Instruments and Their Makers:
a study of experiment, collaboration and identity in seventeenth-century London

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Abstract

This thesis argues that the history of instruments of science has neglected to focus on the materiality of the physical artefacts for too long. A material cultural approach therefore provides a useful corrective to the technology-based studies. This neglect means much of the wider social and cultural use and function of the objects during the seventeenth century has not been fully appreciated by historians. This is especially true because of the relative absence of detailed documentary evidence in archives for how instruments were made. However, a ‘one-size-fits-all’ material methodology does not work because the multiplicity of types of objects is reflected in their traditional categories (Bennett/Baker et al). Why?

In short: the definition of ‘instrument’ changed during the period 1650 – 1730, in the face of new technologies emerging in the early century. The meaning of ‘instrument’ therefore evolved from ‘precise’ mathematical devices used for practical application, to novel and curious luxury objects such as telescopes and microscopes, that were consumed as desirable collectables, rather than used as mathematical tools. This is evident in the material qualities of many objects, reflective of the contemporary demands and tastes, as well as in advertising techniques from the time that demonstrate a widening clientele for more novel instruments for entertainment.

As a result of this change in definition of ‘instrument’, the contemporary understanding of who and what a ‘maker’ was began to expand too, as social boundaries crossed, and users became consumers and both groups assumed a greater agency. The nature of collaboration in production was different for separate instruments. The traditional distinction between different roles and makers changed. Whereas Hooke may have been a hybrid figure, as optical instrument making grew, the ‘maker’ came to be the workshop owner, without claims to invention or commission.

List of Illustrations

Images are used with the permission of the Science Museum, other relevant institutions or are in the public domain. All images credit the institution that owns the object, even when images were obtained by permission or individually by this author.

List of Objects

Objects are listed in order of appearance in the thesis, with their museum object numbers given as a number. It is important to recognise that each object is discussed individually and so grouping objects by maker or type would give the impression that this thesis has put together a directory or catalogue.

It argues for the opposite approach – that by looking in-depth at objects and considering them on an individual basis, we can gain a greater understanding of their own stories, their histories and their makers. For that reason, they are listed in order of appearance.

Calculating Machine by Samuel Morland, 1876-538, Science Museum Group Collection.

Semi-circular Protractor by Henry Sutton, 1953-258, Science Museum Group Collection.

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Author’s Declaration

I declare that this thesis is a presentation of original work, and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

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1

Instruments and Their Makers - the Introduction

This thesis is about instruments – not the musical variety, but those that today we consider 'scientific'.[1] In short, it examines instruments used for calculation, and observation. In the seventeenth century, they were not termed as 'scientific' because 'science' itself was a sparingly used word.[2] Since the 1960s, historians have criticised the accuracy and appropriateness of the use of terms such as 'science', especially when referring to people, activities or objects from the early modern period. Today, scholars try to avoid using terms with very different modern connotations to categorise or identify past persons or practices because of the anachronistic problems this poses. 'Science', 'scientist', 'scientific' and 'early modern science' are all terms that this thesis makes limited use of. The main difficulty is that 'science' is a word that only entered a wider usage in the nineteenth century.[3] If we look at the place and space within which what later became known as 'science' was practised, this presents us with a less certain picture. This work contributes to this very debate, by recognising that although the instruments were not labelled as 'scientific' at the time, the instruments themselves became objects of curiosity in their own right, away from what may be considered by modern standards their intended 'scientific' uses.

Jim Bennett advocates the use of 'mathematical instruments' as an 'illuminating alternative' to the anachronistic 'scientific'. Not only is the terminology one that was well-understood in

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[1] The Scientific Instrument Commission hosts an annual international symposium on 'Scientific Instruments'. In 2022, the Symposium will focus on the relevance of the term itself, and how this has changed in the past four decades: *Scientific Instrument Commission*, accessed Dec 01, 2020, https://www.scientific-instrument-commission.org/sic-conferences/item/xli-symposium-of-the-scientific-instrument-commission

[2] When used as a noun, the style used in this work is 'seventeenth century'. When the phrase is used as descriptive, it is hyphenated as 'seventeenth-century'.

[3] Alexi Baker, 'This Ingenious Business: the socio-economics of the scientific instrument trade in London, 1700-1750' (doctoral thesis: University of Cambridge, 2010), 13.

the time period, as opposed to 'scientific', but it is also a reflection of the 'dominant' type of instrument made during the seventeenth century which was 'mathematical'.[4] Although this thesis looks at mathematical instruments including quadrants and protractors, it also looks at the many examples of late seventeenth-century instruments that may not be thought 'mathematical', but are instead 'optical' such as telescopes and microscopes. The makers of both types considered themselves 'instrument-makers', as this work will show. In a shift from more biographical based theses, and histories, this work deliberately puts the objects first. They are presented, as they were analysed (first) to explain how their makers worked and the world within which they operated. The thesis is not about instrument makers alone, it is about 'Instruments *and* their Makers'.

In arguing that the objects should come first, and by taking a material approach, this dissertation provides a useful corrective to the technological or curatorial studies that have traditionally taken place. This neglect of a focus on materiality means much of the wider social and cultural use and function of the objects during the seventeenth century has not been fully appreciated by historians. This is especially true because of the relative absence of detailed documentary evidence in archives on how instruments were made.

In short: the definition of 'instrument' itself changed during the period 1650 – 1730, in the face of new technologies emerging in the early century. The meaning of 'instrument' evolved from being used to refer to 'precise' mathematical devices for practical application, to novel and curious luxury objects such as telescopes and microscopes, that were consumed as desirable collectables, rather than just used as mathematical tools. This is evident in the material qualities of many objects, reflective of the contemporary demands and tastes, as well

[4] Jim Bennett, 'Early Modern Mathematical Instruments', *Isis* 102, no. 4 (2011): 697-705.

as in advertising techniques from the time that demonstrate a widening clientele for more novel instruments for entertainment.

As a result of this change in definition of 'instrument', the contemporary understanding of who and what a 'maker' was began to expand too, as social boundaries crossed, and users became consumers. The nature of collaboration in production was different for separate instruments, for example as optical instrument making grew, the 'maker' eventually came to be the workshop owner, without direct claims to invention or commission.

Much recent academic work on early modern experimentation has focused on 'science' as a practice and its social context, the relationship between theory and practice, the role of material cultures, or it has focused on the place of instruments within the so-called 'Scientific Revolution'.[5] The long title of Steven Shapin's 2010 collection of essays, *Never Pure*, best explains summarises why the concepts of 'science' and 'scientific' can be problematic.[6] Work in this area and of this type has largely considered instruments as a by-product of, or a stream of, what was termed 'natural philosophy'. Sometimes, when instruments are included, and discussed, the focus turns to their users rather than examines the material qualities of the instruments themselves and their makers. On the other hand, curators tend to focus on instruments and their makers, and usually engage with the mainstream history of science as contextual and descriptive, although Jim Bennett is a notable exception. This sort of 'instrument history' is not easy to define, it exists in many

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[5] In a 2012 article on the historiography of 'not-so-recent science', Peter Dear refers to the '*late* Scientific Revolution', explaining that the concept's death is the result of the increasing tendency to see what is considered 'science' in the twenty first century as a nineteenth century creation. See: Peter Dear, 'Historiography of Not-So-Recent Science', *History of Science* 50, no. 167, (2012): 197-212.

[6] Steven Shapin, *Never Pure - Historical Studies of Science as if It Was Produced by People with Bodies, Situated in Time, Space, Culture, and Society, and Struggling for Credibility and Authority* (Baltimore: Johns Hopkins University Press, 2010).

forms, and is often individual to the curator or the museum within which they work and research. This thesis is different. It seeks to put the objects first and work outwards from them as its starting point.

The instruments in this thesis are not a series of static objects. They may now be stored in museums, but they once were used, handled and exchanged by many people for multiple, unique, reasons. They are instantiations of relationships, conversations, exchanges and transactions among people. Each instrument is a 'solution' to a particular problem, often with practical, mechanical, and economic dimensions. It is also an expression of individual skill. In Stuart London, such problem-solving activity necessarily brought together instrument makers, artisans and in some cases Royal Society Fellows. This thesis tells the stories of twenty-six objects. It considers their observable material qualities, examines their backgrounds, and uncovers information about their makers and the contexts within which they were made, transacted and circulated. It does this by putting the instruments first, which reflects how the research was carried out. This introduction will set out firstly how this was done, what methodological approach is being advocated? Second, it will explain why – what makes this study different?

This thesis is influenced, along with other works, by the ideas and arguments set out by Kiersten Latham and Elizabeth Wood in a 2009 article entitled 'Object Knowledge: Researching Objects in the Museum Experience', where they set out what they believe to be the importance of so-called 'object knowledge'.[7] To be influenced by this article does not mean it needs to be used by the author of this thesis as a repetitive benchmark or referenced

[7] Kiersten F. Latham & Elizabeth Wood, 'Object Knowledge: Researching Objects in the Museum Experience', *Reconstruction: studies in contemporary culture* 9, no. 1 (2009), accessed Dec 10, 2020, https://www.researchgate.net/publication/329542758_Object_Knowledge_Researching_Objects_in_the_Museum_Experience

throughout. But it is true that the philosophy, approach, and the ideas they argue for as well, are all things that unashamedly and implicitly influence this work and the research that underpins it. Their article is not ground-breaking in the conventional academic sense, but it sets out the reasons why, better than any other source that this author has read, the arguments and philosophy that informs the purpose and direction that the research in this thesis subsequently took. 'Object knowledge' may be a concept understood by curators, but whether it is understood and utilised by academic historians, who look at and use objects as a source, is an entirely different question.

Although primarily concerned with the experience and interpretations that museum visitors have, the approaches Latham and Wood set out to explain exactly why a new approach to the study of objects is required. The academic study of objects and the curatorial examination of them have for too long been apart. This thesis gives an example of how that approach could more effectively be used in studies that seek to use objects as sources. It is one thing to examine what the object was made from and how it was made. It is more complicated to analyse what cultural value or meaning the completed object acquired once it was made, and how these meanings changed over time as new users interacted with the objects. This is where Latham and Wood come in. What is 'object knowledge'?

Latham and Wood use an interdisciplinary approach to theorise the best practice in museum research, from the stance of 'object knowledge'. This approach is aimed at describing the ways of 'knowing' that can only be made possible from the interactions that people had with physical objects and that the lived experiences of people are therefore inherently a part of the objects they created and used. It is for historians to uncover this.[8] Historians could learn from

[8] Latham and Wood.

this approach. Objects should not be used as mere illustrative examples. They should be examined and analysed as the first point of research. That is what this thesis aims to do. Latham and Wood's article argues how and why museums should present their objects to have the most impact on visitors. But historians should not be immune from the ideas they present. An object-based history can approach examining the past in the same way. By looking at the objects first, qualitatively examining and describing their appearance, and then by going on to investigate the materials they made of, then the marks and defects that make them distinctive in as much detail as possible is the methodological approach taken.

It is not enough to look at when a type of object was made, how, and then apply this broad understanding to objects of similar types. Each artefact is unique. Every user or consumer of an object means it has new values and meanings attached. Objects are therefore constantly going through a process of 're-contextualisation' of human meanings, as their original meaning, use or value is reduced or reconfigured. According to Stocking this may be due to the paradoxical timelessness of objects, even by the time they come to be stored in museums they sit as both removed from the past and dually as a part of it either on display or in store.[9] Provenance, that is what is understood to be the history of the object's acquisition and ownership, can contribute to our knowledge but this is dependent on the past motivations of owners and collectors. This is sometimes not certain and is further reason why 'object knowledge' and the examination of objects as individual items is important.

