile health, along with others [1, 2]. Such overviews and critical appraisals are important in order to grasp current challenges. However, on the one hand, it is difficult to keep track of the developments and current topics just by referring to scientific publications. On the other hand, these are not indicative for the scientific character of MI [3–5]. Private IT companies in the health sector are dealing with similar topics. The central question is: what differentiates scientific approaches from non-scientific ones, and can MI be considered a scientifically rigorous field, with well-defined theories and methods [6]?

Why is such clarification fruitful? First, it provides a common ground for the core principles, theories and methods used to gain knowledge and to guide the practice [7]. Without such a ground, MI might be subsumed to medical engineering at one institution and to life sciences at another institution, or it might be just regarded as an application domain within computer science. Justification of a discipline and differentiation from other disciplines are only possible if these cores are laid out clearly. Second, the

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clarification of doing science in contrast to applying science becomes possible. Developing prototypes can be part of a scientific practice if it involves theory-based ex-ante hypotheses (e.g., how should a prototype be developed and what is to be expected from its use) that can be evaluated [8]. If no hypotheses are formulated, descriptions of the effect of prototypes amount to nothing more than case studies. Third, related to the second point, the object area can be separated from methods development, allowing to justify a discipline even if it does not have developed its own methods.

There exist some articles on the scientific character of MI (see above), but there is still no conclusive answer to whether MI is a science and to related questions about its principles and methods [9]. Here, we will provide some concrete considerations, which have to be deepened by further investigations. In the next section, relevant aspects of philosophy of science will be outlined succinctly, after which we provide an application of the philosophical notions in order to decide the scientific status of MI. We conclude with the potentials of future developments of MI in terms of its scientific outlook.

2. Methods

The task of the philosophy of science is to formulate and justify claims with respect to the unique nature of scientific knowledge. Concretely, it outlines how scientific evidence is achieved by systematic observation, experimentation, and logical analysis. In addition to that, philosophy of science describes what reliable and intersubjectively testable explanations are. Two important notions in this connection are “theory” and “paradigm”, and both help in assessing the character of a discipline. Some definitions of the former term are “a system of ideas or statements held as an explanation or account of a group of facts or phenomena (e.g., concerning the use of IT in medicine) … a hypothesis that has been confirmed or established by observation or experiment, and is propounded or accepted as accounting for the known facts a statement of what are held to be the general laws, principles, or causes of something known or observed” [4]. In other words, theories are condensed and systemized forms of observations concerning the explanatory relation between state of affairs. They guide scientific investigations by pointing to those facts that are not covered by (valid) theories. A hypothesis is a way to formulate how the gap can be filled without yet being supported by data. For describing hypotheses, facts and their relations, a standardized vocabulary and models that represent entities by their significant properties are useful, for instance, with the help of ontologies.

According to Thomas Kuhn, two sorts of paradigm can be differentiated: a paradigm in a broad sense designates all the common techniques, values and approaches shared by the members of a scientific community [10]. In a narrow sense, it represents a single element, e.g., a theory or a method, with which problems should be approached. In medicine, a shift from the “clinical judgement” to the “evidence-based medicine” paradigm in the broad sense could be observed in the last decades. A paradigm in the narrower sense is visible for data science, with its emphasis on deep learning. As it is possible to establish a paradigm by using knowledge from other scientific fields, different forms of research boundaries are possible [11]. (i) Multidisciplinarity means that knowledge from different disciplines is used, while the perspectives, concepts or methodologies do not merge together into one scientific approach. (ii) In interdisciplinary approaches, knowledge from the different academic disciplines is integrated into synthetic solutions and allow that each discipline affects the output of the other while individual contributions tend to be obscured by the joint product. (iii)

Transdisciplinarity in addition to that, leads to holistic approaches and aims at universal scientific explanation, which lead to new disciplines such as Quantitative Biology, Nutrigenomics or Quantum Biology. No matter which type of science is established, the scientific character is represented by generally accepted theories and methods as well as by a unifying worldview that defines the central problems of a scientific discipline.

3. Results

MI is highly connected to computer science, which deals with the application of formal methods for processing data and information. For this purpose, computer science develops information and communication technology applies them in the context of databases, distributed systems, networks, software engineering, programming, knowledge representation, signal processing, image processing, and others. In addition to that, MI is dealing with the peculiarities of healthcare data in terms of the complexities related to their interpretation. It can establish a paradigm with appropriate theories only if the healthcare data requires genuine approaches and methods, whose elements will probably stem from different scientific fields. When methods and models of several scientific disciplines are integrated into new ways of universal scientific explanation – such as psychology, sociology, statistics, or applied ontology – for guiding health data modeling, a transdisciplinary character of MI would be given. If MI is rather using the insights of several scientific disciplines to provide solutions for health care data with the aim of increasing efficiency, then MI could be seen as an interdisciplinary endeavor. In that case, the paradigm does represent a universal worldview for the scientific discipline involved, but an independent theory building that draws inspiration from other fields. One implication for MI as an interdisciplinary discipline that heavily relies on computer science might be the fact that it reflects its impact on the real-world differently than computer science. Both disciplines create those artifacts they investigate, but MI seems to be more aware of this fact due to the necessity of justifying its existence as an independent subject field in contrast to computer science. In other words, when a computer scientist and an MI researcher model the same domain, the latter should know why her expertise is distinct from the former by reflecting the consequences of her results on the practice and on the different ways she can interact with the stakeholder involved.

