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REVIEW PAPER

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The quality approach and fundamental research: Working towards a constructive alliance (Part I)

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Abstract The quality approach is being progressively used in scientific research and is likely to become a key point in the future. This article critically examines the applicability of the quality approach to fundamental research. A critical survey of the basic concepts of the quality approach is proposed (conformity to a reference, satisfaction of requirements and/or adaptation to use, planning and formalization). The need for quality in fundamental research is then discussed through a review of the scientific, economic and financial, human, social and environmental issues that research will face in the future. An attempt is made to demonstrate that the quality approach incorporates concerns and current practices of the scientific community which are not normally identified and labelled as pertaining to the field of Quality.

Key words Quality · Fundamental research · Basic concepts · Impact of quality

Introduction

The quality approach, which originates from the industrial and services world, is being progressively adopted by the research community. Various specialized institutions have published standards that apply to research (e.g. in the United States, the American National Standards Institute (ANSI)-project of norm [1] and the Department of Energy (DOE) [2]; in the Netherlands, NEN 3417 [3]) but the process of standardization is in its infancy. In the context of international competition, standards are used to discriminate between research laboratories: for example, obtaining European (or other) money for a research programme may depend in the future on the compliance with certain standards and/or certification of a laboratory. Quality is likely to become in a key issue the future of research. For this reason, direction of research of the Science of Matter part of the French Atomic Energy Commission (CEA), which carries out fundamental research across a wide spectrum of disciplines ranging from astrophysics, elementary particle physics, solid-state physics and chemistry to earth sciences has undertaken an in-depth examination of the appropriate standards and guider lines to be used in its activities. This action is part of a programme to implement the quality approach within CEA lead by H. de Kerviler, who heads the "Mission Qualité".

In the field of applied research, many organizations already rely on standards (e.g. the ISO 9000–9004 series; ISO, 1993, 1994 and 1997 [4]), in particular, when the use of a quality system is imposed by their customer(s). It is too soon to assess the actual impact of a quality approach on the "content" of the research in this area. But it does appear to have positive effects on the customer/supplier relationship and on the clarity of programme proposals submitted to research managers. In contrast, no systematic attempt to establish a quality system in fundamental research has been made.

The limited extent of quality implementation in science stems in part from the fact that the research community remains very stubborn to adopting the quality approach. There are two reasons for this:

1. Researchers feel that they already strive for quality in their daily work, and the proposed approach cannot provide more. Especially as quality practitioners use vocabulary and concepts that, due to their origin in the industrial world, are not always understood, and do not seem relevant or even appear unsuitable for fundamental researcher work. In fact, in this context, scientists to often refer to excellence and not "quality" as it is accepted by the quality control practitioners.
2. The quality approach is seen as the latest fashion in managerial projects, which wastes paper, is useless and time consuming. At the worst, it stifles the motivation and creativity of the most dynamic researchers who already have to work in a thicket of complex and bureaucratic procedures. This may not be "politically correct" to mention but it is, indeed, what people think in some quarters. In principle, researchers are naturally open to any approach aiming at continuous improvement, intrinsic to the development of science itself.

The researcher's mistrust of the quality approach often involves a basic lack of understanding which could be overcome by presenting serious and well-reasoned arguments if progress is to be made in this field, since the implementation of a quality approach in fundamental research can only be undertaken with the approval of researchers. This is particularly true as the research community is rich in strong independent personalities, attached above all to their freedom of action and, last but not least, who are often of a very high calibre.

My aim in this article is to contribute to the definition of the quality doctrine in the specific context of fundamental research. I therefore try to define a few general principles which, I believe, should form the foundations of any quality approach in this domain.

Basic quality concepts

In spite of the complexity of the subject and the variety of situations that can be met in practice, three concepts or principles appear to me to form the basis of the quality approach for any considered model and stage of a developmental process (quality control, quality assurance and total quality management). It is very important to discuss these concepts in relationship to the specificities of fundamental research to try and identify possible problems.

