A Thrifty History of Scientific Instruments

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In the summer of 2021, analysis of Jacques-Louis David's famous portrait of Antoine- and Marie-Anne Paulze Lavoisier revealed substantial reworking of the painting had taken place to reach the final version familiar today (**Figure 1**).[1] Among the changes, David had originally drawn a waste paper basket under Lavoisier's desk. This was covered up in the final painting by a long tablecloth, in front of which lay glass chemical vessels. The switch might stand for the theme of this essay, a move in the history of science from what I shall call "thrifty" instruments in the seventeenth and eighteenth centuries, which made use of existing household objects to experiment, to more dedicated apparatus in the nineteenth. We have excellent histories of the latter, but the uses of adapted domestic goods in experimental settings offer great potential for further inquiry.

There have been many answers to the question "what is a scientific instrument?"[2] In recent decades, the scope of what historians include under the banner of instruments has broadened to include everything from Athanasius Kircher's sunflower clock to the "paper tools" of

[1] Silvia Centeno, Dorothy Mahon, David Pullins, 'Discovering the evolution of Jacques-Louis David's portrait of Antoine-Laurent and Marie-Anne Pierrette Paulze Lavoisier', *Heritage Science*, 9 (2021), article 84.

[2] Deborah Jean Warner, 'What Is a Scientific Instrument, When Did It Become One, and Why?', *British Journal for the History of Science*, 23 (1990), pp. 83-93.

phrenology and census-taking.[3] Many of these histories, however, still focus on "dedicated" instruments or items that were designed, made, and used with the intention of pursuing some form of scientific inquiry. In a recent book, I have argued that another area of instrumentation warrants historical attention, which I call "thrifty science".[4] Exploring the history of experimentation in England between the seventeenth and nineteenth centuries, I have argued that much experiment involved householders who "made use" of everyday domestic goods and furnishings, including their own homes, to learn about nature. This activity was not accidental, undertaken because no better instruments were available, but conformed to early modern ideas of thrift and household management. Experimenting, and a number of important instruments, emerged in part from a domestic context where to make use of things was to *thrive*.

My interest in this topic arose from asking about the history of recycling in science. Today, many scientists are concerned that the high energy and material consumption of laboratory research is unsustainable. To alleviate this, numerous "green labs" initiatives have emerged that seek to increase laboratory recycling and reduce energy consumption. This raised for me the historical question as to whether scientists in the past were involved in recycling. Although I quickly learned the practice was widespread in the early modern period, the term

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[3] Thomas Hankins and Robert Silverman, *Instruments and the Imagination* (Princeton, NJ: Princeton University Press, 1995); Carla Bittel, Elaine Leong and Christine van Oertzen, eds., *Working with Paper: Gendered Practices in the History of Knowledge* (Pittsburgh: University of Pittsburgh Press, 2019).

[4] Simon Werrett, *Thrifty Science: Making the Most of Materials in the History of Experiment* (Chicago: University of Chicago Press, 2019).

"recycling" did not exist until the twentieth century, prompting the question why not? The answer lies in the fact that early moderns approached material culture in a different and distinctive way to the present, and understanding this makes sense of many instrumental and experimental practices in the period.

Diverse texts and objects help to elucidate this approach to materials. The literature of domestic "oeconomy" or household management is instructive. Numerous books were printed on the proper management of one's estate, family and servants in early modern England, ranging from Thomas Tusser's works on husbandry and housewifery, all written in memorable verses, to Roger North's *Observations and Advices Oeconomical* (London, 1669). These were complemented by numerous manuscript books of domestic and culinary recipes and advice which householders compiled and passed down through the generations.[5] An important principle expressed in many of these works concerned "thrift" or "frugality". This did not mean "saving money" as it does today, but rather finding a balance between buying new and making the best use of what one already had, between excess and miserliness, between a care-free and a careful mode of living: as William Herbert wrote in 1657, "Frugalitie is a vertue between prodigalitie and avarice, which teaches man to keep his owne,

[5] These works are explored in Karen Harvey, *The Little Republic: Masculinity and Domestic Authority in Eighteenth-Century Britain* (Oxford: Oxford University Press, 2012); Elaine Leong, *Recipes and Everyday Knowledge: Medicine, Science, and the Household in Early Modern England* (Chicago and London: University of Chicago Press, 2018).

or to bestow it well."[6] Historians of consumption and luxury have explored the history of prodigality in this period, but the history of "avarice" is less familiar. Central to such frugality was the idea of "making use" or finding new and extensive "service" for one's possessions. Thrift was ultimately a religious ideal. God bestowed the material world on Man for his benefit, so men should "make use" of these gifts as much as possible. My argument in *Thrifty Science* is that this motivated early modern householders to experiment, to "make use" of what they had in their homes to learn about nature and the potential of things for new and further service. Prolonging the service of things also encouraged a culture of repairs and recycling.

