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Perspectives on the Scientific Method: from Leonardo da Vinci to Space Travel

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Abstract

This paper reports some considerations and insights on the evolution of the scientific method in throughout history. The evolution of the "Method" is explored starting from Leonardo da Vinci (1452-1519), Galileo Galilei (1564-1642), Isaac Newton (1642-1726), Gottfried Wilhelm von Leibniz (1646-1716), René Descartes (1596-1650), Johann Sebastian Bach (1685-1750), Wolfgang Amadeus Mozart (1756-1791) and other brilliant personalities. The common thread and the basis in evolution of the method is mathematics, mathematics that becomes "sublime" with the introduction of differential calculus. How has the method changed over time and what does its evolution foresee today and for the future? I will evaluate a new opportunity for evolution of the method, despite its complexity and difficulty: A challenging issue for researchers.

The scientific method is a systematic process that scientists use to investigate phenomena, solve problems, and test hypotheses. It is a procedure that helps to ensure that discoveries are reliable, verifiable, and based on hard evidence. Here are the main steps of the scientific method today:

- **Observation:** begins with the observation of a phenomenon or problem that arouses curiosity. This can come from an everyday experience, a previous experiment, or an unanswered question.
- **Question:** After observing a phenomenon, a specific question is asked about it.
- **Hypothesis:** A prediction or possible explanation of the phenomenon is made based on what is known. The hypothesis is a statement that can be tested.
- **Experiment** is designed to test your hypothesis. The experiment must be controlled, i.e. it must isolate specific variables and keep constant those that you do not want to test, to obtain clear results.

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Experiments nowadays can also be virtual and performed numerically. DACE "Design and Analysis of Computer Experiments" allows the simulation of real phenomena through factorial factorial analysis that allows the optimization of the prediction of the result without simulating the combination of the levels of variables taken in pairs.¹

- **Data Collection:** During the experiment, objective data is collected, which can be numerical, descriptive, or visual, depending on the type of study.
- **Data Analysis:** The collected data is analyzed to see if it supports the hypothesis or not. This can be done using statistical methods or other analytical techniques.
- **Conclusion:** After analyzing the data, conclusions are drawn. If the data supports the hypothesis, then it can be considered valid (at least in that context). If they do not support it, the hypothesis should be modified or discarded.

It could be useful to understand how scientists such as Galileo and Descartes proceeded methodically in scientific research. Galilei² proceeded by theoretical and experimental means and Descartes³ proceeded mainly by theoretical means. The Discourse on Method (*Discours de la méthode pour bien conduire sa raison et chercher la vérité dans les sciences*) is Descartes' fundamental work, with which modern philosophy ideally begins. Written in French, it was published in the Philosophical Essays in 1637. The work is divided into six parts. In the first, Descartes reviews the various sciences as they were presented by the teaching of his time, still pervaded by the scholastic tradition, noting that none of them corresponded to what is the true office of thought, that is, "the good distinction between the true and the false", that is, the search for truth. Because they either tended to a pleasure, like poetry and eloquence, or towards a practical end, like the technical disciplines, or, remaining in contradiction with each other, like the various philosophies, they showed that they had not reached the truth. Only mathematics, due to the rigor of its method, presented absolute certainty, but it was not applied to the search for reality: it is shown that all this is a consequence of the lack of a precise method in thinking and the four fundamental rules of this method are established: 1) start from rationally evident principles, that is, not accept anything as true if you do not know it clearly as such (methodical doubt); 2) divide each problem into its first elements, which will immediately reveal themselves to be true or false (analysis); 3) gather the elementary knowledge thus obtained in complex organisms (synthesis); 4) enumerate all known truths, to verify that they are related to each other (enumeration and demonstration). The so-called maxims of provisional morality were also given since, doubting everything according to the first rule, it is necessary to establish provisional norms that direct our actions until the truth is reached. Descartes notes that we can doubt everything but not doubt, and, since to doubting is to thinking, we cannot doubt thinking. Thought is the first certainty we have and, at the same time, the essential form of our being: "I think, therefore I am". This is the first truth. But we doubt while we are trying to reach a certainty, that is, we want to overcome an imperfect state in order to reach a perfect one that we do not possess. Where did we get the idea of perfection from? It cannot be proper to thought, which is imperfect, and must therefore have been put into thought by a perfect being, that is, by God. Therefore God exists: second truth. Finally, since in addition to ourselves and God we also know an external world different from us, we must admit that this world exists, because otherwise God, who is most perfect, would deceive us by making a non-existent world appear to us as existing. Third truth.

Such procedure in the method was used also in other disciplines and it is evident that only mathematics gives absolute certainty in many research fields. Differential calculus also enters music with Mozart, one of the first to introduce differentials in music after Bach, after Newton and Leibniz introduced differential calculus in scientific research.

The scientific method consists in the formulation of theoretical models and then experimental validation. Only recently has the use of computers, allowed to simulate reality in a discrete way, without solving the differential equations that govern physical phenomena in a closed form.⁴⁻⁶ The comparison between theoretical models and numerical models allows to face experimentation, sometimes very expensive, with greater certainty of the result. Scientific research can be divided into the levels: short-term research,

medium-term research, basic research. Short-term research gives results to contingent problems that need answers within 15-30 days, medium-term research, with probable prospects of application, usually lasts 6-12 months. Basic research is long-term and takes years to arrive at an innovation. Only long-term research allows for substantial changes to the state of the art.

How can the method evolve today? The solution already comes to us from the past but in a not very "methodical" form. Leonardo da Vinci approached different disciplines with immense curiosity. His method included the use of imagination and the creation of prototypes, when possible and as much as possible in his time. The observation of natural phenomena was fundamental for him. The differential mathematics of Newton's and Leibniz's had not yet been born and could not make accurate predictive theoretical models. Furthermore multidisciplinary saw watertight compartments for each discipline. Today and for the future, different disciplines should contribute to the same objective in the same scientist. I am thinking of mechatronics in which mechanics, electronics and computer science must be known to the mechatronic engineer, aware that within mechanics, computer science and electronics there are other specific disciplines (applied mechanics, machine design, materials science,...). The same goes for medical engineering: we should train a doctor who is also an expert in engineering, clinical psychology, applied sciences, and law.

Finally, a consideration on artificial intelligence (AI): AI is generative, not creative and innovative. AI is a new and very powerful tool available to man and like all very powerful tools it must be used wisely and prudently.

Conclusions

In this editorial article the scientific method was studied, starting from the first researchers who formulated it up to the present day. Today, multidisciplinary is the tool that allows innovation to be achieved. Mechatronics and medical engineering are examples of research fields in which different disciplines contribute to innovation. In mechatronics, the disciplines are mechanical engineering sciences, computer science and electronics. In medical engineering, engineering (mechanics, computer science, management, electronics, materials,...) and medical sciences are involved.

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