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On the Differences Between the Engineering and Scientific Methods*

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This paper examines previous claims regarding the uniqueness of the engineering method, and concludes that the real difference between science and engineering lies not in methods, but in aims. The implications of this for engineering curricula are discussed.

INTRODUCTION

IN RECENT years several articles on the nature of the engineering method have been published [1–4]. It is indeed important that the best possible characterization of the engineering method should be found. Such a characterization is not only important to the engineering profession, but is of particular interest to educators in engineering schools who must prepare students to use this method throughout their engineering careers.

This article is a contribution to the ongoing debate about the nature of the engineering method. It has a four-fold aim:

1. To examine critically arguments for the uniqueness of the engineering method put forward by other authors.
2. To argue that there is no real difference between the scientific and engineering *methods*.
3. To argue that the real difference between science and engineering lies in their respective *aims*.
4. To discuss some of the implications of the conclusions regarding the relation between the engineering method and the scientific method referred to in (2) and (3) above for curricula in engineering disciplines.

ON THE ALLEGED UNIQUENESS OF THE ENGINEERING METHOD

I shall examine the arguments of two authors, namely Professor B. V. Koen [1, 3] and Professor J. G. Andrews [4], on the difference between the engineering and scientific methods.

Koen [1] characterizes the engineering method as '. . . the use of heuristics to cause the best change in a poorly understood situation within the available resources' (p. 151). He identifies four characteristics of a heuristic: it does not guarantee a solution; it may contradict other heuristics; its use reduces the effort for solving a problem; and its validity is problem specific. Koen argues that each of these four characteristics signifies a fundamental difference between the heuristic approach (i.e. the engineering method) and the scientific method. However, I will show below that Professor Koen's arguments are based on misconceptions about the nature of science.

First, with reference to the fact that heuristics do not guarantee a solution, Koen argues as follows [1]: 'Scientists consider this ambiguity a fatal weakness. They seek procedures, strategies and algorithms that give predictable results known to be true' (p. 151). This characterization of the scientific method is contrary to the interpretations of almost all modern philosophers of science. Consider, for example, the following [5]:

> Caution: 'scientific method' should not be constructed as a set of mechanical and infallible instructions enabling the scientist to dispense with imagination: it is not to be interpreted either as a special technique for handling problems of a certain kind. (p. 5)

Also [6]:

> Scientific hypotheses and theories . . . constitute guesses at the connections that may obtain between the phenomena under study, at uniformities and patterns that may underlie their occurrence. (p. 15)

As far as the perceived guarantee of a solution by scientific research is concerned, there is thus no difference between the scientific method and heuristics as put forward by Professor Koen.

Second, with reference to the possibility of contradiction between heuristics, Koen argues as follows [1]:

> Unlike scientific theories, two heuristics may contradict or give different answers to the same question and still be useful. . . . A contradiction [for scientists—M.S.], however, is always unacceptable, for it implies a complete breakdown in the system. (p. 151)

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While it is true that consistency (i.e. the absence of internal contradictions) is a highly valued property of a scientific theory, it is simply not true that a contradiction implies 'a complete breakdown in the system'. Consider, for example, the following statement by Bunge [5]:

> . . . the requirement of consistency does not force us to give up an entire theory: it may be worth while to try to *eliminate* the inconsistencies in a theory. . . . A partially true and fruitful theory is more valuable than a completely consistent but pointless or false or even just shallow theory. This is not to say that consistency can be dispensed with but that it is a desideratum which, as every other desideratum, may not be initially satisfied. (p. 438)

See also the discussion in Feyerabend [8, p. 184–186] on the retention or abandonment of scientific theory, as well as the following statement by Newton-Smith [9]: 'This does not mean that if we find an inconsistency in other theories we simply scrap it and return to the drawing board' (p. 229). Clearly Professor Koen's claim that the possibility of contradiction between heuristics marks a fundamental distinction between the heuristic method and the scientific method cannot be upheld.

Third, in his argument that heuristics are distinguished from the scientific method in that heuristics may solve a specific problem much more quickly than a scientific theory, Koen equates scientific methods to rigorous, analytic techniques. The views quoted in the previous paragraph should demonstrate the incorrectness of such an interpretation of the scientific method. Koen also implies that heuristics are totally alien to the scientific method. In fact, a characterization of the scientific method in terms of heuristic problem-solving is nothing new (see [5, pp. 199–203]). Thus, to insist that a scientific approach will always, or even most of the time, take longer to solve a problem than an approach based on heuristics, is not acceptable.

Fourth, with reference to the restricted validity of heuristics, Koen argues [1]:

> The final signature of a heuristic is that its acceptance or validity is based on the pragmatic standard, it works or is useful in a specific context, instead of on the scientific standard, and it is true or consistent with an assumed, absolute reality. (p. 151)

Also [1]: 'The dependency on immediate context instead of absolute truth as a standard of validity is the final hallmark of a heuristic' (p. 151). The latter quote seems to imply that the scientific method depends on absolute truth as a standard of validity. Contrast this with the following standpoint [5]: '. . . scientific research does not attain complete truth' (p. 29). See also the discussion in Chapters 2 and 3 of Laudan [10] and Section 9.8 of Newton-Smith [9] on the complex set of factors involved in appraising scientific theories. Even Professor Koen himself, in a later article [3], concedes that absolute certainty is unattainable, even in science.

