How to Evaluate Scientific Thinking in Medical Education

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To propose how to **evaluate** scientific thinking presupposes to know **what kind of science** future physicians will need. It is safe to assume, however, that different modes of scientific thinking than the ones inocculated by today's medical education will be required (if scientific thinking is inocculated at all). Thus, before engaging into the topic of evaluation proper one has to find some answers to the what-kind-of-questions, which can be enlarged to the question of what kind of scientists should be enabled to deal with what kind of health priority. This will lead to the more technical question as to what kind of data should be collected to evaluate scientific thinking in medicine.

In an attempt to reduce the complexity of the what-kind-of-question, two essential kinds of scientific problems and - in consequence - of evaluation data will be described. These two kinds represent somehow an overstatement; reality is much less black and white.

What kind of scientist

Medicine obviously needs practitioners, practitioners of health care delivery and practitioners of medical research. For both one can envisage two modes of scientific competence:

1. Practitioners able to reproduce the stories of human sciences, researchers able to multiply already accomplished or ongoing projects.

2. Inquisitive human science workers.

The first individual is in the possession of knowledge which has been transferred to him or her. This is in line with the sad tradition of a majority of educational systems. On the one hand, practitioners are vocationally trained. On the other hand, they have at their disposition some textbooks, prescription books and the dangerously overfilled storages of their memories. They could be described as craftsmen equiped with a scientific encyclopedia.

For this kind of clinician, a patient with epigastric pain occuring two hours after meals, relieved by food or antacids, is someone who needs an endoscopic examination of the upper gastrointestinal tract. Under consideration of the findings there is a choice or combination of medical, dietetic or surgical treatments; it is all in the textbooks. Or, if this clinician feeds these and some additional findings into a well-programmed computer, he or she will exactly be told what to do.

This type of person will not only be found among practitioners delivering health care but among research workers as well. In most instances, what is loosely called research, is no more than the application of stored knowledge.

Drug trials may serve as an example. There are excellent textbooks - one might call them prescription books - describing exactly how to organize, apply and evaluate the double blind study design. Or, a research worker's predecessors in the same institution have probably done the same thing ..., all of it can be reproduced.

Thomas Kuhn (1) has called this "normal science". Normal here also means being satisfied with non-obstrusive, conformist knowledge, in keeping with the rules and regulations of the established research communities.

The second individual, the inquisitive worker, is much more difficult to describe. It is not implied that this type of research worker will reinvent the sciences. To quote the educator Paolo Freire (2), this type of person has "rewritten" what he or she has read. Such a person will then have the tendency to see the object of his or her scientific interest in a wider context than the one traditionally established in a given discipline or speciality.

As a clinican confronted with the same patient suffering from epigastric pain, she or he might be primarily interested in the personality and the situation of the patient, in his very subjective concerns and perspectives, his way of life and his reason to seek help here and now ..., although this second person might have exactly the same knowledge about the nosology, pathophysiology, management and prognosis of peptic ulcer.

The problem to be solved for the first individual is a physiclogical/biochemical/morphological disturbance: Autonomous nervous imbalance, endogenous production of gastrin, secretion of hydrochloric acid and of pepsin, breakdown of the mucosal resistance, ulceration. In the second case one deals with an unknown person in an unknown situation, a psychosocialneuroendocrinological constellation connected with the before-mentioned physio-chemical peculiarities, which can be considered as the tip of the iceberg. One hundred years ago, the first view must have presented much more of a scientific aspect than

it does today. By the accumulation of scientific knowledge, a problem to be solved has become a task to be accomplished.

An analogous research situation is concerned with unknown and unexplained situations. The way to set up the research process is not described in any prescription book.

There was no intention to denigrate the first standardized situation in any way. Everybody has to deal with such situations during most of one's professional activity. However, it should be stressed here that this does not involve scientific thinking. Thus, scientific thinking cannot be evaluated.

The difference between the two situations somehow coincides with Erich Fromm's categories of having and being. The Western society is overconcerned with consuming and possessing and knowledge makes no exception. Consuming knowledge in order to own it is the biggest obstacle preventing the development of scientific thinking. Another difference could be seen in the fact that reproductive scientific work tends to be analytic or reductionist: It originates as a given phenomenon or situation which then is dissected according to a known procedure. Imaginative and inquisitive scientific work more often deals with a context, which covers more than the primarily perceived problem situation.

Scientists and practitioners able to reproduce or to multiply will be comfortable with one or several out of the list of the subjects which make up a traditional medical curriculum. This list ranges from biochemistry, anatomy and physiology over some forty items to cardiology, orthopedics, psychiatry and the like. It is obviously impossible to attain competence in one or any number of these subjects in the course of basic education. For this reason the support of scientific creativity has been replaced by the provision of stories out of these numerous scientific subjects. At the level of evaluation one is then left to search in the students' memories for some fragments of these stories. It becomes evident that the question "what kind of science?" must be preceded by the question "science for what kind of health priority?"