Conformity with a reference ("viewpoint")

First of all, quality is evaluated and if possible quantified with respect to a reference: this is the role played by standards. By definition, the greater the conformity of the process with the reference, the better the quality. Generally, it is not a question of conformity with a standard imposed from outside (in the sense where, e.g. behaviour within society must conform with the law) but conformity with a self-adopted standard. In quality, one states what one has to do and one does what one has stated. Any deviation, without necessarily being an anomaly, must be understood and corrected, where necessary. In this respect, standards such as the ISO 9000 series for instance are only general frameworks, based on organization procedures which must be adapted, in each company, unit, team, etc., to the specific local situation. We observe here a major difference, which is a source of many misunderstandings, between quality as understood by a quality control practitioner and quality in the usual acceptance of the term. Two questions appear relevant to me in this context with respect to fundamental research:

1. Are there recognized definitions and criteria, accepted by all professionals, which define what is science and what is non-science (or bad practices) ? In other words, is there a unique and invariable "scientific method" approved by all? And if not, can one be proposed? This fundamental question tackles difficult epistemological problems which are outside the scope of this article [5, 6]. Even if philosophers of science cannot agree on a definition of science, scientific research must satisfy basic criteria to be recognized as science by a peer review. These criteria include originality, reliability, reproducibility, principle of economy in interpretation of results (a famous principle known as the "Ockham's razor", from the fourteenth century English theologian, Guillaume d'Ockham), internal consistency and no flagrant contradiction with the fundamental principles and/or results considered as acquired, validation by peers, etc. Some of these criteria implicitly result from the quality approach, in particular, reliability, reproducibility and the validation of results (by a suitable procedure in each case) which clearly imply the concept of *traceability*. Traceability is a central requirement and key resource in the quality approach.
2. Is conformity with a recognized reference framework ("viewpoint") the sole criterion of scientific validity? If not, how can it be otherwise characterized? In reality, science is not limited by this conformity because it transgresses current knowledge, concepts, methods and practices [5–8]. If researchers were to remain in an exclusively "conformist" science, human and financial resources would be wasted to no purpose!

Basically, the quality approach in science involves clarifying the standard ("viewpoint") followed by researchers in a given field and conforming to it this is what philosophers of science call a "paradigm"). Researchers, in a given field, define the main focus of their activity without which, in theory, their peers would not be able to recognize the validity of their work. This can be, for example, the quality of the experimental data (reliability, reproducibility, etc.) or the data-processing program used, when modelling plays a major part in the research. The submission of the researchers' work to a major international journal (including the process of a "peer review") acts as an essential tool in the quality control of scientific information. One should note that deviations from the accepted standard can be perfectly normal and even intrinsic in "science in action". It is only a question of knowing when and why one can depart from accepted values and concepts. Quality in fundamental research is nothing more... and nothing less. In theory, every good researcher having learned how "to work properly" maintains a standard of quality. However, the scientific community is aware that there are regrettable drifts, sometimes difficult to detect, which can gradually erode the reputation of scientific research.

Moreover, with the increasing role of science in society quality in research is no longer the prerogative of researchers but concerns all citizens. Society demands the right to control science (in a suitable form) and researchers must accept the responsibility, including legal obligations, for their own research, thus affecting the work of the scientific community. This problem is already perceptible in biology focusing on the ethics of manipulating life itself but it is likely to become an issue in all fields of scientific research.

Satisfaction of requirements and/or adaptation to use

These concepts are rather easy to define when dealing, for example, with a manufactured object like a motor vehicle. In this case, the needs which must be satisfied are those of the customer, i.e. mainly, of the consumers: In the car industry the quality approach is centered on the customer/supplier relationship. Here, the customer is clearly defined (the person or entity who pays and who evaluates the rendered service) and the supplier is the industrial company. The quality of a product (usefulness) is defined in the specifications of the product. Quality, considered in this traditional manner, is objective and measurable.

On transposing these concepts to fundamental research at least two categories of problems appear:

1. Who are the customers of fundamental research? And how can a balance be found that will satisfy all those involved? The recipients and users of the results of fundamental research are different, in general, from the customers contrary to the case of manufactured goods, services or even applied research. The users (consumers) of fundamental research are mainly the researchers themselves. But it is quite clear that researchers must listen to society and take account of its expectations in the development of their work. This is a moral requirement but also, more prosaically, a requirement for their own survival in the medium and long term. Isolation from the rest of society is a danger which periodically lies in wait for those who are "elite". However, the recipients of science do not always formulate explicit needs. The international science "market" operates within restricted and highly specialized networks: the public does not directly consume the results of science but becomes aware of the impact of research only after a certain time lapse through popularization (a devaluated term that should be rehabilitated) or school and university education.
2. What does usefulness (quality) mean in terms of fundamental research? There are three levels of usefulness of scientific results. At the first level, researchers of a given community, being the primary "consumers" of their own products, need reliable results which they can use with complete confidence, i.e. high quality methods and results are regarded as a research acquisition. Procedures are gradually refined, so that the results and their presentation are in conformity. The requirements (scientific and editorial) for publication in scientific journals are variable and sometimes very high. A system of "referees", seminars and meetings, whose practices are codified, constitute the "habits and customs" of the scientific community guaranteeing a minimum (an optimum?) of quality. At the second level, the published results are of interest to scientists and technicians belonging to related disciplines or even other research sectors or industry. In all these cases, scientific knowledge must, traditionally, be published or available in conformity with the currently accepted standards. At the third level, that of the decision makers (economic, political, etc.), or the media and the public, the usefulness of scientific results obeys all other criteria (immediate intelligibility and utility, spectacular character, etc.) to which researchers are not accustomed and which at best, leave them perplexed. Paradoxically, a researcher's training and system of values can be a handicap to communication with the media. Nevertheless, in the future the research community will need to communicate with a wider spectrum of decision-makers and institutions, as well as with the media and the public.