Professor Andrews [4] rejects Koen's definition of the engineering method, but also claims that the engineering method is unique. Consider the following [4]:

> Therefore, because the engineering method is applied to a particular class of problems using a specialized knowledge base, it is an assumption of this inquiry that the engineering method is unique. (p. 30)

The fact that engineers work with particular problems and facts surely does not necessarily imply that they use unique *methods* in their activities. Andrews gives the following definition of the engineering method [4]: '. . . this method is a logical, ordered and systematic procedure or plan for solving engineering problems in an effective and efficient manner' (p. 57). He describes the engineering method as a simplified, three-step, problem-solving procedure:

1. problem definition and analysis;
2. problem solution;
3. evaluation of the result.

Many essentially equivalent definitions have been formulated for the scientific method in the literature. One example can be found in Bunge [5, pp. 199–203]. Thus, neither the argument put forward by Andrews on the uniqueness for the problems and facts with which engineers work, nor his definition of the engineering method, can persuade us to accept his position on the uniqueness of the engineering method.

This critical appraisal of Koen's and Andrew's arguments of the uniqueness of the engineering method—as opposed to the scientific method—leads to the conclusion that there is no real difference between the engineering method and scientific method. It is significant to note that the engineering and the scientific methods are also equated in the definition of the concept 'engineer' formulated by the Engineering Societies of Western Europe and the USA in 1960 [11]:

> A professional engineer is competent . . . to apply the scientific method and outlook to the analysis and solution of engineering problems. (p. I.10)

If there is no difference between the engineering and scientific *methods*, what is then the real difference between engineering and science? This question is considered in the next section.

THE REAL DIFFERENCE BETWEEN SCIENCE AND ENGINEERING

A careful perusal of the literature on the philosophy of science will reveal that engineering can be classified as an applied science. The difference between an applied science and a 'pure' science lies not in the method employed, but in the final goals of the problem-solving activities. See for example [5]:

> Applied science (technology) employs the same general method of pure science and several of its special methods, only applied to ends that are ultimately practical. (p. 26)

Also:

> The central goal of research in pure factual science is, by definition, to improve our knowledge of the world of facts; that of applied scientific research, to improve the control of man over facts. (p. 27)

Thus it is clear that engineers will use the scientific method to solve practical problems, whereas scientists will use the same method to solve more abstract problems concerning scientific theories. Engineers are involved with those objects that form part of their problems, e.g. machines, and with the way in which these objects can be controlled, e.g. the decisions that precede and steer the manufacture or use of machines. Their specialist engineering knowledge is made up of theories, well-founded rules and data, which is an outcome of the application of the scientific method to practical problems. This knowledge is chiefly a means to be applied to the achievement of certain practical ends. The engineer will be regarded as competent if (i) his/her actions are maximally adequate to a present goal, and (ii) both the goal and means to implement it have been chosen or made by deliberately employing the best available relevant knowledge (state-of-the-art, as put by Koen [2]). The goal referred to is successful action rather than pure knowledge, which is the goal of the scientist.

The ramifications and implications of the difference between scientific and technological activities can be thrashed out in great detail. We can leave that to more competent authors, e.g. Bunge [7, pp. 120–150].

In sum: the essential difference between science and engineering lies not in the methods employed by them, but in the goals of the respective activities.

IMPLICATIONS FOR CURRICULA IN ENGINEERING

The similarities and differences between science and engineering outlined above have important implications for curricula in engineering. Since engineering is an *applied* science, scientific knowledge is a prerequisite for successful engineering. After all, there must be knowledge before it can be applied. Engineers must thus be taught scientific knowledge. But the conclusions of the previous two sections also imply that the scientific training of engineers should not be of the 'black box' type. Engineers should be exposed to the fact that science is not only the cataloguing of facts, but the search for patterns or laws (or heuristics, as Koen would call them). In effect, engineers should be exposed to the scientific method from the beginning, since this is in essence the method they will employ in their engineering activities.

To say that engineering students must be taught the scientific method does not mean that the science content of engineering curricula should be equated with the teaching of mere sets of techniques. The aim should be to equip the students to deal with different sets of problems (i.e. to provide them with a method). Knowledge of specific techniques forms only part of the ability to handle a problem. See Bunge [5, p. 8] for the distinction between method and technique. Note that in the engineering modules of such curricula, too, emphasis should be placed on the methodology and less on the techniques.

Given the practical goals of engineering, engineering graduates will be judged on what they actually *do*, and not on what they may *know*. Since it was argued above that engineers employ the scientific method in the solution of engineering problems, the training of engineers should be geared towards this end.

CONCLUSIONS

There has been a tendency in the recent past to reinvent the wheel as far as the methodology of engineering is concerned. This paper is an attempt to prevent such a waste of effort. By recognizing the equivalence of the scientific and engineering methods, engineers can skip much of the fruitless debate that philosophers of science had to go through, and devote their time to the implementation of the results of that debate.

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