Experimenting in the History of Science

*By James MacLachlan**

ABSTRACT

In history of science, valuable information about classical experiments can come from reconstructing them. Reconstructions have furthered understanding of the work of Galileo Galilei and of Isaac Newton. While Alexandre Koyré denied the validity of most of Galileo's experiments, particularly one where water and wine exchanged without mixing, James MacLachlan showed that this phenomenon occurs exactly as Galileo described. That Galileo may have heard of the water-and-wine trial elsewhere does not invalidate his construction of it. Studies of seventeenth-century physics are not assisted by narrow-minded interpretations limited to scientists' mental activities. Rationalism and empiricism need each other.

I

Gently pour a narrow stream of water into half a glass of red wine. You will see the water immediately mix with the wine. Experiences like this provide us with our intuitive notion that water and wine are virtually completely miscible.

But instead, use Ambroise Paré's wine-raiser or Galileo's apparatus. Then you may stare in fascination as a clear layer of water forms at the bottom of the container of wine and gradually enlarges while the wine wafts upward through the water. This is a startling counterintuitive phenomenon—I wouldn't have believed it if I hadn't seen it with my own eyes.[1]

Antonio Beltrán has added to our knowledge of this phenomenon by finding descriptions of it in the writings of Ambroise Paré. Beyond that, what is the major thrust of his essay? Is it that Alexandre Koyré got it wrong? Well, no! For Koyré offered the possibility that Galileo could have read of the phenomenon someplace.

Now Beltrán tells us that he has found the place. Let us be generous with him, and not bother about the unlikelihood that a medical student in Pisa (being indoctrinated from Galenic treatises) would have read a French surgical work or that the wine-raiser was widely known. I recommend a small shave with Occam's razor before uncorking the wine.

Beltrán seems to think that Koyré was right while being wrong. Since Koyré denied the details of the water-and-wine phenomenon, he was accusing Galileo of making a false report. And, since Koyré denied the phenomenon, then what he thought Galileo had read must also have been false. In my 1973 article I simply wanted to show that Galileo's report

* 813-633 Bay Street, Toronto, Ontario M5G 2G4, Canada.

[1] James MacLachlan, "A Test of an 'Imaginary' Experiment of Galileo's," *Isis*, 1973, *65*:374–379.

Isis, 1998, 89:90–92

0021-1753/98/8901-0006$02.00

was not false. The phenomenon does occur as Galileo described it, barring his typical exaggeration to "The globe is *completely* filled with wine."

I did not mention how I supposed that Galileo had heard of this phenomenon, since it was not germane to the thrust of my essay. I have no reason to think Galileo invented the demonstration. With Beltrán's assistance, I can now say what I think is most likely: I suppose that while Galileo was a professor in Padua, one of his French medical students mentioned the phenomenon to Galileo, and he tried it out one day.

I believe Galileo did see the water-wine transfer because of the way he described it—not because his description was detailed, but because it was precise. Galileo wrote of the wine: "*lo vedremo subito con tratti rosseggianti lentamente ascendere per mezzo l'acqua, e l'acqua con pari tardità scender per il vino sensa punto mescolarsi*" ("we promptly see it slowly ascending in rosy streaks through the water, while the water with equal slowness descends through the wine, without their mixing [at all]").[2] The language that Paré used suggests that he too likely saw the phenomenon he described. If not, we'll have to go searching for where Paré read about it!

I doubt that Koyré performed the experiments he describes because I do not suppose he would have lied about it. I am presuming that if he had done what I did, he would have made the same observations I did. Besides, he never said that he had made the trials. He writes: "if we repeated it exactly as described . . . we should not see the water and the wine simply replacing each other; we should see the formation of a mixture."[3] Dare I presume that apriorist rationalists get their data intuitively from common experience?

Another reason for considering Galileo to be truthful is that the fact that the water and wine do not immediately mix made no contribution to his argument. So he had no reason to lie about it. He was describing an incompatibility (*disconvenienza*) between water and air and contrasting that with *no* incompatibility between water and wine. He wondered why water does not fall easily out of a narrow-mouthed container into air when it does fall out into wine. That the two liquids did not immediately mix was simply an interesting by-the-way fact—intriguing because it is counterintuitive.

Thus, Galileo made no use of Paré's idea of a "separating faculty," which referred always to two *liquids*. Beltrán may have been misled in this by Koyré's phrase "the incompatibility of water with wine."[4] Galileo never used such a phrase.

So the argument of Beltrán's penultimate paragraph is in error—in any case, the terms of his relationship should be

Paré : Galileo :: Galileo : MacLachlan.