Arjun Appadurai argues in *The Social Life of Things* (1986) that researchers should 'follow the things themselves, for their meanings are inscribed in their forms, their uses, their

[9] George W. Stocking, 'Essays on Museums and Material Culture', in *Objects and Others* ed. George W. Stocking (Madison: University of Wisconsin Press, 1985), 3-14.

trajectories'.[10] Appadurai acknowledges that the attribution of a 'social life' to inanimate objects is something of a 'conceit', but that it is the 'transactions that surround things are invested with the properties of social relations'.[11] This dissertation agrees with this approach. That is why each of the objects that is included is presented as an individual item, with individual characteristics and unique aspects all accepted as the result of the individual 'life' the object has had.[12] Igor Kopytoff argues that 'things' have a 'cultural biography' in one of the articles from Appadurai's edited volume.[13] This dissertation makes a contribution to the history of early modern instrument making by doing just that: recreating the hidden pasts of the objects, how they were made, and used by thinking of their biographies. It tells the stories of the objects.

The objects presented in this dissertation are included for two reasons. First, the research that was carried out into them meant it was possible to tell their stories more than other objects that were researched but not used in the final dissertation. In many cases they typify the changes that took place during the period, and embody the social and economic interactions that were mentioned earlier in the Introduction. For some of the objects, this research has led to a further and more detailed understanding of how individually they were made, as well as the interactions that the makers had with others. Second, most of the objects come from the collection of the Science Museum and many are not on public display. This dissertation therefore seeks to remove them from their hidden lives in the Museum stores and place them at the centre of a new history on seventeenth-century instruments and their makers. Bennett

[10] Arjun Appadurai, *The Social Life of Things – commodities in cultural perspective* (Cambridge: Cambridge University Press, 1986)
[11] Arjun Appadurai, 'The Thing Itself', *Public Culture* 18 (2006): 15-22.
[12] Daniel Miller argues that objects are subjected to many cycles during their lifetime such as through exchange, appropriation, consumption, use and later collection. See: Daniel Miller, *Material Culture and Mass Consumption* (Oxford: Blackwell, 1987)
[13] Igor Kopytoff, 'The Social Biography of Things' in *The Social Life of Things* ed. A. Appadurai (Cambridge: Cambridge University Press, 1986), 64-91.

often looks at ‘fabulously rare’ objects – a phrase used in ‘Early Modern Mathematical Instruments’ but a common theme in his work.[14] When objects are placed on display for their rarity, it can give us a distorted image. Objects that are not on display, but held in museum stores, are often there because they are considered typical. As this work shows, despite what superficial ordinariness there may be to some pieces not deemed worthy of display, the objects still have hidden, long and individual stories that can give us an unique insight into the lives of the people who interacted with the objects.

The Science Museum has over 380,000 objects, only a small fraction of which are on display. Of course, there are other significant collections across the world, including in England. The Whipple in Cambridge, Oxford Museum of the History of Science, and British Museum in London, all have comparable objects in varying number. This dissertation looks at the Science Museum’s objects for one simple, and essential, reason: access. Every one of the objects included in this work has been handled by the author during their time as a researcher at the Science Museum, in some cases on more than one occasion. The ‘object knowledge’ approach, looking at objects close up, handling them, examining them, recording them and replicating how they would have been held or used, can only be achieved with this direct access. It cannot be done by viewing items in other museums behind a glass display. Almost 4,000 objects owned by the Science Museum date from between 1600 and 1750.[15] That means the twenty-six objects in this study represent a small number of the Museum’s catalogue. Unlike other studies into museum collections of scientific instruments (L’E Turner and Clifton’s studies feature later), this is not a directory or a list of groups by type or maker. Those studies already exist, and this research is positioned to offer a new approach. It is an

[14] Jim Bennett, ‘Early Modern Mathematical Instruments’, *Isis*, 102, no. 4 (2011): 697-705.
[15] As a museum that acquires new pieces, the exact figure fluctuates. It is possible to search the database online: *Science Museum*, accessed March 03, 2022, https://collection.sciencemuseumgroup.org.uk/

examination of individual objects and their stories. Some are included because they have features typical to other instruments, others are included for their quirks. All are considered on their own terms and because more was uncovered during the research than others that this author handled, examined and analysed. If museum displays put the most attractive examples of artefacts on display, then what about the many that are stored behind the scenes? They have unique, long and hidden histories. This research aims to uncover those histories.

The main body of this work is divided into six chapters including this introduction chapter. The second chapter 'Mathematics and Mechanics' examines the changing nature of mathematics and the resultant changes in mathematical instrument making and consumption. Mathematical instruments were niche, precise objects used by a range of practitioners. Through an examination of a series of mid-century instruments it is argued that the traditional distinctions of modes of knowledge crossed over and a form of hybrid mathematical maker emerged. With reference to the work of Margaret Jacob, Bruno LaTour, Igor Kopytoff and E. Taylor, the chapter explains why the closed social boundaries of who could practice mathematics opened up and the effect this had as a consequence on the realm of mathematical instrument making. The chapter focuses on objects created and sold by Henry Sutton, Walter Hayes and Isaac Carver. These changes to what constituted 'mathematics', and 'mathematical instrument' making, led to developments elsewhere that are the focus of subsequent chapters.

The third chapter, 'Curious Playthings' examines the boom in the consumption of telescopes and microscopes that occurred after the mid-seventeenth century. It argues that after their creation in the early century, their application was first for the observation and exploration of the natural world by philosophers and for practical ends such as in surveying at warfare, but that this changed too from the 1650s and 1660s. A growing market for consumer goods led to telescopes and microscopes being produced in greater number, more cost effectively and marketed towards a greater number of clients. These were not only used for practical purposes but positioned as novel, new, fun objects that were curious, collectable, and desirable. This itself altered the status of the makers that produced them as ‘instruments’ became less about precision and were more accessible to non-traditional consumers than before. A detailed material study of telescopes and microscopes in the Science Museum collection includes investigative work into the origins of materials including paper and pasteboard and the presentation of original new findings about some of the objects studied.

The fourth chapter, ‘Paper Merchants’, examines an unique source that has featured in other studies but not as a standalone exploration into the trade in mathematical and experimental ‘instruments’: trade cards. Collections of eighteenth and nineteenth-century ‘cards’ are numerous, but the rarer, more sporadic pieces from the seventeenth century can reveal much about the way instrument makers identified and marketed themselves and their objects. Through a cross-comparison with other forms of advertising and newspaper advertisements from this time, the chapter shows about the way makers positioned themselves became more targeted towards a broader consumer base and that their activities often crossed into publishing and the production of other types of objects that were not ‘instruments’. The fifth chapter concludes the thesis and summarises the fundamental findings of the research as well as promoting areas for future research or material cultural studying. As this work is primarily a material study into historic objects, they feature prominently in the chapters as the main source of evidence for the argument. The selection and inclusion of instruments at different points is explained in each chapter. In some cases, objects are included because they are typical, at other times because of their unusual qualities.

A sixth and final chapter, ‘Coda – Watchmaking and Future Research’, introduces ideas about the potential for future research on the links, or differences, when the instruments in this project are examined alongside watchmaking and clockmaking. The trades of watchmaking and clockmaking are often separated from those studies about other objects. In some works, watches and clocks are included alongside instruments, at other times they are omitted. This final chapter is based on research and findings that came up during the doctoral project and questions the links that could be made with instruments in the future.

2.

Mathematics and Mechanics: how the concept of a 'mathematical instrument' changed during the seventeenth century.

'If any person desire to have either of these Instruments exactly made, and So as it my Serviceable for many years. He may bespeak it of Mr. Humphry Adamson, living at present at the House of Jonas Moor, Esqs in the Tower, who is the only Work-man that ever as yet could be found by the Author to perform the said Instrument, with that exactness that is absolutely necessary for such Operations'[16]

Samuel Morland, 1673

Introduction

Morland recommended Adamson because of his 'exactness'. Only his 'exactness' could put together the calculating machine that he designed. The sort of precision that Morland meant by this was the artisanal skill used to make a small, metal, mechanical device, with multiple components. The 'mathematical' exactitude, used to *design* a new form of instrument, was Morland's. Regardless of this 'exactitude', the calculating machine did not become popular. It was criticised by Pepys in his *Diary* as '[an] invention for casting up of sums [which is] pretty but not very useful'.[17] It may be that the picture this instrument gives us about seventeenth-century mathematics is distorted. It leads to two questions: what was a mathematical instrument, and who was the maker? Was the maker the one versed in mathematics, or craftsmanship? Morland's machine is explored later in the chapter as a case of instrument making on the cusp, as the traditional division between modes of knowledge began to dissolve.

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[16] Samuel Morland, *The description and use of two arithmetick instruments* (1673), 12.

[17] '14 March 1660', *The Diary of Samuel Pepys*, ed. Robert Latham and William Matthews (Berkeley: University of California Press, 1971), 87-8.

Illustration 1: Calculating Machine by Samuel Morland, 1876-538, Science Museum Group Collection

This chapter argues that in the seventeenth century, there was a breakdown in the consensus over the question of who could practice mathematics, and this led to a change in mathematical instrument trade and the social status of instrument makers. This meant that 'mathematical' instruments themselves crossed the boundary from niche, precise instruments, towards desirable ones that were marketed towards and consumed by a larger and more diverse clientele. The working practices and the relationship between maker and mathematician therefore changed as the former division between forms of knowledge broke down, so that by the end of the century instrument makers acted as 'hybrid' agents. These 'hybrid' agents combined mathematical understanding and craft skill. Their knowledge and skill existed in both forms.

The instruments are the embodiment of these changes. Through four mathematical instruments, this chapter explains how the instruments and their makers are the manifestation of gradual changes in consumer behaviour, working patterns and the purpose of the instruments. As Igor Kopytoff says, it is possible to ask questions of objects as with people, such as what were the key moments in their development and when did their status change?[18] This question is fundamental to the chapter. If the status of the instruments changed, then this provides an insight into when the role and status of the maker changed. It also promotes a biographical approach by which the life of the object is traced and understood, before it became part of a collection and its meaning changed again.[19] As Sam Alberti argues, objects acquired their meanings through social interactions before they became part of a collection.[20] In the case of seventeenth-century mathematical instruments, these interactions often centred on claims to maker-ship and as the meaning and concept of what constituted a 'mathematical' instrument changed, so too did the role and self-fashioning of the maker.

The four objects selected in this section have been chosen because more is known about the lives and careers of their makers than those of other comparable instruments. This aided the subsequent research and 'object knowledge' approach. In many ways they are representative of similar instruments, but sometimes they have unique physical characteristics that point to wider changes in the trade of the objects. The chapter does not argue that the objects were the most important of their time, instead they are emblematic of broader changes, for example through their materials, their inscriptions and accessories such as books that accompanied the instruments. Nor is it claimed that it is the objects rather than the people that were the drivers

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[18] Igor Kopytoff, 'The cultural biography of things: commoditization as a process' in *The Social Life of Things: Commodities in Cultural Perspective*, ed. Arjun Appadurai (Cambridge: Cambridge University Press, 1986), 64-94.
[19] S. J. M. M. Alberti, 'Objects and the Museum', *Isis* 96, no. 4 (2005): 559-571.
[20] Ibid.

of change. Whilst Pickering believes human-made objects possess a form of agency, this thesis argues that the central agency was with the maker.[21] As tools that were used for mathematical purposes, the agency was with the maker and the consumer, who used them to practice mathematics. As Lorraine Daston argues, the objects did not act, but were acted 'upon', and to allocate agency to the inanimate is to diminish the power of human agency.[22] This is especially true of instruments.

Clearly, as human-made objects, the mathematical instruments caused some effects amongst their users and consumers that their makers may not have designed. After all, when objects left the workshop, they were used for varied purposes. As museum and collection objects, they acquired a later meaning that their maker would not have had in mind. The associations and meanings ascribed by curators or visitors centuries later are very different, and in part caused by the full life of the object.[23]

The chapter makes four inter-connected claims about the instruments, about the mathematical culture in later seventeenth-century London. First, instrument makers occupied a prominent place within the network of mathematical practitioners. The distinct types of knowledge and the statuses of the instrument makers became less rigidly defined. Second, that the concept of who a 'maker' was changed. Signatures, names and monograms can be used to explore how the 'credit' for instruments was not straightforward and is indicative of the broad, fluid nature of the status of the 'makers'. Third, that the emergence of 'novelty' items such as Morland's calculator are indicative of a breakdown in the former specialist culture of instrument use.