Paper provides a useful example of thrifty "making use".[7] Early moderns kept old papers (perhaps in baskets like the one under Lavoisier's desk) and used paper rather like we use plastic today, as a pliable material ideal for diverse two and three-dimensional forms. Paper was a material made from old clothes, the rags being collected up and shredded to produce it. Old papers – letters, envelopes, old books – were routinely given new uses, as wrapping for food, as "baking paper" in ovens, for lining bandboxes for hats, as toilet paper, and, in papier mâché, for making decorations, furniture, and stands for wigs. Householders "made use" of

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[6] William Herbert, *Herbert's devotions, or, A companion for a Christian containing, meditations & prayers, fitted for… the church, closet, shop, chamber, or bed* (London, 1657), pp. 93-94.

[7] Simon Werrett, 'The Sociomateriality of Waste and Scrap Paper in Eighteenth-Century England', in *Working with Paper: Gendered Practices in the History of Knowledge*, eds. Carla Bittel, Elaine Leong and Christine van Oertzen (Pittsburgh: University of Pittsburgh Press, 2019), pp. 46-59.

paper for diverse scholarly ends. Playing cards were blank on one side, and so did service for sketching apparatus designs, announcing lectures, or recording the contents of a library or collection (the origin of the 'card catalogue') (**Figure 2**). Glassware was equally thrifty.[8] Joseph Priestley's first eudiomenter consisted of an upturned beer glass into which a mouse was inserted (**Figure 3**). The goodness of air bubbled up into the glass was measured by how long the mouse survived inside it. Windows provided a source of light and wind for various experiments, and opening and closing them could alter the conditions of an experiment, as in Newton's prism experiments or Hooke's use of the microscope (**Figure 4**). Apparatus in these experiments were often a bricolage of elements ingeniously combined to produce an effective apparatus. These might combine dedicated instruments purchased from an instrument maker with everyday household items, echoing the thrifty impulse to balance the use of new with old. Electrical machines were highly specialized, expensive instruments, but were routinely used with gun barrels, glass jars and other domestic items. Franklin's kite experiment combined use of a Leyden Jar with a silk handkerchief and a door key.

Such activities often involved all the family, including children and servants. "Experiment" was a term used to describe many domestic tests, trials, and preparations. Women made medicines and cosmetics, prepared food, and distilled essences and drinks in early modern homes, and these might be referred to as experiments, sometimes recorded and exchanged to form collections of recipes in manuscript. Activities such as cleaning involved diverse skills and material knowledge (**Figure 5**). Thrifty apparatus therefore included a diverse range of metal, glass, and ceramic wares from the kitchen, the closet and distillery, whose history is

[8] See Werrett, *Thrifty Science*, pp. 59, 64, 69, 76-77.

only beginning to be explored.[9] What, for example, were the uses of stay busks, sailors' fids, costrels, pounce pots, wimbles, fleam mallets, flummery moulds, or quaiches in early modern experiments?[10] This is not to say that women enjoyed equal status with men as experimenters. Some (though not all) male experimenters denied that domestic experiment could be the basis of scientific knowledge, without certification of such experiments in an all-male academy. Other men ridiculed women for failing to "make use" of goods in appropriately scholarly ways. Men scoffed that women would sooner use books and journals for paper to curl their hair than read the contents to improve themselves.

To maximize the serviceable life of bodies, early moderns spent much time cleaning, repairing, and preserving things by storing them carefully and when bodies were injured beyond repair they could still be recycled. Householders paid great attention to storage, with homes typically containing some form of chest or cupboard to keep linen or tableware in good order. Instrument makers expended great care in making boxes and containers for telescopes, microscopes and other instruments to preserve them safely. Containers might be an important part of the instrument, as in Edward Nairne's compound microscope, whose box formed the base of the instrument, or Martin Frobene Ledermuller's microscope case whose

[9] See e.g. Lucy J. Havard, 'Almost to candy height:' knowledge-making in the early modern kitchen, 1700-1850', *Cultural & Social History* (2022), published online <<https://doi.org/10.1080/14780038.2022.2033148 >>