Planning and formalization

Classically, in companies, the quality approach is a very structured approach in which the process in question is subjected to a thorough analysis and rationalization. Its construction, is that of a planned approach involving, in general, a thorough formalization. This traditional concept of quality, which corresponds to efficient practices, in particular in certain industries, shows major disagreements with the concrete reality of fundamental research. In fact, it is prejudicial to the formulation of a quality approach to which the researchers can subscribe. Three principal difficulties can be found despite the apparent similarities:

1. Any research programme, even the most fundamental, always starts with the definition of *an objective*. This is determined according to the state of knowledge in the field (the "research front"), the scientific capabilities of the group and an assessment, partially rational and largely intuitive, of the chances of success. However, even if researchers know what they are looking for... they can seldom predict what they will find! This is the beauty of science and, in addition, its usefullness for society is precisely here as it creates new opportunities or maintain open options and scenarios for appropriate political decision. The achievements, i.e. the performance of a system of fundamental research and the researchers themselves can only be properly judged a posteriori. Looking for consistent agreement between the objective and the result as a basis of evaluation is not relevant and often counter-productive.
2. There is a certain degree of *planning* involved in a research programme: a working plan is usually made, the various expected stages in a research topic are specified in an experimental or financing proposal, etc. This appears necessary and normal to all researchers. However, if a precise enumeration of the research programme and a highly detailed formalization of its progress is required, it is practically certain that this will be far from the reality of the research process and, from the researchers' motivation viewpoint, highly counter-productive. In many aspects, fundamental research cannot be planned: the path actually followed is observed and rationalized a posteriori.
3. Any research process encounters *deviations* or *anomalies* with respect to the anticipated development. However, the mission of fundamental research is not to correct deviations and anomalies but to understand why they occur. Anomalies and deviations often contain information which make it possible to transcend the state of knowledge, concepts and practices at a given time in the history of science. The question of anomalies is a traditional subject in epistemology.

The need for quality in fundamental research

Quality is essential in fundamental research not only for scientific and economic reasons but also because of the major impact science is having on society and the environment.

Scientific issues

The potential impact of the quality approach seem to me essentially linked to the formidable explosion of scientific information and its reporting, reproduction and transmission. It is well-known that "too much information kills information". Researchers need not only to seek information but also to be able to consider its quality in order to process it on a hierarchical basis. This is done by consulting the literature and by personal communication within a network of laboratories working on the same subject, even in the absence of an active collaboration. Scientific journals are evaluated by tools such as the impact factor, which are used as filters to process useful information, i.e. relevant and reliable hierarchically (see for instance [9, 10]). The rapid circulation of information on data-processing networks (Internet is already a well-established tool in state-of-the-art disciplines) without any control or censorship, risks upsetting these practices. But no precise and effective answer seems in sight. Control of the quality of scientific information at the production level needs to be tightened to combat the dissemination of misinformation.

Economic and financial issues

Science, whose costs are markedly increasing in many fields, faces financal problems. This problem is prevalent in countries where the majority of fundamental research is funded by public money (Mustar 1997). The issue of funding is critical since, according to the majority of economists, public expenditure must decrease to ensure a balance of the State budget. Thus, there is a problem of optimizing the allocation of relatively rare human and financial resources in research institutions (universities, large organizations), at all levels. "Hunting for waste", in all fields (procedures, organization, etc.) thus becomes an obligatory exercise if one wishes to maintain the resources necessary for competitive research at the national and international level. The burning question is whether the new organizational management of fundamental research is likely to improve the performance of the research system?

Human, social and environmental issues

I will develop this point for it seems to me that the relationships between science and society will have a decisive influence on the future of research, in particular in the fundamental sector.

The concern for the safety of the goods, people and the environment are primary issues in research, at least in the developed countries belonging to the Organization for Economic Cooperation and Development (OECD). For organizations which work in (or in connection with) the nuclear field, such as the CEA, safety is, in fact, a strategic objective. How can society and public authorities have confidence in the capacity of these organizations to guarantee nuclear safety in industrial circles, if safety measures are not completely ensured, in a transparent way, in their own installations? This is a sensitive question particulary regarding the financing of nuclear research.

