# Galileo Galilei's Experimental Discourse: Perspectives in the History and Philosophy of Science

**By**

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## Abstract

Reconstructing the history of science is one of the most difficult tasks. The lies should be unmasked and justice must be done. This explains the pivotal goal of this paper and why it is the role of the philosopher to write history; for as Voltaire puts it, only the philosopher can write history. The paper focuses on the Galilean orientation to scientific experiment or "experimental philosophy" generally (as modern empirical science was aptly called). All the criticisms leveled against Galileo Galilei's discourse of scientific experiment in this historical excursus were in one way of the other neutralized, showing Galileo as the real master of the experimental method. Even where it appears Galileo was talking about making a trajectory from probability to certainty, which cannot be regarded as appropriate, I tried to re-interpret it and put it within the right context or framework. With the proper hermeneutical approach, the paper clarifies the vision of Galileo as a hardcore philosopher and practitioner of scientific experiment.

**Keywords: Galileo, Experiment, Probability and Certainty.**

## Introduction

Modern empirical science is said to have begun in the sixteenth and seventeenth centuries. There were numberless significant scientific figures that made their marks during this period. Leonardo da Vinci, Giordano

Bruno, Francis Bacon, members of the Invisible College (including Robert Boyle and Robert Hooke, among others), René Descartes, and Galileo Galilei (1564-1642), among others. Beyond what Bacon did in the area of philosophical discussions of scientific experiment (See Emedolu and Makpu 2019), the modern philosopher Descartes also contributed a whole lot to the early modern discussions of the scientific methods of experimentation and hypothesization. As was the case, Descartes was the known master of mechanistic philosophy and Cartesian geometry.

But, then, among all the foregoing great scientific figures, the light shines brightest on Galileo. His brilliance in the area of practical mechanics, mathematics and experimentation is something so great and indispensible. He insists that experiment is an indispensable part of modern empirical science and this specifically marks the Galilean footpath in modern empirical science. Galileo was declared an undisputed master of the experimental science, so much so it was generally insinuated that he perfectly understood the technical intricacies of it and quite dramatically accelerated people's interest in experiment – through open-air demonstrations. One interesting fact is that modern empirical science was at its early stage called "Galilean Science" in acknowledgement of Galileo's primacy and contributions as far as modern empirical science was concerned – having dedicated himself to whatever empirical data detects in *Siderius Nuncios*, and having accepted or endorsed the mathematical magic of unlocking the secrets of Nature in *Il Sagiatore*. More importantly, it has been said that the Italian Academy of "Lincei (1603-1629), *partly because Galileo was a member*, established experiment as an important, usual and privileged means of advancing science, and the academy as a body both sanctioning this method and authenticating the result" (Olby *et al* 1996, 970).

By and large, Galileo did not actually cut or sever any links with his forebears. To be sure, he continued with the experiments conducted at Merton College before his wake, say, on the theory of uniformly accelerated motion. Jordanus Nemorius of the 13th Century, in his statics, equally had a

significant impact on Galileo. Furthermore, Galileo had contacts with the Aristotelian tradition of statics and dynamics, having been taught and groomed in that tradition at the university in Pisa. Galileo was so much affected especially by the principle of the lever; for he "composed an important treatise in Italian on this topic, which also goes back to Aristotle's *Mechanics*" (Hall 1983, 75). I tend equally to see Galileo's gamble with the theory of free fall and the impetus of the projectiles as immanent in the Aristotelian tradition. Therefore, in recognition of his attachment to the very philosophical tradition that gave birth to the new modern empirical science, "Galileo himself did not despise the title of 'philosopher' despite his quarrels with the many Aristotelians who bore that title" (Hall 1983, 103). Robbertto Torretti also affirms this when he writes that, "Galileo requested that the title of philosopher be added to that of mathematician in his appointment to the Medici court" (1999, 1).

In point of fact, Galileo's life-long aim was to perfect the experimental method and device some great techniques in such a way that results may no longer be considered as merely *probable* but could be seen as completely *accurate* or *certain*. He quite understood the role of hypothesis in science but made it clear that the subject matter of physics should be limited to primary and manifest qualities. Therefore, in Galilean physics, if the value of any relevant aspect of experimental phenomenon cannot be properly measured then the experimental technique and/or the hypothetical concept must be redefined. H. D. Anthony reveals, in *Science and its Background*, that Galileo held an inductivist view of experiment strictly in the sense that the most important thing for him "was to accept the facts and build the theory to fit them" (qtd. Chalmers 1976, 2). Perhaps all this was in the bid to guarantee certainty in science. But this early Galilean dream has never been realized in the history of science. Hence it somewhat poses a challenge to science. However, there could be other ways of re-interpreting *certainty* in the Galilean experimental quest. This is the basic question of the paper that demands an answer.