Health priorities

Maintaining health in the face of

- war
- maldistribution of resources
- diesintegration of families
- stress at work/unemployment
- environmental threats
  - polution of air, water and
  - soil traffic
- addiction, consumerism

Restoring/improving health in

- old age
- prenatal/adolescent disorders
- mental/social disorders
- degenerative disorders
  - cardiovascular
  - musculosceletal
- (tropical) infectious disorders
- acute organ failure and injuries

Fig. 1

In trying to look into the future of the medical profession, one should put "maintaining health" in the first position and "restoring and improving health" in the second. By listing the major situations connected with health and with the major disorders of health characteristics for this society one specifies the field for which students have to be prepared, in this case concerning the scientific level. The question, whether and to what extent a medical student has to be engaged in molecular biology or psychoanalysis, depends on the priorities encountered in today's circumstances of health and health disorders (Fig. 1). If there is no such requirement, one should happily drop these subjects from any medical curricular make-up. One should break with the misfortunate tradition to define educational goals on the basis of subjects. Subjects are artificial constructs emerging more from the evolution of the health professions than from the panorama of health and health disorders.

On the basis of these preconditions one finally arrives at the technical questions of evaluation:

What kind of evaluation data to collect

The choice of categories of data is quite limited:

- scores of multiple-choice tests
- scores of essays and interviews
- observation and analysis of clinical and scientific work

Still, a world of difference separates the two extremes: clean numerical figures at the top, descriptive and qualitative statements at the bottom. The benefit of objectivity or assumed objectivity shines on the one side and the ghost of subjectivity lurks on the other. However, one obviously cannot get through the clean objective way in the case of scientific thinking; it is too complex a process to be reduced to multiple choices. One should not overlook the trivial fact that the evaluation of scientific thinking can only take place if scientific thinking is included in the process of learning. Unfortunately, this doesn't usually take place. It takes place during the interaction in problem-based tutorials, in which scientific instruments are needed to get at solutions, i.e. when problems are put in a sufficiently wide context to imply the use of scientific methods.

Since the introduction of the McMaster University MD-programme in Hamilton, Canada, such sessions have become components of an increasing number of undergraduate medical curricula. It is obvious that informal and highly relevant evaluation is going on in these tutorials. An education consisting of a representative sample of problems to be solved could cover all the essential scientific domains needed in practice and research. However such informal evaluation does not necessarily cover the need for the legitimization and the documentation of the competences attained.

A comprehensive evaluation of medical clinical competence	**Time schedule**	
1. Collection of data by candidate - interview - physical examination - requesting investigations	candidate 45 min.	observers 45 min.
.... and review of additional information	2 hrs.	
2. Orientation/Information of patient by candidate	10 min.	10 min.
3. Presentation of case by candidate to the observers	15 min.	15 min.
4. Consultation of experts by candidate	10 min.	10 min.
5. Questioning of candidate by observers	10 min.	10 min.
6. Self-assessment of performance by candidate	10 min.	10 min.
7. Preliminary assessment of clinical performance by observers and information of candidate	(15 min.)	15 min.
8. Formulation of questions concerning scientific aspects of case	10 min.	10 min.
9. Preparation of scientific essay (homework)	2-5 days	(.....)
10. Presentation of scientific essay and of theses. Assessment SMACT (Scientific Method and Critical Thinking)	45 min.	45 min.
11. Evaluation and decision	(15 min.)	15 min.
Total:	5 hrs. + n days of praparatory work	3 hrs. 5 min. + preparatory work

Fig. 2

For this reason, a model evaluative procedure is presented in Fig. 2, which might allow to somewhat formalize the observation of scientific thinking and reasoning in the context of an overall assessment of clinical competence. Elements of such a model have been tested under several circumstances (3). It consists of the observation of all phases of clinical work (points 1-7), followed by the elaboration and the work-up of a scientific aspect of this case. Considerable time and effort will have to be invested in such a procedure. However, it might be worthwhile to consider this type of assessment at the expense of much of the evaluation procedures emphasizing recall of factual knowledge which traditionally accompany medical curricula. Moreover, it should be emphasized again that even such a complex but formal setting is second choice, a concession in order to legitimize formal decisions for promotion and licensure by distinct procedures which can be standardized to a certain extent. The main effort should go into making the learning process and its results more transparent and into integrating it with scientific thinking on the one hand and professional services on the other.

In summary one can conclude that scientific thinking has to be evaluated in the broad context of problem solving, which goes beyond the confines of disciplinary and reductionist scientific tradition. Those responsible for it have therefore to transgress the limits of their own more or less specialized subject. In addition, this type of evaluation involves time consuming engagement and observation. If this effort is not made, one will never know whether and how scientific thinking is taking place in those who are prepared for the medical profession, which in part is a scientific one.

Literature

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