However, the most significant element of fundamental research, which gives rise to the need for a quality approach, is its impact on society. In fact, since the beginning of the century, science (and technology which is closely associated with it) play an increasing part in modern society. Scientific discoveries have profoundly affected man's living conditions, his vision of the world (and even his fundamental values) as well as the organization of society. This tendency has accelerated since the beginning of the Second World War. Science is now institutionalized and closely linked to politics and concerns which are not exclusively cognitive [11]. We know for example the part played by science in the competition between the most advanced nations, both from the economic and military viewpoints, which justifies the implementation, by governments, of scientific and technological policies [12, 13]. In this respect, the most notable change in the perception of science by society is that its impact appears ambiguous. Science is no longer seen as having a systematically positive effect on society. Science is also seen as a risk (see for instance [14]).

Although researchers are not the only members of the community responsible for the impact of science on society, the traditional and comfortable ideal distinguishing ”pure“ research from applied science is increasingly inapplicable. Researchers benefit from the existence of the community and, as such, have a certain share of responsibility in the uses which are made of their discoveries. Moreover, a link is automatically established between science and applications when the latter are considered to be beneficial to society (e.g. as in the case of biomedical research for example). Why should this relationship be derived when the applications are potentially harmful to society? Due to the intention of researchers which is always assumed to be positive? However, in Law, the intention does not remove responsibility even if it modulates its breadth.

I evoke the Law here since the current evolution of the Western societies towards more judicial regulations and settlements allows us to predict that researchers, like all members of society, could be increasingly held responsible for their actions. This is a tendency which is advisable to anticipate and of which few researchers are yet aware. Up to now, science has been the exclusive domain of specialists (scientists). Differences of opinion and controversies have been dealt with within the scientific community, between scientists, i.e. between “qualified people” having similar educational backgrounds, sharing the same values and using, at least in theory, the same rhetoric where only “rational” arguments are admissible. However, society is lobbying for the right of inspection, and naturally, the media plays a central role in this process. For example, there is an exceptionally strong involvement of the recipients of the results of medical research on certain diseases, through the creation of associations, in areas usually reserved for researchers (meetings, programme agendas, etc.). It is not a question, of course, of systematically discussing detailed technical questions with the public: I no longer know who said, very justly, that the laws of physics are not voted by universal suffrage. But the confidence of society (which, it is recalled, finances research) can be granted only to a scientific community whose methods are indisputable (without prejudice to the evolution of science itself), whose practices are transparent and results truly validated.

In this context, researchers have a responsibility to produce ”certified“ knowledge, the uncertainties and validity of which are explicitly identified. Society must be able to rely on scientific results, with complete confidence, and to use them without wondering constantly about their reliability. This, one will say, is self-evident and even constitutes the basis of a researcher's work. But, in view of certain behaviour within the scientific community, which is undoubtedly restricted to a minority of its members, which has been criticized in the popular press, society has the right to wonder about the practices of a scientific community whose spectacular growth in the twentieth century has been accompanied by regrettable deviations [15]. Parliamentary procedures already exist in some countries to investigate deviant practices in science. For example in the United States, the House of Representatives, Committee on Science and Technology monitors and investigates cases of scientific malpractice and fraud.

In the future, the responsibility of researchers with respect to their published results could be subject to legal proceedings when two conditions are simultaneously met: (1) if the results are proved to be erroneous due to an obviously poor scientific procedure and (2) their use will have led, in one way or another, to an unacceptable impact on people, certain communal property or the environment. The integration of a quality approach, attesting to the will to guarantee good scientific practices, appears to me to be an effective way of assuring society that the scientific community is fully aware of the public's perception of science as a potential risk.

Conclusion

In this paper, I have argued that quality is strategically important for fundamental research, although few researchers seem to be aware of its value. The basic concepts of quality are discussed in relation to specific problems which may arise when applied to fundamental research: conformity with a reference ("viewpoint"), satisfaction of requirements, planning and formalization. However, I also argue that there is a need for quality in fundamental research due to the increasingly complex relationship between science and society (scientific, economic and financial, human, social and environmental issues). Therefore, quality in science is not limited to the excellence of its results, even if this naturally is its first and principal responsibility. Other components must be taken into account such as the quality of the research process (see [16]), science's image in society and the capacity of researchers to communicate with the public. And, finally, the impact of science's activity on the safety of people, products, and the environment.

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