Henceforth, I shall look at Galileo's attempt to make a transition from probability to certainty. **I** shall also look at Galileo's idea of reinforcement of experimentation. Then, again, I will focus on some philosophical critiques of Galileo's attitude to modern empirical science. This will be followed by a conclusion.

**On the Galilean move from Probability to Certainty in Experimentation**

Galileo, in *The Dialogue Concerning the Two New Sciences*, produced the last and most mature of his work. Therein he sought for experimental accuracy and exactitude. He seems to have transcended the level of probability in the *Dialogue Concerning the Two Chief World Systems* (which concentrates mainly on astronomical issues) and have gone to the level of experimental certainty in *The Dialogue Concerning the Two New Sciences*. Be that as it may, I must clearly observe, following Edith Sylla's stipulation thus: "Among physical propositions there are some with regard to which all human speculation and discourse cannot supply more than a probable opinion and a truth-like conjecture in place of sure and demonstrated science" (Dahlstrom 1991, 221). By "demonstration" I suppose Sylla is referring the modern idea of experimental demonstration, not to the ancient Aristotelian idea of it as certain and assured intellectual deduction.

At any rate, the great and genuine ambition of Galileo to move from probability to certainty must be seen within a given context. *The Dialogue Concerning the Two New Sciences* is more or less a manifesto, a declaration of unflinching faith in the infallible proofs or finality of scientific experimentation. Towards the end of the First Day (in the dialogue) Galileo says:

> The experiment with the inflated leather bottle of Aristotle proves conclusively that air possesses positive gravity and not, as some have believed, levity, a property possessed possibly by no substance whatever; for if air did possess this quality of absolute and positive levity, it should on compression exhibit greater levity and, hence, a greater

> tendency to rise; but experiment shows precisely the opposite (1990, 164).

Here, I must respond to Galileo's position on certainty of proof from scientific experiment. No doubt, finality of proof may be true in the foregoing Aristotelian experimental context, but it is not just generalizable for all other experiments. In our time, for instance, we take it for granted, contrary to what Galileo said, that some gases (like Helium, etc.) possess the power of levitation. This power of levitation could be said to tie in well with what the phlogistonists, at some point, called "negative weight". More so, in Aristotle's doctrine of teleology, fire is rightly conceived to have its place "up-above", and that is why it keeps going up. But that is by the way, for we do not have time here to properly examine the philosophical or mathematical implications of levity or negative weight.

The upshot of my argument is that given the inductivist nature of all scientific experiments and the experience of near perennial scientific revolutions (or theory change), it cannot be universally said that experiments conclusively prove anything with certainty of truth. Now, the more cautious falsificationist Karl Popper (with his Hypothetico-Deductivist method) is wary of the fallibility of science and has chosen rather to popularize the idea of *verisimilitude* – the doctrine that what scientific theories, through the aid of experiment, can achieve is "approximate truth". And the majority of contemporary thinkers on experiment endorse the view that all what experiment can do is to *corroborate, confirm* or *disconfirm* a scientific theory, not to *prove* it with any sense of finality. Ron H. Naylor, in "Galileo's Experimental Discourse," equally challenges the air of certainty of proof rife in Galileo as he expounds:

> His response to the relationship between theory and experiment in a truly mathematical science proves rather different in the *Two New Sciences*, primarily because he

> determined at all costs to establish that his new science of motion is an empirically true theory rather than *merely probable*. As a consequence, simple experiments that establish directly an observational law such as that of isochronisms, are claimed to be precisely true. The cork and lead pendulum of the "First Day" are said to be exactly isochronous over hundreds, indeed thousands, of oscillations. *This is presented as a direct appeal to Nature – but it is not* [emphasis added] (Gooding, Pinch, and Schaffer 1989, 132).

The last sentence of the above passage seems to raise some doubts about the reported results of the supposed pendulum experiment. From simple pendulum experiments one perceives that such magnificently consistent results are not possible. Haven performed the pendulum experiment a number of times during my career as a physics student; I never achieved any such consistent results. So, I clearly submit that, Galileo must have somewhat faked (cooked up) or tampered with his actual data on that experiment. Or, I may just conclude that he merely performed a thought experiment, which though is still an essential tool in science. However, I am not trying to stultify or muffle Galileo's great ambition of bringing about certitude in scientific experimentation.