As no universal scientific explanation for the scientific disciplines involved are established in MI, we assume that MI is on the way to be an interdisciplinary field of study. This is corroborated by Hasman et al. [12], who state “most of the authors agree that biomedical informatics is an interdisciplinary field of study where researchers with different scientific backgrounds alone or in combination carry out research the essence of biomedical informatics, as opposed to related disciplines, lies in the modelling of the biomedical content”. Now, what kind of theories and paradigms are or should be borrowed from other disciplines? The process-oriented design paradigm in the organizational development field related to sociotechnical systems is a very promising candidate (a paradigm in the broad sense), although it is not commonly referred to as such [13]. MI research is mainly a creative activity of defining a problem in the context of health data, of working out solutions and of fitting it into human contexts by considering several goals that go way beyond validity concerns. As designing is drafting and shaping at the same time, most MI research projects take the form of developing prototypes. By intentionally adapting such a paradigm, it becomes possible to develop theories and hypotheses that reflect the state-of-the-art and the potential future developments in MI, which probably also lead to the development of genuine methods.

Defining the core of MI using the design paradigm is not new and was suggested by Patel & Kaufmann [14]. However, they did not relate this idea to concepts of philosophy of science and emphasized that the design process should be qualified as local, as only parts of the domain of interest is covered by such activities. One major problem of this perspective is the definition of boundaries: when does an activity belong to the design paradigm? What kind of criteria should be put in place? The same problem can be observed in user-centered design approaches that are not unified via universal principles, but only by being assigned to a list of positive examples. Without theoretical guidance, such assignments can neither be validated nor extended to broad paradigms. Of course, there is an interdependence between the practice and theorizing this very practice, but it is exactly the accumulation-view represented by statements such as “the collection of particulars (derived from specific systems and approaches) advanced by individual institutions leads to the development of notions that are nearly universal, and they in turn shape the discipline and guide development” [14] that Kuhn has criticized vehemently. A scientific discipline is defined by a unifying worldview that provides a model for problems and solutions, as well as for its boundaries. This is precisely what can lead to a dispute about what constitutes an adequate demarcation for a discipline.

Due to the heterogeneity of MI, the design-oriented view cannot cover all the research activities in this domain, e.g., developing tools for record linkage or applying deep learning to annotate image data. However, not all of these activities are inherently related to MI, they could be carried out by data or computer scientists, and the pressure to justify why MI should be responsible for these activities is high [15]. In other words, all endeavors outside the paradigm gain their justification primarily by being tied back to that very paradigm. The added value of an MI researcher applying deep learning lies in their design perspective, which includes the ways and means for collecting data, the processes related to the training and testing of the neural net as well as those related to the practical use of the system. Stakeholder involvement at some stage is essential for an MI researcher, who takes the technical and social impacts of her digital intervention into account [16]. It is crucial not to give up one expertise for the other. An MI researcher should work on problems at different levels, technically as well as organizationally.

An alternative to the broad design paradigm could be one in the narrow sense, for example, clinical decision support. One major problem with such a paradigm is that it easily gets stuck with developing and applying tools, without providing an integrative perspective. As a result, it is difficult to link activities that are not related to clinical decision support to such a paradigm. We assume that narrow paradigms only function in scientific disciplines that do research on method developments, for which it is beneficial to have different communities that focus on special problems and techniques.

4. Discussion

Our proposal of regarding the design paradigm in the organizational development field as effective in MI has some caveats. First, it stems from a different scientific field and could be assessed as inappropriate for MI. Yes, this would be a risk, if no adaptations to the specificities of the biomedical domain were made and if it would be not clear enough that this paradigm can have very different formulations, such as user-centered process-orientation, which corresponds to the semantic difference between statements and propositions. Second, validation of final results developed according to the paradigm could be difficult. Evaluation is difficult in MI, as there are many different levels to be considered, at the very least the technical and social ones. However, that could be one way of adapting the paradigm, for example, by relying on criteria and methods developed for implementation studies. It is important to note that it is not primarily the utility of the solutions that is peculiar to science, but the theory-based methods and approaches with which they are achieved. Third, one can deny that a paradigm is sufficient to justify the scientific character of a discipline. We concur with that view and emphasize again that theories must be developed in order to achieve the status of a mature paradigm.

Even if MI is not merely applied computer science, it still remains uncertain whether it will attain the status of a mature science, especially if it is merely chasing after technological developments in a multidisciplinary way. MI must be able to assess technologies and develop such assessments on the basis of theories. If MI becomes nothing more than a collection of tools, it will make itself superfluous in the long term and will be replaced by other subjects that will both develop and assess new technologies. A highly acute desideratum is the evaluation of generic artificial intelligence with its disruptive impact on healthcare. We currently lack explanatory theories for the meaningful use of these technologies, so the pacesetters are currently actors outside MI. We often notice that MI experts are only experienced as project managers in practice. As management consultants can do this at least as well, it becomes vital to actively challenge this perception and emphasize that both technical and organizational knowledge are essential and interconnected through a design and process perspective in MI contexts.

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