He describes the relation as being "exactly the same." It is not! (*1a*) Galileo *may* have read Paré. (*1b*) MacLachlan *did* read Galileo. (*2a*) Galileo did not use Paré's explanation of the phenomenon by mentioning any incompatibility between water and wine. Galileo gave no explanation for it. (*2b*) MacLachlan did give an explanation in terms of our current understanding of the properties of water and wine.

[2] Galileo Galilei, *Discorsi e dimostrazioni matematiche intorno à due nuove scienze* (Leyden: Elzevir, 1638), p. 72; cf. Galilei, *Le opere di Galileo Galilei*, ed. Antonio Favaro, 20 vols. (1890–1909; Florence: Barbèra, 1968), Vol. 8, pp. 115–116. For the English translation see Galilei, *Two New Sciences*, trans. Stillman Drake (Toronto: Wall & Emerson, 1989), p. 75.

[3] Alexandre Koyré, "Galileo's Treatise *De motu gravium*: The Use and Abuse of Imaginary Experiment" (1960 [in French]), in *Metaphysics and Measurement: Essays in the Scientific Revolution*, trans. R. E. W. Maddison (Cambridge, Mass.: Harvard Univ. Press, 1968), pp. 44–88, on p. 84.

[4] *Ibid.*

II

Historians of science owe Koyré a great debt for denying that Galileo performed his experiments. Until we read his work, we had been inclined to take the experiments for granted. In the face of Koyréan intransigence, several of us have examined experimentation more critically to determine what Galileo or Newton (for example) could or could not have achieved in his experimenting.

In 1961 Thomas Settle refuted Koyré's denial of the precision that Galileo's water clock could achieve. Despite Koyré's claims—"What an accumulation of sources of error and inexactitude!" and "The Galilean experiments are completely worthless"—Settle was able to use apparatus like Galileo described to achieve results with precisions similar to those Galileo reported.[5] Not that either was perfectly exact; they had similar small degrees of error.

Roger Stuewer put experimentation to a different use in 1970.[6] He reconstructed some of Newton's experiments on the diffraction of light. By noting the relative intensity of various fringes in the diffraction pattern, Stuewer showed very convincingly how it was possible for Newton to have missed a faint brightness in the center of the pattern.

In 1976 I repeated a number of Galileo's experiments with pendulums to test claims he had made about them.[7] I was able to demonstrate that some of his claims were unsupportable and others possible. In particular, I found that one of his claims could be substantiated if the suspended metal balls were about 2 centimeters in diameter but not if they were much larger.

Results such as these demonstrate that we may learn more about the historical scientists we study by repeating some of their experiments—more, that is, than by sitting on our hands and limiting ourselves to deep reading and hard thinking.

None of this turns us into naive empiricists. Our use of experiments to test historical claims is simply a helpful technique. It can be added to other techniques, such as careful textual readings, error analysis, and rational reconstruction. Critical empiricism can be useful in some historical interpretations.

So, I can readily agree with Koyré's remark that "far from being opposed to each other, experiment and theory are bound together and mutually interdetermined, and it is with the growth and refinement of theory that grow the precision and refinement of the experiments." So as not to be misunderstood, I should stress that they grow *together*. It is wrong to give exclusive priority either to theory or to experiment. This is consistent with Galileo's own claim that science depends on *both* "sensible experiences and conclusive mathematical proofs" ("*sensate esperienze e . . . dimostrazioni necessarie*").[8]

Epistemological sobriety need not confine historians of science to a spare rationalist diet of bread and water. Surely, occasional drops of empirical wine can aid historiographical digestion.

[5] Thomas B. Settle, "An Experiment in the History of Science," *Science*, 1961, *133*:19–23; and Alexandre Koyré, "An Experiment in Measurement" (1953), in *Metaphysics and Measurement* (cit. n. 3), pp. 89–117.

[6] Roger H. Stuewer, "A Critical Analysis of Newton's Work on Diffraction," *Isis*, 1970, *61*:188–205.

[7] James MacLachlan, "Galileo's Experiments with Pendulums: Real and Imaginary," *Annals of Science*, 1976, *33*:173–185.

[8] Koyré, "Experiment in Measurement" (cit. n. 5), p. 90; and "Galileo's Letter to the Grand Duchess Christina" (1615), in *Opere*, ed. Favaro (cit. n. 2), Vol. 5, pp. 309–348, on p. 316 (my translation). Cf. Maurice A. Finocchiaro, *The Galileo Affair: A Documentary History* (Berkeley: Univ. California Press, 1989), pp. 93–94.