[10] On the material culture of the kitchen, see Sara Pennell, *The Birth of the English Kitchen, 1600-1850* (London: Bloomsbury, 2016); Sara Pennell, ''Pots and Pans History': The Material Culture of the Kitchen in Early Modern England', *Journal of Design History,* 11 (1998), pp. 201-216.

lid formed the support of the instrument (Figure 6).[11] Similar attention was paid to keeping household goods, including instruments, in good repair. Intricate early modern lead and copper braces have been found in London which were used to reattach the stems and bowls of wine glasses.[12] Ceramics were stapled back together if they broke. "Repairability" was often a consideration in instrument design. Robert Hooke agonized over the capacity of his marine way-wiser, described in 1691, to be easily repairable.[13] When items were finally broken, their parts could be recycled. Makers used old glass and metals to construct new instruments, and simple geometrical manuals were available teaching how to make the most of broken glass by cutting it into new sheets.[14]

This culture of "thrifty science" did not go unchallenged in the early modern period, and would suffer a transformation over time. In the eighteenth century, numerous commentators lambasted thrift as a value that would only lead to stagnation. Bernard de Mandeville, in *The Fable of the Bees* (1714), argued that profligacy was a good thing that stimulated economic growth and hence the wealth of all. Adam Smith and others redefined thrift to mean "saving", so that to be thrifty by the nineteenth century meant making the most efficient use of one's

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[11] Werrett, *Thrifty Science*, pp. 95-96; Edward Nairne, *Directions how to Use the Compound Microscope* (n.d.). American Philosophical Society. Thomas Court Scientific Instruments Collection. Mss. 509.078 M582.

[12] Three examples may be found in the collections of the Museum of London, ID nos. 16945, 13322, 86.240/2.

[13] Werrett, *Thrifty Science*, pp. 86-86.

[14] Simon Werrett, 'Recycling in Early Modern Science', *British Journal for the History of Science*, 46 (2013), pp. 627-646.

money and capital, an economic incentive to growth rather than a religious motivation to find balance. In the course of this change, attitudes to material culture changed. Because early modern households valued the finding out of new uses for things, and put things into service in diverse ways, they viewed possessions as what I call "incomplete objects", in a constant state of flux or change. Things and their uses were not particularly connected. This was reflected in a very open-ended definition of scientific instruments. Hence Herman Boerhaave defined an instrument as that, "which either has or may be given… a certain motion, which being applied to the Body to be changed will produce such an Alteration in it, as the Art had before determined." (*Elements of Chemistry*, 1735). An instrument was not a specific devise, but anything that could be turned into an instrument. In the nineteenth century, the definition became more narrow. Over time, men of science promoted the use of more specialized and dedicated instruments and spaces for science. Lavoisier's portrait depicts a seventeen-litre glass balloon used to make precison measurements of masses of air, with a brass cap and stopcock soldered into the top to allow air to enter or leave the vessel.[15] This instrument had one use, and did it very well, but it was a far cry from Priestley's converted washbasins and beer glasses.

Now specialization, large budgets, and dedicated spaces were favoured over the old thrifty domestic culture. Instruments became those things specifically designed to achieve some distinctive scientific goal. Hence their number proliferated and their production became a

[15] Horton A. Johnson, 'Revolutionary Instruments: Lavoisier's Tools as Objets d'Art,' Distillations (April, 2008), accessed online on February 16, 2022 << https://www.sciencehistory.org/distillations/revolutionary-instruments-lavoisiers-tools-as-objets-dart>>

matter of exclusive and specialized skill. The rise of precision helped distinguish these instruments from the thrifty bricolages of the past, and indeed, one might see this change less as the inevitable progress of science than as a shift reflecting a new industrializing economy and the desire of men of science to distinguish themselves from their thrifty forebears. Now a dedicated instrument served even where an adapted item might serve equally well. In the 1930s, Max Joohs of Switzerland made model apples that separated into segments for the teaching of fractions in schools.[16] It is hard to imagine an early modern lesson with such an instrument, when a basket of apples would serve the purpose equally well.

One problem with such dedicated instruments, and with the multiplying commodities of the Victorian era more generally, was that because they were designed for a specific use, when they could no longer serve that use, they became "waste". Early moderns did not really have a general, abstract notion of waste. They started with a material such as paper or glass, used it to for some kind of service, then could adapt it to a different use when needed and did so for as long as possible. Moderns, in contrast, started with a design, sought out the materials to make it work, then considered the object perfected when it fulfilled the intended design well. However they gave little thought to the aftermath of the object, what happened to it once it was broken. The result was a burgeoning of waste in the nineteenth and twentieth centuries which has been a signficant source of pollution and environmental damage ever since.