[21] Andrew Pickering, 'Material Culture and the Dance of Agency', in *The Oxford Handbook of Material Cultural Studies*, ed. Dan Hicks and Mary C. Beaudry (Oxford: Oxford University Press, 2012): 191-208.
[22] Lorraine Daston, *Biographies of Scientific Objects* (Chicago: University of Chicago Press, 2000).
[23] Alexander Stevenson, 'Experiencing Materiality in the Museum' in *Museum Materialities: Objects, Engagements, Interpretations*, ed. Sandra Dudley (Oxford: Routledge, 2010): 103-113.

Instead, instruments were marketed to a widening consumer base as desirable and useful commodities. This had implications for other objects, such as optical instruments (chapter three) and can be observed from the evidence of advertising ephemera later in the century (chapter four). Fourth, that the use of new, exotic, materials show that the functionality of the instruments in some cases was equalled by their aesthetic appeal and allure as desirable objects. They circulated within a market where the raw materials were new, international and parallel to the world of culture and learning, but in a less institutionalised setting.

These all support the argument that a breakdown in the former boundaries between types of knowledge, and concepts of what constituted an 'instrument' led to the blending of different types of knowledge and the emergence by the later century of 'hybrid' agents that possessed both mathematical and craft-based knowledge.

Who practiced mathematics?

E.G.R. Taylor argues that the world of the 'mathematical practitioner' comprised a diverse range of peoples. In the sixteenth and seventeenth centuries, astronomers, surveyors, military engineers and navigators 'remained in close touch with the instrument-maker'.[24] The concept of the 'practitioner' occupies a primary place in her work. Longitude, navigation and surveying appear prominently in *The Mathematical Practitioners of Tudor and Stuart*

[24] E.G.R. Taylor, *Mathematical Practitioners of Hanoverian England* (Cambridge: Cambridge University Press, 1966), 3-4.

England. The founding and early years of the Royal Society are often linked to the issues surrounding solving the longitude puzzle.[25] For Taylor, 'mathematical practitioners' were those whose income was obtained from selling their skills or knowledge in mathematics, either '…by teaching, writing, constructing [or] selling instruments', and that since the end of the sixteenth century both university educated and self-taught men in London positioned themselves as practitioners of mathematics for a variety of social and economic purposes.[26]

Mathematical instrument makers might better be understood as these 'practitioners'. This is because the blending of different skills (artisanal) and knowledge (mathematical) gathered pace as the century progressed. The fusion of previously segmented types of knowledge between the mechanical (used by the hand) and the theoretical (used by the mind) led to the creation of a form of hybrid mathematical instrument maker. These makers produced objects that were marketable to a broader, less specialised, consumer base, as the objects became more likely to be fashioned as desirable commodities as well as instruments of precision.

In England, a 'culture of the mathematicalls' emerged after 1570 from a mix of activities that included globe-making. As Higton argues, the concept of 'mathematical practitioner' is not one that 'can be held rigidly … [the] nature of the [term] meant that academic mathematicians, gentlemen amateurs, mathematical teachers and instrument makers were

[25] Cambridge University Library and the National Maritime Museum at Greenwich collaborated on a project that compiled over 60,000 images and documents related to the Longitude Board between 2011 and 2014, alongside a five-year AHRC project that compiled a written history of the Board with the University of Cambridge and the Museum.

[26] Lesley B. Cormack, 'Practical Mathematics, Practical Mathematicians, and the Case for Transforming the Study of Nature', in *Mathematical Practitioners and the Transformation of Natural Knowledge in Early Modern Europe*, eds. Lesley B. Cormack, S. Walton and John A. Schuster (Bern: Springer, 2017), 3-4.

linked to the 'mathematical practitioners'.'[27] She argues that the practical (professional) application of instruments was carried out by a range of trades. For example. the surveying of land was one reason for the purchase and use of mathematical instruments.[28] In this sense, instruments were more akin to a 'tool' according to Deborah Warner.[29]

When Nehemiah Grew compiled an inventory for the Royal Society in 1681, he differentiated between instruments used for 'mathematics' and those applied for the purposes of 'natural philosophy'.[30] This thesis argues that this distinction slowly broke down as the eighteenth century approached. As later chapters show, 'makers' came to produce and supply mathematical objects, and those for natural or experimental philosophy, at the same time. For Bennett, the 'distance' that mathematical instruments had from natural philosophy is striking, as despite appearing to be more 'theoretical' as opposed to 'practical' they do not necessarily reveal truths about the natural world.[31] Furthermore, the 'freedom' that this gives them means they are not restricted by the 'problematic issues of natural philosophy'.[32] They are instruments for doing. This may explain some way why the makers may not have needed a theoretical background in mathematics.

In the 1990s the banding together of all sorts of instruments as 'scientific' was forcefully debunked as anachronistic.[33] Jim Bennett argues the term 'mathematical instrument' was one

[27] Hester Higton, 'Does using an instrument make you mathematical? Mathematical practitioners of the 17th century', *Endeavour* 25, no. 1 (2001): 18-22.
[28] Ibid.
[29] Deborah Jean Warner, 'What is a Scientific Instrument, When Did it Become One and Why?', *British Journal for the History of Science* 23 (1990): 83-93.
[30] Ibid.
[31] Jim Bennett, 'Practical Geometry and Operative Knowledge', *Configurations* 6 (1998): 195-222.
[32] Bennett, 'Practical Geometry and Operative Knowledge', 209.
[33] This is the subject of a series of essays in *Reappraisals of the Scientific Revolution*, ed. David C. Lindberg & Robert S. Westman (Cambridge: Cambridge University Press, 1990).

that had acquired much cultural ‘currency’ by the second half of the seventeenth century in England.[34] By 1700, the term ‘mathematical instrument’ possessed a common meaning that was distinct from other types of instrument, and was used by the array of ‘practitioners’ within varied cultural, social and commercial spheres.[35]

Alexi Baker distinguishes between three categories: the mathematical, the optical, and the philosophical. For Baker, ‘mathematical’ instruments were those used to perform arithmetical and trigonometrical calculations and for measuring distances or angles.[36] This was true, but it is the argument of this work that this clear distinction began to break down as the century progressed and this is evident in some of the artefacts. After all, by 1700, the ‘life’ of instruments was not for academic purposes alone, as surviving instruments, publications and ephemera, all demonstrate.[37]

The Breakdown of Consensus

As the seventeenth century progressed, changes to working practises indicate that the socio-economic boundaries between the mathematical academics and professionals and the craft-based artisans began to break down. This breakdown first took place in the realm of

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[34] J.A. Bennett, ‘Early Modern Mathematical Instruments’, *Isis* 102, no. 4 (2011): 697-705.
[35] Ibid.
[36] Alexi Baker, ‘This Ingenious Business: the socio-economics of the scientific instrument trade in London, 1700-1750’, (doctoral thesis, University of Oxford, 2010); 6-7.
[37] Bennett, ‘Early Modern Mathematical Instruments’, 700.

mathematics itself. During the 1630s, William Oughtred, the inventor of the slide rule, was embroiled in a much-documented dispute with Richard Delamain. In the pamphlet dispute that followed, Oughtred's view on the distinction between mathematics and instrument drew attention; Florian Cajori argues that Oughtred was slow to respond to Delamain.[38] For Oughtred, the untrained Delamain was able to teach mathematics by way of demonstrating a 'set of tricks' with the instruments alone.[39] Whereas Oughtred felt that students of mathematics should be introduced to using instruments only after acquiring a solid intellectual foundation in pure theory, Delamain believed that beginners should be given instruments to use immediately.[40]

For Katherine Hill, this episode represented a turning point; it showed that '[…the] breakdown of consensus over internal mathematical boundaries' had started, and she argues that this had repercussions in the succeeding decades.[41] This chapter expands on her view that the mathematical world witnessed such a breakdown, as a means of explaining why changes took place in the production and consumption of instruments. Oughtred complained in *The Circles of Proportion* (1631) that mathematics with instruments alone, without any theoretical knowledge or understanding, was 'vulgar' and made him 'stricken with dread and trembling'.[42] Delamain was trained as a joiner and made the mathematical instruments that he also taught with (without any qualification) for financial gain. The wealthier Oughtred was

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[38] Florian Cajori, *On the History of Gunter´s Scale and the Slide Rule during the Seventeenth Century* (Frankfurt: Verlag, 2018), 18.
[39] A.J. Turner, 'William Oughtred, Richard Delamain and the Horizontal Instrument in Seventeenth Century England'. *Annali dell'Istituto e Museo di storia della scienza di Firenze* 6, no. 2 (1981): 99-125.
[40] Tony Gardiner, 'Rigorous Thinking and the Use of Instruments', *The Mathematical Gazette* 476 (1992): 179-181.
[41] Katherine Hill, ' "Juglers or Schollers?": Negotiating the Role of a Mathematical Practitioner', *British Journal for the History of Science* 31, no. 3 (1998): 253-274.
[42] William Oughtred, *The Circles of Proportion and the Horizontall Instrument*, (printed by William Forster: London, 1639), 32.

known to give away tuition and instruments to his students without charge.[43] Both could be considered 'practitioners' but with different modes of knowledge and socio-economic positions. As the century progressed the separation between the two types of knowledge that Oughtred argued for became blurred.

By the 1720s thinkers such as Thomas Hearne lamented that the field of mathematics had become '...scarce looked upon as Academical...but rather Mechanical: as the business of Traders, Merchants, Seamen, Carpenters, Surveyors...'.[44] In less than a century, it had become accepted that it was not necessary to have a mathematical education before using instruments. Despite the Elizabethan mathematicians' emphasis on understanding the 'theoretical' in order to perform the 'practical', it was in the seventeenth century that the supremacy of one over the other came to be forcefully argued in print, as is evident in some of the surviving printed works of the time, and as the 1630s dispute shows. For Richard Poss, practitioners in Elizabethan England favoured the 'speculative' rather than what he calls the 'practical' side of mathematics (building on concepts outlined by Francis Bacon in *The Advancement of Learning*), and that the focus of 'craft mathematicians' was the creation of mathematical texts that could be used to emulate other Europeans.[45] Instead, it was in the seventeenth century when the forms of knowledge became less rigidly defined. This meant the agency of makers changed from a rigid model where forms of knowledge between mathematics and craft were separate, to a more hybrid form where artisanal craft and mathematical knowledge were blended.

[43] Hill, 263-4.
[44] Thomas Hearne, *The Works of Thomas Hearne – Peter Langtoft's Chronicle* (London, 1810), xclviii.
[45] Richard P. Poss, 'The Social and Economic Causes of the Revolution in the Mathematical Sciences in Mid-Seventeenth-Century England', *Journal of British Studies* 15, No. 1 (1975): 46-66

Making the Mathematical – instruments of precision

The types of instruments that academic and professional practitioners of mathematics used included those for calculation and measurement. These were specialised and niche instruments and in the mid-century were consumed by a specialised clientele and included items for geometry such as protractors. A sign that they were not well-known outside the world of mathematical learning comes from Thomas Blount's *Glossographia*. In it he recorded the definition: 'Protractor (Lat) a prolonger or drawer out; also a Mathematical instrument, made of brass, used in surveying land.'[46] The book also includes: 'Quadrant (quadrans) the fourth part of a pound, or of any number or measure; Also a Mathematical Instrument so called, being the quarter of a Circle.'[47] In both cases, the use of each term as a sort of instrument was only the secondary definition.

Blount defined what he considered to be unusual words, all derived from what he called '[the] English tongue'.[48] He achieved this through the composition of a long list of the '...etymologies, definitions and historical observations [of] the terms of divinity, law, physick, mathematicks and other arts and sciences explicated'. Blount's work was one of the few to focus on words that were found and used in the arts. Now considered to be one of the 'early dictionaries', it was compiled around a century before Samuel Johnson's famous masterpiece, one of a number of similar works to be published before the eighteenth century.[49]

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[46] Thomas Blount, *Glossographia or, A dictionary interpreting all such hard words of whatsoever language now used in our refined English tongue* (London: 1661), Bodleian Library, Oxford.