In spite of the foregoing remarks, one can still exculpate Galileo. I say this because Galilean science fundamentally thrives on ***mathesis*** or what he calls idealization. It was, in fact, William Whewell who later explained it very well when he pointedly declares that, "Science is the idealization of facts" (Brown 2012, 20). Beyond the way Whewell interpreted the Galilean ***mathesis***, I hold that, in every scientific experiment, ideal conditions must be uppermost in the mind of the experimenter. Errors may arise from both preventable and unpreventable situations – though, in unpreventable situations, errors are often factored into the solution base. It has always been the great objective of the analytic tradition of experiment to ward off all unnecessary interferences from the immediate environment of scientific

instruments. The variables are also under serious control. In some experimental techniques, control could be resolved into positive and negative controls. It is nonetheless not in my place here to discuss the issues of warding off interferences and deployment of control in scientific experiment.

Further still, one can legitimately argue that the Galilean notion of accuracy or exactitude can never be faulted based on the simple fact that his own measuring instruments cannot compete with the digital pinpoint accuracy of our computerized contemporary instruments. To now argue against this is merely to bring Whiggism into full play. Such Whiggish orientation should forever be down-played in any genuine discussions of the history of science. Contemporary digital experimental science is quite closing in on pin-point accuracy and mathematical exactitude. Hence, I am inclined to think that this was the simple ambition of Galileo and nothing more. If this were to be the only dream of Galileo, then it has been fully achieved in our current digital quantum world of science.

**Galilean Reinforcement of experimentation**

The primeval and pacesetting role of Galileo in the reformation or overhauling of modern empirical science by the triadic combination of mathematics, experimental data and practical mechanics can never be overemphasized. Adam Morton, in *Philosophy in Practice: An Introduction to the Main Questions*, confirms that Galileo's way of studying nature combined mathematics, practical mechanics and experimental data. Accordingly, Galileo appealed to experimental data each time he wanted to remonstrate against Aristotelian physics (Morton 1996, p.65). As a matter of urgency, Galileo confirmed experiment as the decisive centre of his new science – the path from which modern empirical science has never departed. The necessity of experiment was made open through the mouth of Sagredo (one of the interlocutors) who says: "At times also I have been put to confusion and driven to despair of ever explaining something for which I could not account [by experiment]" (Galileo 1990, p.131). In the

mid-20th century, Reichenbach paid a glowing tribute to Galileo in the following words:

> Galileo gave to modern science the quantitative experimental method. The experiments in which he established his law of fallen bodies have determined the pattern of a method that combines the experiment with measurement and mathematical formulation. With Galileo, a generation of scientists went over to the use of experiments for scientific purposes (1951, 98).

In the *Emergent and Contentious Issues in African Philosophy*, Boniface E. Nwigwe and Christian C. Emedolu submit that Galileo used his combined mechanistic, mathematical and experimental expertise to transmogrify Aristotelian science (which was based primarily on the teleological study of the four causes) into modern empirical science by simply discovering the immanent law of the falling bodies through the co-relation of distance and time (Nwigwe and Emedolu 2004, 86). Along this line of demarcation between Aristotelian science and Galilean science, Naylor, for his part, contends:

> Galilean science revealed a dilemma – it was a victory and yet a defeat. On the one hand, it changed the basis of scientific discourse in rejecting the teleological approach of the Aristotelians for an approach more abstract and yet more empirical. Aristotle had found the cause of motion in terms of his cosmology and in ideas of natural place. Galileo at first, in *De Motu,* rejected Aristotle's theory but regained the cosmological explanation of motion in terms of place … For the Aristotelians it was *cause* that was paramount while *form* played an entirely secondary role … Galileo's position was the polar opposite. It was cause (in the Aristotelian sense of final cause) that could be left aside but on the contrary the *precise* form of motion *was* of

> overriding significance (Gooding, Pinch, and Schaffer 1989, 132-133).

From two important positions: namely, that Galileo was able to locate and ascertain the immanent laws of falling bodies by correlating the distance covered and the time taken to cover the distance; and that Galileo's approach was more abstract and yet more empirical, one begins to see the origins of modern sophistications in theorization. Indeed, the Galilean mechanistic genius consisted in being able to *empiricalize* that which hitherto seemed conceptually abstract. This showcases him as a most skillful experimenter who had the verve and aptitude for reinterpreting hypothetical concepts about phenomena and designing experimental means of testing them and calculating their results.

Now, I seem to think that Galileo's blending of mathematics, practical mechanics and experimental data is actually what makes modern science unique in a way. This uniqueness places Galileo as an ingenious manipulator of nature through instrumental contrivances. This does not, of course, suggest that the ancient and the medieval scientists never conducted any scientific experiments. There are several instances in the history of science that show instances wherein experiments were dutifully performed by Anaximenes, Pythagoras, Anaxagoras, Empedocles, Aristotle, Archimedes of Syracuse, Theophrastus, Strato, Galen, Ibn al-Haytham, Robert Grosseteste, Roger Bacon, Theodoric of Freiberg and numerous others. Yes, those experiments were conducted, but none of them really came close to the kind of combination that Galileo achieved. With such verve and skill he was able to completely or seamlessly glue experimentation to theorization in modern science.