The nineteenth century did not spell the end of thrifty science. Householders continued to improvise ingeniously. But the new stress on dedicated instruments reshaped household

[16] Model apples used to teach fractions, c. 1929-1950, by Max Joohs, Switzerland. Whipple Museum, Cambridge, accession no. 6572.

instruments as, at best, the starting point in a process of making more professionally-made designs. New dedicated instruments were increasingly used in new dedicated spaces – the research laboratory – so that the home became associated with a more "amateur" form of experimenting, as when mothers and children used household items to learn simple lessons on the path to studying more serious science.[17] Effectively, thrifty science was 'historicized' to be seen as the beginning of science, but not as its culmination in professional, male, laboratory practice. It might be noble, as recorded in romantic histories of experimenters who began with simple means (such as James Watt's kettle), but thrifty experimenting was now only a prelude to proper science.[18]

What, then, is a scientific instrument? For early moderns, anything could be a scientific instrument. Instruments were typically a mix of specialized and ready-to-hand objects, following the thrifty value of balancing the use of old and new. The culture of instruments shared the culture of the households where instruments were made and deployed, so that exploring domestic history is a way to gain new insights into the history of scientific instruments.

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[17] See e.g. Melanie Keene, 'Domestic Science: Making Chemistry Your Cup of Tea,' *Endeavour* 32 (2008): 16-19.

[18] Ira Remsen, 'The Simple Origin of Great Discoveries', in *The Mechanic Arts*, ed. Richard Cockburn Maclaurin (Boston: Hall and Locke, 1911), pp. 370-379; Frank James offers a valuable critique of this position in his Turner Lecture of 2020, Frank A.J.L. James, 'Instruments from Scratch? Humphry Davy, Michael Faraday and the Construction of Knowledge', *Bulletin of the Scientific instrument Society* 148 (2021), pp. 2-13.

The sociologist Harry Collins has argued that a key element of modern science involves "tacit knowledge", the hacks and gestures and arrangements that go unnoticed in scientific experiments which are, in fact, essential to the experiment's success.[19] The focus of twentieth-century science and, until recently of many historians, was on the finished product – the scientific paper or the pristine instrument – in which all these improvisations and unspoken techniques disappeared, prompting problems of replication without first-hand experience of the original experiment or object. The fate of thrifty science might be seen in tacit knowledge, a bricolage of techniques that has become unacknowledged and ignored. Which history of the telescope will mention the dumbell wieight from Gold's Gym that I spotted balancing one of the telescopes in Greenwich Observatory on a recent visit (**Figure 7**)? Nevertheless, as historians rethink science as practice, so tacit, and thrifty techniques and devices are coming back into focus. The green labs movement seeking to make scientific research more sustainable is one part of a broader effort to rethink our material lives to move away from the modern goal of unending growth and consumption to return to a picture of balance, between what the world can provide and what people can consume. There are surely lessons from early modern history and its thrifty approach to materials that can elucidate means to achieve this. The rise of repair cafés, hack and makerspaces, the maintainers movement, green labs, and other environmentally-driven sites mixing community, sustainability, and technical knowledge are evidence in my eyes of something of a return for thrifty science. The history of instruments can play a significant role in these enterprises, teaching us about the history of how people "made use" of things, how they repaired and recycled, and how they made sense of the world of material things in ways that used them effectively to learn about nature without destroying the environment.

[19] Harry Collins, *Tacit and Explicit Knowledge* (Chicago: University of Chicago Press, 2010).

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Figure 5. Geertruydt Roghman, ‘A Woman Cleaning’, Plate 5 from Five Feminine Occupations, ca. 1648–50. Engraving, New York, Metropolitan Museum of Art. https://www.metmuseum.org/art/collection/search/383483?showOnly=openAccess&ft=kitchen&offset=80&rpp=40&pos=88

Figure 6. Compass microscope whose case forms part of the instrument. Plate 12 from Martin Frobene Ledermuller, *Amusement microscopique, tant pour l'esprit que pour les yeux, contenant... estampes... d'apres nature*, plates volume (Adam Wolfgang Winterschmidt, Nuremburg, 1768). Royal Society, RS.19934. © The Royal Society.

Figure 7. Gold’s Gym weights used to balance the 28-inch refractor, Royal Greenwich Observatory, London. Photograph by the author.