[47] Blount.

[48] Blount.

[49] Lynwood Carranco, 'Let's stop worshipping the dictionary', *The Clearing House* 29, No. 2 (1954): 72-76. For a detailed, not exhaustive, list, see: Richard Leo Enos and Tony M. Lentz, 'A Bibliographical Guide to English Linguistics: 1500-1800', *Rhetoric Society Quarterly* 6, no. 4 (1976): 68-79.

This is an indication that objects such as protractors were specialised instruments whose use and purpose was not widely understood. For example, a search on *Early English Books Online* shows that ‘protractor’ returns a single hit for the 1660s, thirteen occurrences from the 1670s and then thirty-one in the 1680s, suggesting the use of the word increased more widely. This is far lower than a comparable search for the word ‘telescope’, where in the 1660s there were 128 returns, almost doubling to 252 for the 1690s. In the mid to late seventeenth century, telescopes and microscopes (as a later chapter argues) were popularised and marketed towards a larger, domestic and less specialised consumer base. But clearly, there were also changes afoot within the trade of mathematical instruments. To chart these changes, the first case study to focus on is that of Henry Sutton.

Henry Sutton: Protractor by Sutton (1953-258)

Henry Sutton (1624c.-1665) was the leading mathematical instrument maker of his day: he operated in London and first became active in 1649, when he was recorded as a member of the Joiners Guild.[50] At least thirty of the instruments he made during his short career survive.[51] His favourable reputation amongst collectors means a variety of different types of instruments that he made have survived: paper, brass, wood all feature. Although historians still have ‘relatively little reliable knowledge about the construction [...of] early [...] instruments’, due to a ‘[…] lack of documentary evidence’, the number of surviving objects in museums means that an analysis of their physical properties can be helpful.[52] Seventeenth-

[50] ‘Henry Sutton’, *Science Museum Group.* Accessed Nov 01, 2019, https://collection.sciencemuseumgroup.org.uk/people/cp11780/henry-sutton
[51] Ibid.
[52] Allan Chapman, ‘A study of the accuracy of scale graduations on a group of European astrolabes’, *Annals of Science* 40, no. 5 (1983): 473-488.

century instruments and forms of knowledge were segmented, but Sutton was active at the time this changed. Sutton's craft skill and training in precision engraving were key to his success.[53] At this time, instruments often were made of a single material (for example, brass) and as such required specific, specialised skill, knowledge and training in working with that individual material.

The instruments Sutton made were precise, mathematical tools, used for the application of measurement, surveying and calculation. As the craftsman who physically created the object (at least if the attribution is anything to go by), he was considered, at the time of their manufacture, and in subsequent centuries, as their 'maker'. There is evidence that his workshop was active at Tower Hill; he also operated out of a premises at Threadneedle Street, and then from 1658 behind the Royal Exchange.[54] During his short career, Sutton took a number of apprentices, notably Samuel Knibb, whom he later went into partnership with in 1664 and whose work with Sutton, on Morland's calculating device especially, occupies a place later in this work. After Sutton's death, Samuel Knibb (who was a member of the Clockmakers' Company) kept the workshop on Threadneedle Street, the name or sign of which is unknown; active until 1670, he died in 1674.[55]

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[53] Boris Jardine, 'Henry Sutton's Collaboration with John Reynolds', *Bulletin of the Scientific Instrument Society* no. 130 (2006): 4-7.
[54] Gloria Clifton, *Directory of British Scientific Instrument Makers 1550-1851* (London: Zwemmer, 1995), 275.
[55] Clifton, 203.

Illustration 2: Semi-circular protractor by Henry Sutton,1953-258, Science Museum Group Collection.

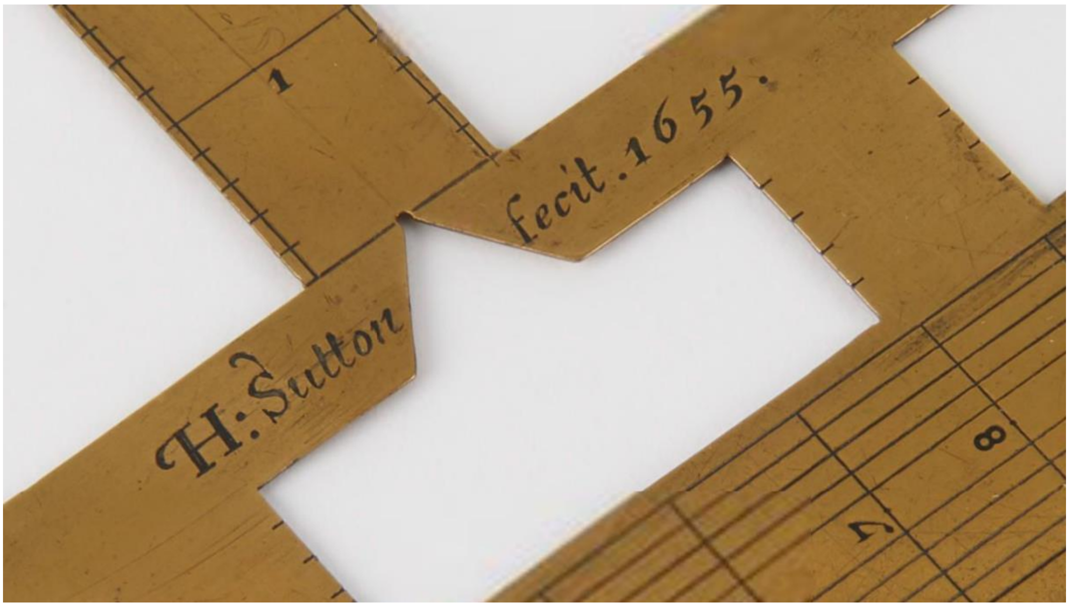

Illustration 3: Semi-circular protractor by Henry Sutton, 1953-258, Science Museum Group Collection.

The brass, semi-circular protractor has a rectangular base and weighs forty-five grams, meaning it was portable, durable and easy to handle, and could be used away from a table or desk. The exact year that Sutton produced this protractor is known. Engraved on the front side of the protractor, prominent and centre in the rectangular rule at the base, are the words: 'H. Sutton fecit 1655'. 'Fecit' is a Latin term indicating 'he made [it]' and from the beginnings of the instrument trade in Elizabethan London had been used when the name of the maker was engraved on the object.[56] 'Fecit' was also used in engraving, to indicate who had done the original drawing and made the plate; similarly, 'sculpsit' was sometimes used to indicate who had engraved the plate with a burin. This first began in the middle of the fifteenth century, when printmakers began to use this as a way to describe their role and differentiate themselves.[57] Sutton used 'fecit' and also occasionally the Latin 'Henricius Sutton' to indicate that he, the artisan, was the 'maker'. The use of a Latin form of his forename may have been to demonstrate to consumers that he was a man of learning, not only an artisan. It may also have been that his instruments were marketed towards a growing international market.

The use of an inscription and the term 'fecit' amongst the artisanal trades was not consistent. Trying to assess whether it was a signifier of being responsible for carrying out most of the manual work, or the possession of both the material knowledge and mathematical understanding to produce it, is complicated. It is similar to the issue around whether the engraving had been made by the artist or the engraver: the design and crafting of the instrument leads us to a similar dilemma. The use of the term 'fecit', and Sutton's name, is an indication that he may have seen himself as the person most responsible for producing the

[56] Helen Turner, 'A newly discovered Elizabethan pocket sundial' *Apollo* 109 no. 159 (2004): 35-37.
[57] Madeleine C. Viljoen, 'Aes Incidinus: Early modern engraving as sculpture' in *Sculpture and Print: 1480-1600*, ed. Anne Bloemacker, Mandy Richter and Marzia Faietti (Leiden: Brill, 2021): 41-69.

item, but this may not mean he was the only manual 'maker' of the object. The prominence of the 'H' on the signature is reminiscent of a monogram, with the flourish above the 'S' for Sutton a mark showing he had abbreviated his full name. Although too much should not be read into it, the fact that on this mid-1650s instrument Sutton chose to omit writing his full first name is a sign that by this point his name amongst the mathematical instrument trade was known. But signing the name in this way was not a guarantee of authenticity. The Oxford History of Science Museum has in its collection a brass quadrant inscribed '1669. Hen: Sutton fecit', but Sutton died in 1664.[58]

On the reverse of the protractor, on the bottom left of the piece, close to the rectangular ruler, the faint etching of a name, most likely not from the workshop, is partially observable. The name appears to be 'R. Har--' with what looks like the figures '04' or possibly '09'. The gap in the etching means it is unlikely these final two pieces of the marking are letters, as does the fact that the first part of the mark is clearer, as a result of being made on the instrument with greater force, than the latter parts. The object came into the possession of the Science Museum in 1953, and its former owner is listed in its documentation record as 'R. Harrison'. The mark from its last collector before being acquired by the Museum, is therefore a modern addition, one to signify ownership, perhaps added in haste, or even whilst handling the object. With no other such contemporary markings on this object, it is evidence that the seventeenth-century consumers and users of these types of protractors likely felt no need to claim 'ownership' of such an object. This is in contrast to the markings that can be found on other types of objects, including optical instruments, where forms of 'graffiti' are a clear, lived part of an instrument's history.

[58] J. Bennett, 'Henry Sutton Thinking: A Reading of a New Acquisition' *Sphaera* 10 (Autumn, 1999).

It also pre-dates what Bennett describes as the 'fashionable' new art in 'natural philosophy' and the accompanied growth in the production and trade of a range of new experimental and observational instruments, away from the world of pure mathematics, that began in the years after this particular object was made.[59] As a form of mathematical instrument, its precision engraving, high quality material (brass), durability, good condition, and the preciseness of the protractor and the accompanied ruler at the base, are all part of a key trend: that this instrument was made for a mathematician, be that the theoretical intellectual type favoured by Oughtred, or the applier of practical mathematics in the realms of surveying, architecture, or another field.

Sutton's background was not in mathematics, but in craft. It is known from the records of the Company of Joiners that he was bound as an apprentice to Thomas Brown, likely in 1638 when he would have turned fourteen years of age.[60] Brown was an instrument maker and was considered a member of the mathematical community in London.[61] This Brown was the father of the 1660s maker John Brown, who was mentioned in Pepys' Diary.[62] The Thomas Brown that supplied Pepys with his devices across the 1660s was active from 1654 and must have collaborated with Sutton, although in what capacity is difficult to say. A small book entitled *The Description and Use of a Joynt-Rule* circulated in London in the 1660s. An area of future research may be to consider how far this book, and similar titles, circulated and how many editions were published; it is also a matter of audience.[63] In this case, the went through

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[59] J.A. Bennett, 'The Museum of the History of Science: Oxford' *Arbor* CLXIV, (1999): 435-444.
[60] Catherine Eagleton and Boris Jardine, 'Collections and projections: Henry Sutton's paper instruments', *Journal of the History of Collections* 17 (2005): 1-13.
[61] Ibid.
[62] Confusingly, John Brown had a son who also became an instrument maker and named him Thomas after his father. Crawforth asserts that despite the surname being common in records from this time, John was the son of Thomas 'senior' and was freed from an apprenticeship in 1654.
[63] Methodologies for such approaches can be found in: Natasha Glaisyer and Sara Pennell, ed. *Didactic Literature in England 1500-1800: expertise constructed* (London: Routledge, 2003).

multiple editions since first published in 1661.[64] It comprised of twenty chapters, and the frontispiece shows that whilst it was '*Contriv'd & written* by J. Brown. *Philom*', it was '[…] Printed by *J. Brown* and for *H. Sutton* and sold at their houses in the *Minories* & *Threadkneedle Street*, 1661.'[65] The use of 'philom' indicated that Brown considered himself a 'philomath': a learned or scholarly person. By positioning himself in this way, Brown projected an identity that he was an authority on the mathematical theory, as well as the crafting of physical instruments.