**Some Philosophical Critiques of Galileo's Experiments**

A few of the experiments that appear in Galileo's *The Dialogue Concerning the Two New Sciences* are considered in recent times by most scholars as

*thought experiments* – that is, mere constructions of the mind. In the exact words of Naylor:

> As Koyré discerned, the claims for the accuracy of Galileo's experiments in the *Two New Sciences* are unreal and there was a reason for this. Koyré's intuition was that it was the experiments that were unreal (Gooding, Pinch, and Schaffer 1989, 131).

Perhaps Samir Okasha, in *Philosophy of Science: A Very Short Introduction*, is even more ruthless in describing particularly the Pisa Leaning Tower experiment (on falling bodies) as "mythical experiment on the velocity of objects" (2002, 6). As I mentioned in an earlier section, it is difficult to accept a perfect result from Galileo's experiments. Koyré and Okasha are not to blame if they made their arguments or inferences based on the technology of this new age. The truth of the matter is that during Galileo's era, the clock or time system was still a little bit crude and cannot compete with the present day advanced digital clocks that tick in nanoseconds. Nowadays, one can easily pick out time differentia in successive experiments.

Rom Harré, *pace*, Koyré and Okasha, opines that Galileo's experiments were actually performed. Prominent among the so-called "dubious" experiments are, of course, the Inclined Plane experiment and the Pisa Leaning Tower experiment. Harré reveals that T. Settle, in "An Experiment in the History of Science," repeated Galileo's experiment on uniformly accelerated motion, using Galileo's original method and replicating his results; and by "so doing he puts paid to the once prevalent view that Galileo's experiments were mostly imaginary" (Harré, 1981, 69). Accounting for subsequent developments in the sphere of science of motion, Harré asserts:

> In the centuries that followed Galileo's demonstration that the mathematical analysis of motion begun by the Mertonians was *applicable to the real world,* there was a fairly steady progressive refinement of concepts and elaboration of more sophisticated mathematical methods. Energy and momentum

> were distinguished, and the calculus replaced geometry as the main tool of analysis. These developments allowed for more complex motions and more elaborately structured mechanisms (1981, 72).

From history, it is obvious that Galileo and Isaac Newton relied much on model experiments, but at other times some of their experiments were very direct unfolding of reality. It goes, therefore, without saying that Galileo was an entrenched and thoroughgoing experimenter. He accepts it as fact that, scientific experiment, observation and concomitant measurement and calculation of results help to unravel the secrets of Nature. Toward exemplifying this: Galileo believes throughout *The Dialogue Concerning the Two New Sciences* that his experimental results are perfect "*unfoldments*" of the real world, benefits of artful exploitations of Nature – beginning from the preliminary First Day to the second Day when he consumes or sandwiches himself in propositions and demonstrations on lever, unto the Third Day when he begins with complete demonstration of change of position, uniform motion, naturally accelerated motion, and onward to the final or Fourth Day, wherein he concludes with the demonstration on projectiles.

Say what one may, it has become very obvious, as Reichenbach says, that the "general turn toward experimental method can scarcely be regarded as the effect of one man's work (namely that of Galileo's or any other person's)" (1951, 98). In Reichenbach's view, the modern empirical scientific revolution "…is better explained as the result of change in social conditions which freed the minds of the scientists from preoccupation with Greek science in the form of scholasticism and led naturally to an empirical science" (1951, 98-99). This does not mean that Galileo has no worth any more, nor does it imply that there was no empirical or experimental science before the rise of Galilean science. Galileo, just like Bacon, was such an admirable popularizer of the experimental approach to science to such an extent that his footpath became his trademark. This should not warrant any

envy, for Galileo paid his dues as a fine-grained mechanistic philosopher, great mathematician and ingenious experimenter in his own right. With such single-mindedness he lifted people or witnesses' attention and interest toward experimentation and its established validity as a sure instrument for gleaning the truth about reality.

**Conclusion**

I cannot end this paper without re-emphasizing that, there were other significant scientific figures, especially, Descartes and Bacon, who contributed a whole lot to the early modern discussions of the scientific methods of experimentation and hypothesization. Notwithstanding the capacity of the above two figures, Galileo's creative manipulation of the experimental method can never be undermined; hence, my choice of him in this paper remains legitimate.

Ultimately, to twist the gains of Galileo in modern empirical science out of phase is simply to show that one is not appreciative of the ingenuity of the one who has gained world acclaim in the field of physico-mathematical sciences. Even though he suffered a humiliating Inquisition, which I still consider far better than being burnt at the stake like Giordano Bruno, Galileo's abiding greatness in experimental science remains what it is in the history and philosophy of science. At least his unappreciated contributions to experimental discourse have been adequately highlighted.

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