The maker Sutton must have known the son of his former master, who was also an instrument maker, and they collaborated to produce and sell a detailed written guide on how one of the instruments that they sold (one assumes as competitors). Although he was not the author of the guide, the fact it was produced for him, and for his clients to use, suggests a blending of knowledge between craft and theory. In Oughtred's view, this would have been incorrect order of learning: craft and then mathematics was not the preferred order.

Modes of Knowledge

In the Introduction it is argued that the breakdown of mathematical consensus led to a change in role of mathematical instrument maker and the emergence of a new 'hybrid' maker who was versed in mathematics and in craft. Sutton can be considered an emerging 'hybrid' maker. Although he was craft-trained with no formal mathematical education, as with Delamain, the publication of the book on his behalf is a sign that he may have had some

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[64] John Browne, *The Description and Use of a Joynt-Rule* (London: T.J, 1661). His name is given variously as 'Brown' or 'Browne'.
[65] Ibid.

mathematical understanding of how to use such instruments. It was also part of the identity and role he projected to consumers of his workshop's objects.

Margaret Jacob argues that the relationship between the physical makers, or the 'fabricants', and those with the theoretical knowledge who commissioned works, the 'savants', changed during the Industrial Revolution.[66] For Jacob, up until the eighteenth century the savants passed their knowledge and learning on to the fabricants, and these ideas were then put into manufacturing items at the savant's direction.

This means that a complicated view of which of the two agents could be considered the 'maker' is prompted. Sutton was clearly the artisanal 'fabricant' but did his mathematical understanding make him also perform a dual function as the 'savant'? In his case, this is not clear. The fusion of the previously segmented forms of knowledge led to a 'hybrid' maker, where knowledge and therefore the status of the maker was more fluid, and this happened in small measure before Jacob believes. The distinction between 'savant' and 'fabricant' in instrumentation had broken down as knowledge crossed the former boundaries.

The transferal of innovation led to the 'fabricants' themselves innovating and the resultant 'hybrid' industrialists of the later eighteenth and nineteenth centuries becoming successful, wealthy and the dominant economic figures.[67] They focused on reducing time, costs and

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[66] The concept is central to much of her published work. See: Margaret C. Jacob, *The First Knowledge Economy – human capital and the European economy 1750-1850* (Cambridge: Cambridge University Press, 2014); Margaret C. Jacob, *Scientific Culture and the Making of the Industrial West* (Oxford: Oxford University Press, 1997); Margaret C. Jacob, 'Mechanical Science on the Factory Floor: The Early Industrial Revolution in Leeds', *History of Science*, 45, no. 2 (2007): 197-232; Margaret Jacob, 'The cultural foundations of early industrialization: a project' in Maxine Berg and Kristine Bruland ed., *Technological revolutions in Europe: historical perspectives* (Cheltenham: MA, 1998), 67-85.

[67] The concept of the close relationship between science and industry is the subject of: Margaret Jacob and Larry Stewart, *Practical Matter: Newton's Science in the Service of Industry and Empire 1687-1851* (Cambridge: Cambridge University Press, 2014).

waste in order to maximise output and profit and many remain prominent names for historians.[68] The new 'hybrid' connected engineering, craft and 'science' to create a new form of 'technical science', where industry and experimentation were in the dual command of single agents and the separation between 'savant' and 'fabricant' closed.[69] But the term 'hybrid' with a more nuanced definition could also apply to seventeenth-century instrument makers because notions of what mathematics, and who could practice it, had changed. At its heart, Jacob's ideas rests on an assumption that one of these agents held a superiority in the socio-economic partnership, and implicit in her theory is an idea of the 'elite' side of a partnership.[70] In instrument making, the 'elite' was not the mathematician alone as Oughtred had argued for, it came to be the maker: who had the craft knowledge to make such objects.

According to Joel Mokyr, the early modern world was characterised by the segmentation of knowledge into two 'useful' types: 'prescriptive' and 'propositional'.[71] The prescriptive form of knowledge can be summed up as the 'what', whilst 'propositional knowledge' was the understanding of 'how'. This prescriptive is the action or instruction that preceded carrying out a task. It is the employment of the two types in combination that the 'useful' modes of knowledge combine to produce a product, in this case mathematical instruments. The artisan

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[68] For an example of a recent study on such a figure that incorporates many of the ideas here, see: Kenneth Quickenden, Sally Baggott and Malcolm Dick, ed. *Matthew Boulton – Enterprising Industrialist of the Enlightenment* (Oxford: Routledge, 2013).

[69] Ursula Klein, 'Hybrid Experts' in *The Structures of Practical Knowledge*, ed. Matteo Valleriani (Cham: Springer, 2017).

[70] Pencho D. Penchev, 'Book Review: The First Knowledge Economy', *Economic Alternatives* 2 (2017): 323-326.

[71] Much like Margaret Jacob, Mokyr's ideas on 'knowledge' are well-established and explained in many of his published works. It features prominently in the following: Joel Mokyr, *The Gifts of Athena: Historical Origins of the Knowledge Economy* (Princeton: Princeton University Press, 2001); Joel Mokyr, 'Useful Knowledge as an Evolving System: the view from economic history' in *The Economy as an Evolving Complex System – current perspectives and future directions, III*, eds. Lawrence E. Blume and Steven N. Durlauf, (Oxford: Oxford University Press, 2006), 309-338; Joel Mokyr, 'Knowledge, Technology, and Economic Growth during the Industrial Revolution', in *Productivity, Technology and Economic Growth during the Industrial Revolution*, eds. Bart van Ark, Simon K. Kuipers, Gerard H. Kuper, (Boston: Springer, 2000), 253-292; Joel Mokyr, 'Long Term Economic Growth and the History of Technology', in *Handbook of Economic Growth*, eds. Philippe Aghion, Steven N. Durlauf, (Amsterdam: Elsevier, 2005), 1113-1180.

held the prescriptive propositional knowledge: how to export the savant's knowledge in mathematics and create an instrument out of two or three materials that could be returned for practical application. This 'propositional' knowledge, according to Mokyr, was more encompassing than mathematics, or knowledge about the natural world and was a blend of taught learning about craft, mathematical theory and artisanal practice.

Sutton's participation in the world of early modern mathematics may have expanded beyond being the artisanal 'fabricant' alone. He was a 'practitioner', with knowledge, understanding and the ability to sell services that extended beyond mere craft production, and encompassed a more complete mathematical thinking. He was apprenticed to a joiner, but his own learning could mean he was also aware of mathematical principles.

The insight that the book mentioned previously on how to use a rule provides is key. Sutton's collaboration with Brown is perplexing, especially as even less is known about John Brown's life than Henry Sutton's and yet it is his name that features more prominently at the start of the published guide previously mentioned. Even Brown's objects do not survive in high number.[72] Sutton was clearly the fabricant, and it was his propositional knowledge in engraving and metalwork that was crucial to his success as a maker. This led him to sign his instrument and take credit as the maker, but as this chapter argues it was around this time that a form of 'hybrid' maker also emerged, who utilised both forms of knowledge and performed both functions in the socio-economic dynamic. Sutton could be considered such as a figure.

[72] Of two items in the Science Museum listed as made by this junior Brown, at least one may be attributed erroneously. The item in question, 'Wooden Quadrant, 1922-235', is listed as having been made by Brown, but on inspection is clearly inscribed 'Tobias Wildboare'.

Illustration 4: English Horary Quadrant by Walter Hayes, 1911-250 Science Museum Group Collection.

Walter Hayes was another mathematical instrument maker and book seller. He operated from 1647, until his death in the 1680s.[73] His workshop was active from 1653 until 1684 and was situated at the 'Cross-Daggers next to the Dog's Head Tavern' near Bethlem Gate in Moorfields, London. Like Sutton he was not trained in mathematics. Instead, he was a member of the Grocers' Company and was a craftsman. Hayes' association with mathematical books (an example is cited in chapter four) meant that similar to Sutton, he may have acquired some mathematical understanding on the theory and use of instruments. He was the 'fabricant' of mathematical instruments. As with the Sutton protractor, the Hayes quadrant was engraved brass, although Hayes also worked with wood and paper, like Sutton. As the Science Museum's own record on the object shows, this was a 'Gunter quadrant':

> 'Gunter quadrants are mathematical instruments that were used for basic astronomical calculation and time-telling. This quadrant has a scale for measuring degrees of

[73] Clifton, 130.

altitude and Gunter's trigonometric scale for making calculations. It has a volvelle on the reverse consisting of a planispheric nocturnal.'[74]

Brass was a more expensive material than paper or wood, and this meant that it was perhaps intended that these objects would have a longer life than others. As the century progressed the market for all sorts of instruments expanded. Portable quadrants, in contrast to the larger mural quadrants that were built for observatories in the eighteenth century, became '…the characteristic instrument [….used] to measure the size and shape of the Earth' in the realms of surveying, but also to make astronomical observations and calculations by a number of practitioners including amateur ones.[75]

Made from brass, this object is noteworthy for the prominence, size and styling of the inscription, that indicated both its craftsmanship and origin, namely the monogram of Walter Hayes. The use of a monogram instead of the full name or the term 'fecit' is intriguing, but not unusual. Monograms are common, especially where there was little physical space on the object.[76] The use of the monogram is reminiscent of a form of branding or stamping that became common during the early modern period – hallmarking. From the Late Medieval period, tradesmen in Western Europe aimed to assert a form of quality control on goods manufactured from the closed trades of metalwork, in particular silversmithing and goldsmithing, and many traders and artisans began branding their products with individual

[74] 'Gunter Quadrant by Walter Hayes', *Science Museum Group*, accessed Dec 01, 2020, https://collection.sciencemuseumgroup.org.uk/objects/co56433/gunter-quadrant-by-walter-hayes-gunter-quadrant/
[75] A.J. Turner, 'The Observatory and the Quadrant in Eighteenth Century Europe', *Journal for the History of Astronomy* 33, no. 4 (2002): 373-385.
[76] In the 1990s, Gerard L'E Turner identified and deciphered until then unnoticed small monograms to identify them as belonging to sixteenth-century maker Gerard Mercator, and attributing astrolabes in collections to him when previously it was thought none had survived: G. L'E Turner, 'The Three Astrolabes of Gerard Mercator', *Annals of Science* 51, no. 4 (1994): 329-353.

marks (many derived from shop signs) as a precursor to hallmarking, before the guilds and companies made such imprints mandatory, or where guilds gave no such governance.[77] If the idea that the inscription of initials or a monogram was preferable in order to save time, and space on the object, then this cannot surely apply to the Hayes quadrant.

The hallmarking of precious metals '…was closely related to the minting of coinage, with both practices having a similar aim: restricting the movement of precious metals, both geographically and between different classes of object.'[78] It is clear that Hayes' brass instruments were a different 'class' of object from their paper counterparts, and as a leading maker, Hayes's objects were sought-after. Early modern hallmarks on regulated precious metals and coinage were a mark of metal purity and quality.[79] The use of monograms on brass or higher quality or larger pieces might not have been to symbolise the 'purity' of the brass but was a signal to the consumer of the 'quality' of the object. No claim to 'fecit' or maker-ship was required, Hayes' monogram may have acted as a reassurance to the consumer that the product was of good quality.

The mark signifies the 'translation' of materials into a mathematical instrument; this 'translation' was achieved through knowledge and training in precision engraving, and some mathematical awareness.[80] It was that 'translation' into a purposeful, niche, specific,

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[77] Bert de Munck, 'The agency of branding and the location of value. Hallmarks and monograms in early modern tableware industries', *Business History* 54, no. 7 (2012): 1055-1076.
[78] Peter Oakley, 'Containing Precious Metals: Hallmarking, Minting and the Materiality of Gold and Silver in Medieval and Modern England', in *Mobility, Meaning and Transformations of Things: Shifting Contexts of Material Culture through Time and Space*, ed. Hahn Hans Peter and Weiss Hadas, (Oxford: Oxbow Books, 2013): 63-77.
[79] For origins of this practice, see Rory Naismith, *Money and Coinage in the Middle Ages* (Amsterdam: Brill, 2018).
[80] Sven Dupré argues that whereas trademarks and hallmarks were a sign of material quality, other marks represented the 'translation' of superior raw materials into high value objects in S. Dupré, 'The value of glass and the translation of artisanal knowledge in early modern Antwerp', *The Netherlands Yearbook of the History of Art 64*, (2014): 138-161.

instrument with a practical purpose that Hayes' monogram gave the consumer assurance of. Without 'fecit' or a full name, there was a realignment from being the practical craftsman, and a repositioning as the authority. This 'maker's mark' was ungoverned but still signified quality assurance about material and production to the consumer.[81]

Hayes' longevity makes him an interesting case study for this thesis. When this object was made, he was principally a mathematical instrument maker of permanent instruments (brass) such as this one, that would have been used by practitioners in the mathematical trades. The object is dated from the mid-century. A later chapter explores Hayes' connections to book selling. Hayes was not a 'hybrid' maker, but he operated at a time where the crossover between mathematical knowledge and craft training was emerging. His name was known and the use of monograms on larger objects was due to the possible positioning of his workshop to clients as a prestigious supplier.

Instrument-making on the Cusp: Morland's Calculating Machine

If by the 1660s, instrument making was on the cusp, as modes of knowledge shifted and a form of 'hybrid' maker emerged, then Samuel Morland, whose calculating machine was mentioned at the outset of this chapter, provides a revealing case study. The story of Morland's calculating device shows us that the idea of who the 'maker' was not straightforward and that in the mid-century, designers such as Morland had the mathematical

[81] Carlo Marco Belfanti, 'Branding before the brand: Marks, imitations and counterfeits in pre-modern Europe', *Business History* 60, no. 8 (2018): 1127-1146.

knowledge, but not the artisanal material skill, that was necessary to produce such objects. The two forms of knowledge were separate. This instrument demonstrates much about the disruption to the instrument trade that occurred.

Illustration 5: Calculating Machine by Samuel Morland, 1876-538, Science Museum Group Collection.

Samuel Morland was not a craftsman as a maker such as Sutton. His courtly background and career as a diplomat were marked differences. In the 1640s, Morland studied and taught at Magdalene College, Cambridge, having first been educated at Winchester.[82] In 1653, he was appointed by John Thurloe, Cromwell's Secretary of the Council of State, to accompany Bulstrode Whitelock, who had been appointed Ambassador the Queen Christina of Sweden to negotiate a treaty.[83] He was then posted in 1655 to the court of Louis XIV on a diplomatic mission, to negotiate for the toleration of Protestants in Piedmont.[84] Despite his apparent allegiance to the Protectorate, in 1660 he was knighted by Charles II for supposedly

[82] H.W. Dickinson, *Sir Samuel Morland – Diplomat and Inventor* (Cambridge: Heffer, 1970 edition), xiv-xv.
[83] Dickinson, 6-8.
[84] Dickinson, 8-9.

uncovering a plot to assassinate the new monarch; he was created a baronet, member of the Privy Council and rewarded financially.[85] But the evidence also shows that he considered himself an 'Inventor' more than a diplomat or politician. Prominently engraved on the bottom right of the outward brass plate, and with adequate space from the mechanisms to make it stand out, is the inscription, 'Samuel Morland Inventor 1666'. The customary 'fecit' was not used. Morland, as we know from the testimonial at the start, tasked the craftsman Humphrey Adamson with producing the physical object. The inclusion of the engraving in a space that was away from the circular dials makes this prominent, and eye-catching. The inclusion of the year is somewhat, but not entirely, unusual. Perhaps it says something about Morland's own ideas about the significance of his design that being named as the 'inventor' and the 'year' of this invention was considered worthy of inclusion. As an 'inventor', Morland positioned himself more as someone who knew, rather than the 'maker' who made the object. As we will see, the calculating machine was based on other, earlier devices.

On a different machine, the year was inscribed as '1664', but in the *Description and Use of Two Arithmetick Instruments* (1673) Morland wrote that the object was: '[i]nvented and Presented to His most Excellent Majesty *CHARLES* II. King of *Great Britain, France,* and *Ireland,* &c, 1666.' .[86] This was a clear attempt to take credit for a new invention, and to associate his name, with the object. What is crucial is that it was Morland who acted as the 'savant' in this scenario, and yet it was his name that took precedence. The credit he ascribed Adamson was public but published some years later.

[85] Dickinson, 22-24.
[86] Samuel Morland, *The description and use of two arithmetick instruments* (London: 1673), 12.

Morland possessed the mathematical and mechanical knowledge to design such a device, but he was not trained in creating it, and so this was contracted out. Later makers used a form of subcontracting for individual parts. Morland's commissioning of Adamson could constitute a different form of subcontracting. Giorgio Riello believes that economic historians are incorrect to say that subcontracting emerged as a result of cost-reduction strategies and instead he argues it reflected new patterns of consumption and artisanal life.[87] He argues that technical knowledge and social capital mixed together and ensured that subcontracting involved the 'reciprocal and continuous' exchange of information, materials, skills and resultant goods: in other words, it was the means to a network through the exchange of knowledge. As with Jacob on the 'savant' and 'fabricant', Riello points to the eighteenth century as the period when this economic practice first emerged.

For J.R. Ratcliff, Morland's calculating machines were '…the earliest known mechanical calculators in England'; but Morland's role as a 'courtier-inventor', traversing both the royal courts and the world of artisanal craft meant that he could claim a high social status, even more so than someone such as Robert Hooke.[88] J. R. Ratcliff attests that whilst the machine was popular at courts (Cosimo de Medici requested one), it was dismissed by leading Royal Society Fellows such as Pepys and Hooke, who failed to see its originality or practical worth.[89] This may also explain the inclusion of Morland's name on the object. The social status he held was higher than his collaborator and so his name took precedence.

[87] Giorgio Riello, 'Strategies and Boundaries: Subcontracting and the London Trades in the Long Eighteenth Century', *Enterprise and Society* 9, No. 2 (2008): 243-280.
[88] J.R. Ratcliff, 'Samuel Morland and His Calculating Machines c. 1666: The Early Career of a Courtier Inventor in Restoration London', *British Journal for the History of Science* 40, no. 2 (2007): 159-179.
[89] Ibid.

In other words, the name engraved on the piece had less to do with who had the greater part in the collaboration to create the calculating machines, and instead more with social convention. When Robert Hooke and Thomas Tompion collaborated on a watch in 1675, in a sign of their comparatively equal social standing, it was engraved with both names: Hooke as 'inventor', Tompion as 'maker'.[90] This too was a sign of a form of contracting, with Hooke imparting his ideas and tasking the artisan with the craft of the object. In both cases, Hooke and Morland had the artisanal connections and the mathematical and mechanical knowledge to design objects, but they were not to produce these themselves. The social boundaries had blurred, but the forms of knowledge between 'fabricant' and 'savant' had not quite merged. The blending of skills, knowledge and connections meant Morland should be considered part of this emergent 'hybrid' figure.

Morland's machine was similar to a device invented by Blaise Pascal some decade earlier, an object also based on the earlier, manual adding tool, Napier's Bones. Turning the wheels of the device would, by its mechanism, cause connected wheels on the inside to rotate and provide a readable, running total at the top of the object. Pascal's calculating machine was built in 1642. Historians are divided on how far Morland was aware of Pascal's design, but a sign of Morland's unique emergent 'hybrid' role can be seen, especially when a comparison is made with Pascal.

Matthew Jones concludes that Pascal and Morland had starkly different relationships with the artisans who manufactured their designs. In Paris, Pascal directed those who were interested in his machines to a mathematics professor at the College de France to explain the principles, but Morland, as we saw at the start of the chapter, directed those keen on his device to the

[90] This is the subject of a subsequent chapter.

craft ‘maker’ Adamson.[91] So Pascal believed that mathematical theory was key to a successful calculating machine; two decades later, Morland in London believed it was the artisanal skill that mattered most when sourcing such an object. When in contact with potential buyers, Morland broke down the costs and named the artisans he employed at different stages (there is some correspondence from 1669 between Morland and Charles Stuart, Duke of Richmond and Earl of Lennox), but Pascal ‘shielded’ the craftsmen he employed from his buyers.[92] This points to a distinct situation in 1660s London where the socio-economic barriers between different types of knowledge and skill (the mathematical and the artisanal), of what we may term the ‘mind’ and the ‘hand’, became blurred.

Adamson’s name is not inscribed on Morland’s object, but Morland credited him elsewhere. The machine is accompanied by a leather case, and this indicates it may have been made as a luxurious and desirable item. This function as a marketable, desirable item, may in part explain the recommendations Morland gave to others about Adamson’s work. The key to answering this apparent paradox, is to accept that there was a collaborative, hybrid working relationship between Morland and Adamson, where the exchange of modes of knowledge was made possible by a form of ‘proto-subcontracting’ that was part of the dismantling of the clear boundaries between ‘savant’ and ‘fabricant’ that existed elsewhere. This was likely influenced by Morland’s own social status, and his courtly connections as similar to Hooke, meant he occupied a place in both social spheres. Morland’s reward by Charles II with an annual pension of £500 (a rather different route than a ‘maker’ such as Sutton), may have given him financial licence to use his time on invention.[93] Close to a century after Morland,

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[91] Matthew L. Jones, *Reckoning with Matter: Calculating Machines, Innovation, and Thinking about Thinking from Pascal to Babbage* (Chicago: Chicago University Press, 2016), 14-17.
[92] Jones, 16-19.
[93] H.W. Dickinson, *Sir Samuel Morland – Diplomat and Inventor* (Cambridge: Heffer, 1970 edition), 22.

the role of the maker was clear cut: the ‘maker’ required both forms of knowledge and acted as the singular hybrid figure. In his list of London trades in 1747, Richard Campbell wrote:

> ‘The Mathematical-Instrument-Maker makes all kind of Instruments constructed upon Mathematical principles, and used in Philosophical Experiments: He makes Globes, Orrerys, Scales, Quadrants, Sectors, Sun-Dials of all Sorts and Dimensions, Air-Pumps, and the whole Apparatus belonging to Experimental Philosophy. He ought to have a Mathematically turned Head, and be acquainted with the Theory and Principles upon which his several Instruments are constructed, as well as with the practical Use of them. He employs several different Hands, who are mere Mechanics, and know no more of the Use or Design of the Work they make…’[94]

For the 1740s instrument ‘maker’, being ‘acquainted’ in the principles and theory behind instruments was important. It was less so for the ‘hands’ employed in the workshop, where more industrious craft-based skills were required. When the calculating machines were put together, this was less likely to be the case. Even though he was a ‘maker’ of instruments, it was not Adamson’s mathematical training, but Morland’s that was necessary for the object to be created. By 1747, the ‘maker’ was the head of the workshop who possessed the ‘propositional’ knowledge cited by Mokyr and Jones, but a separate ‘savant’ was not required. This ‘maker’ could act as both, even if the ‘hands’ in the workshop who worked to make the component parts did not require as great a level of mathematical knowledge. This change must have happened after the mid seventeenth century and is evident by the turn of the eighteenth.

[94] Richard Campbell*, The London Tradesman* (London: Publisher T. Gardner, 1747): 253.

Instruments as Consumer Goods: Isaac Carver Example

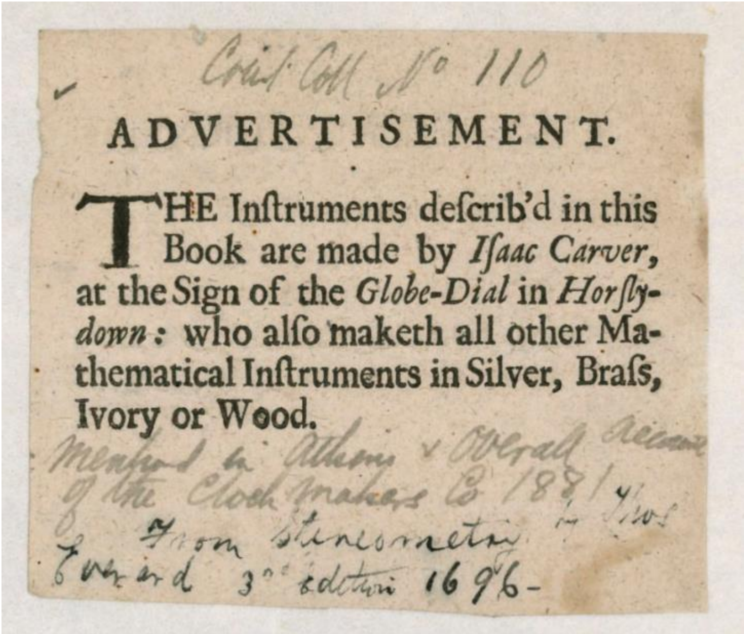
Sutton, Hayes, Morland each operated in the mid-century, with roles that had moderate variation. The assumed 'savant-fabricant' axis in their cases is sometimes blurred and they may best be seen as emergent 'hybrid' figures. This final section will look at an instrument from the end of the century by a little-known maker, Isaac Carver. Carver worked on many different instruments, and similar to Hayes, he was recommended in mathematical books as a preferred supplier. The section considers what we know about Carver and his work and whether he was a hybrid figure, before examining the materiality of one of his objects.

Little is known about Carver except that he was active as a maker between 1668 and 1713; the Science Museum has three objects attributed to Carver in its collections.[95] Despite the comparative scarcity of his objects compared to more eminent London makers, some of his objects were exported and in 1741, Carver's name appeared in a catalogue of instruments owned by the Imperial Academy in Russia.[96] One of the items in the Science Museum is a print that advertised Carver's workshop.[97] The advertisement informs the reader that Carver produced instruments in silver, brass, ivory and wood. The ordering of these materials is indicative of cost and prestige; whereas silver and brass were the two premium materials, the more exotic ivory was listed as an alternative to the more financially economical wood.

[95] Mark Rees, 'Two Early Slide Rules', *Journal of the Oughtred Society* 7, no.2 (1998): 9-13.

[96] W.F. Ryan, 'Scientific instruments in Russia from the Middle Ages to Peter the Great', *Annals of Science* 48, no. 4 (1991): 379.

[97] Trade Card by Isaac Carver, 1934-121/21, Science Museum Group Collection.



ADVERTISEMENT.

THE Inſtruments deſcrib'd in this Book are made by *Iſaac Carver*, at the Sign of the *Globe-Dial* in *Horſly-down*: who alſo maketh all other Mathematical Inſtruments in Silver, Braſs, Ivory or Wood.

Illustration 6: Trade Card by Isaac Carver, 1934-121/21, Science Museum Group Collection.

The annotation by the collector of this paper indicates that it appeared in a book by Thomas Everard in 1696, *Stereometry*.[98] As advertisements themselves were a still new phenomenon (detailed in chapter four), early 'testimonials' such as this were often brief, to the point and similar in nature to the early advertisements of instrument makers that might run to a few sentences.[99] These endorsements likely came about, as in the case of Hayes, from a pre-existing socio-economic relationship based on transactions, although there is a possibility that instrument makers paid the author and publisher, or offered discount, for these advertisements. When Everard's work was republished as a fifth edition a decade later in 1705, Carver's advertisement appeared once more, but with something of a twist: Carver had been relegated. Instead, a greater recommendation was placed directly above his:

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[98] The book's full title: Thomas Everard, *Stereometry: or, the art of gauging made easy, by the help of a sliding-rule: ... With an appendix of conic section* (London, 1696).

[99] The use of the testimonial in the field of 'early modern science' can be seen more clearly in the field of medicine. Chapter four makes some comparison between instrument maker testimonials and seventeenth-century medical quackery such as Anderson's Pills. See also: Hannah Barker, 'Medical Advertising and Trust in late Georgian England' *Urban History* 36, no. 3 (2009): 379-398.

‘The Sliding-rule, mention’d in this Tract, and all other Mathematical Instruments, particularly the TOBACCO BOX, mention’d in the Preface before-going, are accurately made by Mr John Rowley, at the Globe, under St Dunstan’s Church near Temple Bar, London’.[100]

Carver’s advertisement appears instead at the very bottom of the page with much the same wording, except one minor amendment, it begins: ‘The Sliding Instrument are also very exactly made by Isaac Carver [...]’ before continuing with the same wording as the 1696 advertisement.[101] The ‘exactness’ that Carver promoted himself as having is similar to the recommendation Morland made of Adamson. It was the ‘exactness’ in engraving and measurement that was considered critical for the production of good quality instruments.

John Rowley became Master of Mechanics to George I and was well-known as a hydraulic engineer at the Offices of Ordnance and Works, but he was also involved in the creation of more novel objects such as orreries.[102] His engineering background is reminiscent of Samuel Morland’s career trajectory. Orreries were decorative mechanical devices used to replicate planetary motion, and made from glass, brass, ivory and wood. The only object of Rowley’s at the Science Museum is an orrery that was copied from a George Graham design.[103] Copying the design of an esteemed Royal Society Fellow and watchmaker may have given Rowley’s object credence or prestige with consumers. Planetary devices such as this, despite

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[100] Thomas Everard*, Stereometry: or, the art of gauging made easy, by the help of a sliding-rule: ... With an appendix of conic section* (London, 1703: fifth edition).
[101] Ibid.
[102] John H. Appleby, ‘A new perspective on John Rowley, Virtuoso Master of mechanics and hydraulic engineer’ *Annals of Science* 53 (1996): 1-27.
[103] Orrery by John Rowley, r952-73, Science Museum Group Collection.

being for education (or even entertainment) were included in lists and catalogues of 'instruments' from the mid-eighteenth century.[104]

Carver's ivory sector (as seen in the image below) was a mathematical instrument used for measurement and calculation. Searches in other museum collections for seventeenth-century ivory instruments returned fewer comparable objects for objects pre-1700.[105] The sector is engraved with 'Carver Fecit'. A sector like this is more correctly known as a 'proportional compass', the function of which is to assist in the calculation of proportions without relying on arithmetic alone.

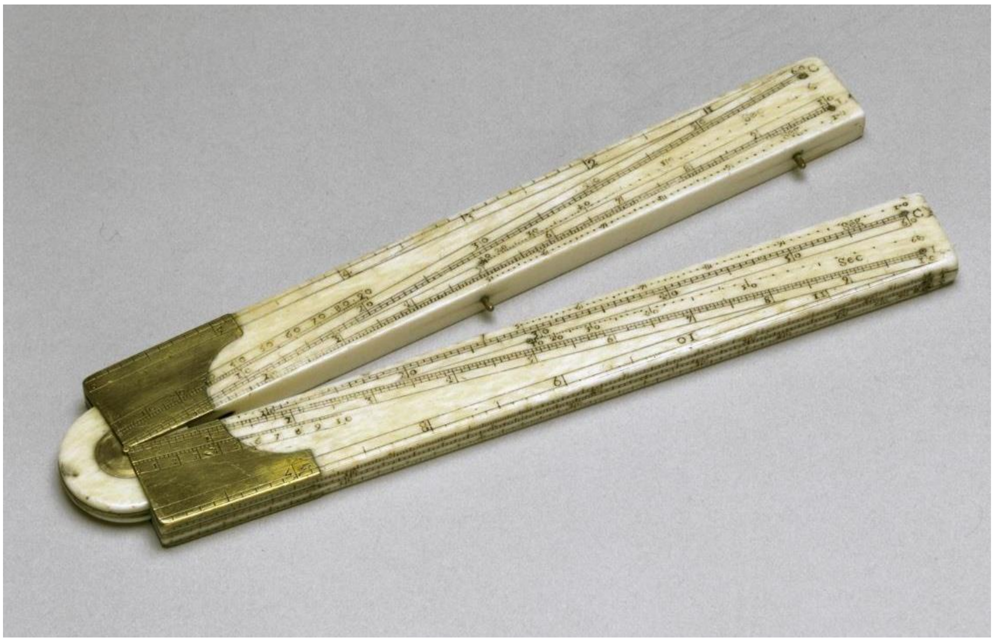

Illustration 7: Ivory Sector by Isaac Carver, 1917-92, Science Museum Group Collection.

[104] John R. Milburn, 'Benjamin Martin and the Development of the Orrery', *The British Journal for the History of Science* 6, no. 4 (1973): 378-399.

[105] The History of Science Museum Oxford has a late seventeenth-century Napier's Rod device made from ivory (Inventory no. 51138). The Science Museum has very few objects from this time made primarily from ivory, except an unattributed ivory rule (1985-557) which has no signature, date, nor other clues to its maker, or year of production. Despite being an exotic, curious material, it appears that even amongst later collections of scientific instruments, objects made from ivory were rare.

Carver's instrument making, and his recommendation in a mathematical work may again hint that he was able to cross the traditional boundaries on knowledge and blend craft skill and mathematical theory to produce objects for clients. The makers in the mid to late seventeenth century were not craftsmen alone; they occupied a place within the world of mathematical practitioners where the division of roles and knowledge was less rigid than it had once been.

The recommendation by Everard implies that Carver was an authority on instruments, not mere materials, and that would have meant some theoretical understanding. Cajori cites a 1687 sixteen-page work by Carver entitled *Description and Use of a New Sliding Rule*, that was published on behalf of William Hunt.[106] The difference between this and the much earlier book published for Sutton (along with Brown) is that he was not named as the 'author' but as the agent the book was 'published for', according to Cajori. Carver likely crossed the boundaries of craft, instrument and mathematical knowledge and was part of this emergent change. At the least, he wished to be seen as an authority on mathematics, not only in the production of mathematical objects.

[106] Florian Cajori, *On the History of Gunter´s Scale and the Slide Rule during the Seventeenth Century* (Frankfurt: Outlook, 2018 edition), 33.

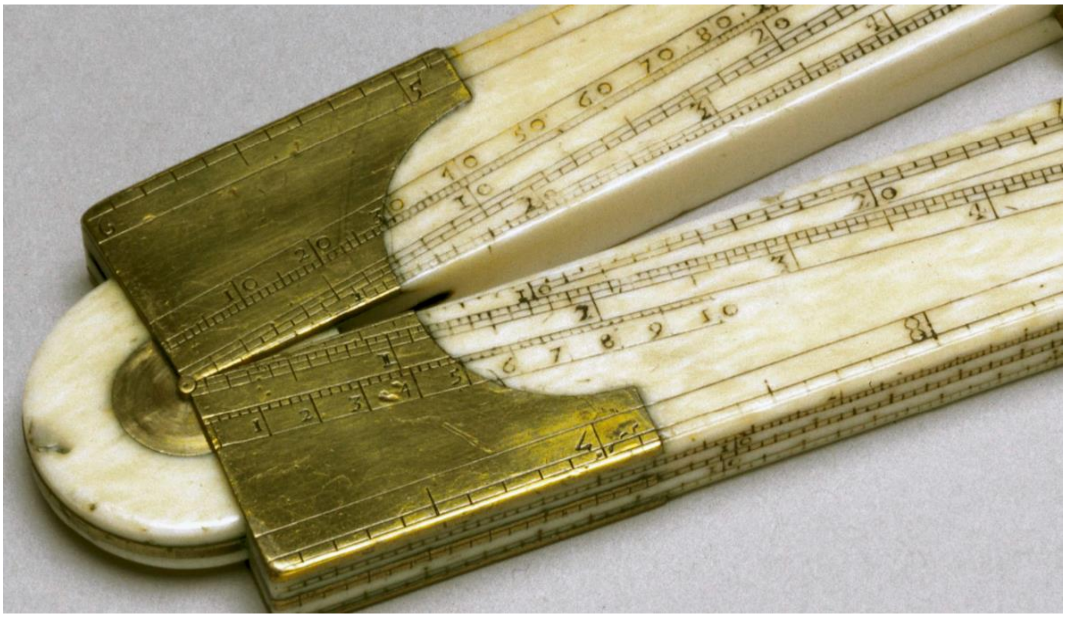

Illustration 8: Ivory Sector by Isaac Carver, 1917-92, Science Museum Group Collection.

Crossing Cultures – a note on ivory

In closing, this chapter will now comment on the use of ivory as a material. In contrast to the engraving of metals, the more durable ivory could have been stamped.[107] Ivory was not a new material in the 1690s when Carver used it for his sector. In 1644, Evelyn recorded in his Diary that he had visited a shop dedicated to curious and exotic foreign objects. He wrote that during a trip to France he came across a market, where,'[there was…] a shop called Noah's Ark, where are sold all curiosities, natural or artificial, Indian or European, for luxury or use, as cabinets, shells, ivory, porcelain, dried fishes, insects, birds, pictures, and a thousand exotic fragrances'.[108] This French experience left an impression and it was not until eight years later, in 1652, that Evelyn recorded that in London he, '...went to see some workmanship of that admirable artist, Reeves, famous for perspective, and turning curiosities

[107] Rees, 9.
[108] '3 February 1644', *The Diary of John Evelyn*, ed. E.S. de Beer, (Oxford: Oxford University Press, 1959), 59.

in ivory'.[109] This was the maker of 'perspectives', Richard Reeves, and the same maker that Robert Hooke mentioned in the Preface to *Micrographia*.

Reeves' work in producing optical instruments for Hooke's use, and at his direction, meant that he was credited as a reputable maker during the 1660s. Yet a decade earlier, the well-connected Evelyn described him as an 'artist'; part of a wider trade as an artisanal maker of 'curiosities', including in ivory.[110] Samuel Pepys made two references to ivory in his own Diary, first in 1660 ('a bucket') and then again in 1667 ('ivory pipes').[111] Ivory was used during this period for a variety of curious and domestic products, as well as instruments and as Pepys and Evelyn show, the material was one that people recognised.

In many cases, seventeenth-century 'ivory' might have been 'bone' or 'horn'. However, 'ivory' as a material was equated with elephants. Carver's instrument could have been used by mathematical practitioners with Royal Society or institutional connections, and they would have been versed in the natural and experimental philosophies of the time. There is a curious crossover between the new aims of the observational philosophers that Carver and others supplied, and the materials that as craftsmen they used that also attracted mystery and myth amongst other groups. But how far ivory was recognised and used did not equate necessarily to widespread understanding about how it was sourced.

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[109] '21 April 1652', The *Diary of John Evelyn*, ed. E.S. de Beer, (Oxford: Oxford University Press, 1959), 319.

[110] There has been no major research into the single issue of English ivory consumption at this time, although archaeological research has been conducted into the import patterns of the Dutch East India Company, concluding its use by artisans in Amsterdam was culturally significant in many spheres. See: Marloes Rijkelijkhuizen, 'Whales, Walruses, and Elephants: Artisans in Ivory, Baleen, and Other Skeletal Materials in Seventeenth- and Eighteenth-Century Amsterdam', *International Journal of Historical Archaeology* 13, no. 4 (2009): 489.

[111] '28 July 1660', *The Diary of Samuel Pepys (Volume I),* ed. Robert Latham and William Matthews (Berkeley: University of California Press, 1971), 209. See also: '19 July 1667', *The Diary of Samuel Pepys (Volume VIII)*, ed. Robert Latham and William Matthews (Berkeley: University of California Press, 1971), 344-345.

In August 1675, a young elephant was brought to London and paraded for entertainment; an event that was recorded by writers in the city. An anonymous account of the 'strange and wonderful elephant brought from the East Indies' was published by J. Conniers at the 'Black-Raven in Duck Lane'.[112] Evidence such as Conniers' account recorded that whereas ivory was known to come from the animals, myths surrounded how the material came to be imported in large number. The writer noted that:

> 'Of these Elephants teeth comes our Ivory (though some erroniously have thought it to be a Horn) and that you may not too much admire the vast quantity which yearly comes over you are to know; that Elephants every tenth year cast ther Teeth; which they industriously hide in the Earth that Men may not find them; but the sagacity of the Indian defeats their envy, by a device very wonderful, for one would think when the teeth are buried so privately by the Beasts no body knows where, nothing but Witchcraft or digging up while Countries could discover them…'.[113]

The 'device' believed to find buried ivory by the 'Indians' was a 'bottle of water' that 'by a secretive attractive power' emptied when placed over an area where ivory was thought to be buried. This myth is emblematic of the uneasy sphere within which encounters with items and cultures from outside of Europe, and the power of myth, occupied still in early modern London. The elephant captured the interest of natural philosophers and naturalists. In explaining how ivory was made, a mythical explanation circulated. There is some irony that the ivory with which a fantastic myth was attached was used by those interested in explaining

[112] Anon*, A True and perfect description of the strange and wonderful elephant sent from the East-Indies: and brought to London on Tuesday the third of August, 1675: with a discourse of the nature and qualities of elephants in general.* (London: 1675).
[113] Ibid.

the natural, and mathematical, worlds. But it is also evidence of the uneasy tension that existed between mythical belief and natural observation. Knowledge was being acquired in this area: for example, in 1664 John Ray described an elephant skeleton he had seen in Florence, that was drawn by Rembrandt in 1637.[114]

Known as 'white gold', ivory was imported into Europe from the later seventeenth century and was a profitable material for the Dutch and English companies in Africa. The lack of quantitative records for ivory imports in England means it is difficult to quantify how much, but records are clearer for the Netherlands. Archaeological studies into Portuguese shipwrecks have also shown that it was a major importer of the material.[115] The Royal African Company imported considerable amounts of ivory into England after the reign of James II, but complete records are available from 1699, by which time the Company had lost its monopoly on Africa.[116] Analysis by Feinburg and Johnson shows that in 1699 alone, at least 697 full elephant tusks were imported to England from across Africa, and based on their quantitative analysis of the accounts for 1699-1725, they estimate that close to four thousand elephants in Africa alone must have died each year during that period to satisfy English consumer demands for ivory.[117]. For ivory, its production involved the destruction of many parts of a natural world not observed by philosophers at the seats of learning in England but who may have used instruments that diminished it. It was a material that also attracted implausible myth based on hearsay amongst the populace and in print, but was used by Fellows, scholars and others who rejected such myths.

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114 'Research discovers new 'type specimen' for the Asian elephant', *Phys.Org,* Nov 04, 2013, accessed Dec 01, 2020, https://phys.org/news/2013-11-specimen-asian-elephant.html

115 Sila Tripati and Ian Godfrey, 'Studies on elephant tusks and hippopotamus teeth collected from the early 17th century Portuguese shipwreck off Goa, west coast of India: Evidence of maritime trade between Goa, Portugal and African countries', *Current Science* 92, no 3 (2007): 332-339.

116 Harvey Feinburg and Marion Johnson, 'The West African Ivory Trade during the Eighteenth Century: The "... and Ivory" Complex', *The International Journal of African Historical Studies* 15, No. 3 (1982): 435-453.

117 Ibid.

Although ivory had been used since from ancient times, it was during the Early Modern era that the trade in Western Europe increased significantly.[118] Slave labour was closely linked to the production and sale of ivory and the expansion of English, Dutch and Portuguese merchants into Africa for ivory and other goods, before turning eastwards, can in part explain its growth at this time.[119] The quantities of ivory entering the English market meant that its relative price compared to brass may also explain its use by makers such as Carver. In the next chapter, the use of paper and wood for telescopes and microscopes as opposed to metal is also considered in relation to the cost of such materials. It may also, of course, have been more practical to use a material such as ivory when lathes were used, instead of metal. Gowin Knight later in the eighteenth century, for example, used a mix of agate and ivory for the caps of his steering compasses, as he thought this was more economical than using only agate or ivory alone, or in his words, so that he could make the parts: 'with as little Expence as possible'.[120] In short, ivory's useability and its relative cost may have made it a desirable alternative for makers, as well as an attractive prospect for consumers.

[118] Martha Chaiklin, 'Ivory in World History: Early Modern Trade in Context', *History Compass* 8, no. 6 (June 2010): 530-542.
[119] Chaiklin, 536-538.
[120] Gowin Knight, 'A Description of a Mariner's Compass Contrived by Gowin Knight, M. B. F.R.S.', *Philosophical Transactions*, Volume 46 (1749-50), 508.

Conclusion

This chapter argues that in the seventeenth century, there was a breakdown in the consensus over who could practice mathematics, and this led to a change in the role of the mathematical instrument trade and the social status of instrument makers. This meant that 'mathematical' instruments themselves changed from niche, precise instruments, towards desirable objects of learning that were marketed towards and consumed by a larger and more diverse clientele. This is evident in many of the physical characteristics these objects have. The former division between forms of knowledge became more blurred, so that by the end of the century, many mathematical instrument makers acted as 'hybrid' agents, who performed both the functions of craft and theory.

Makers from the mid-century such as Sutton, Hayes, Morland and then later makers, crossed the boundaries of older working practices between the traditional 'savant' and 'fabricant'. The practice of publishing, selling and writing mathematical instrument pamphlets or books is a further sign that knowledge had crossed over and the assumed model of divided roles had begun to break down. This meant they likely positioned themselves as emergent 'hybrid' instrument makers, who were highly skilled, but also as authorities on using instruments, or mathematics itself. In turn, this change in the concept of mathematics, instruments and who could make and use mathematical instruments expanded to other forms of instrumentation. The next chapter argues that the increase in production of telescopes and microscopes from the mid-1660s was due to a popularisation of instrumentation, where these makers moved beyond being authorities for practitioners, and instead promoted consumer goods for domestic and collectable use.

3

Curious Playthings: The changing role and value of telescopes and microscopes as objects of curiosity, collection and fun (1660-1720)

'…much against my will staid out the whole church in pain while […] expected […] at home, but I did entertain myself with my perspective glass up and down the church, by which I had the great pleasure of seeing and gazing at a great many very fine women; and what with that, and sleeping, I passed away the time till sermon was done.'[121]

Samuel Pepys, 26 May 1667

Introduction

Samuel Pepys often recorded his sexual exploits and desire in his diaries.[122] The 'great many fine women' may be one of the tamer references in it. The intriguing part of the above May 1667 entry is that he overcame his boredom at a Church service, by using a 'perspective glass'. The terms 'perspective', and also 'perspective glass', were both contemporary ones.[123] They were used for items that also came to be understood at this time by the term 'telescope'.[124] The instruments had various terms attached to them until the early nineteenth century, although by the 1690s (two decades after Pepys' account), the terms 'telescope' and 'microscope' were the most widely used and well recognised of the eclectic list. We will never know whether Pepys' use of the device for his own titillation and arousal was commonplace for the buyers and users of the optical instruments in the 1660s, or even if this

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[121] '26 May 1667', *The Diary of Samuel Pepys (Volume VIII),* ed. Robert Latham and William Matthews (Berkeley: University of California Press, 1971), 235.

[122] A recent study places this topic within the wider context of 'corruption': M. Knights, 'Samuel Pepys and Corruption' *Parliamentary History*, 33, (2014): 19-35.

[123] It has also been identified as used to describe prisms, looking glasses, lenses and also distorting mirrors. The difficulty with interpreting it is the source of much debate. For example, see: Allan Shickman, 'The "Perspective Glass" in Shakespeare's Richard II' *Studies in English Literature*, *1500-1900* 18, no. 2 (1978): 217-228.

[124] Often thought to have been coined by the Greek mathematician Demisiani in 1611, the term emerged in English from the Latin word 'telescopium' sometime in the 1650s.

was the real reason Pepys acquired one in the first place. As a Fellow, and at this point a future president, of the Royal Society, he likely purchased such an object through his Society connections. From the 1660s the number of devices made and sold in London rose, but Pepys' account is a sign that in 1667, the application of telescopic lenses was already being appreciated for novel, fun purposes. These uses were different from the more 'serious' uses such as observing nature, astronomy, or for practical ends such as surveying.

At around the same time that Pepys wrote his account, Thomas Sprat published *The History of the Royal-Society of London, for the Improving of Natural Knowledge* (1667). Sprat's account of the Royal Society's early years also acted as a defence of the experimental approach to observing the natural world. The 'Baconian' ideology that experiment and observation should take precedence was at the forefront of the *History*'s overall message; on the engraved frontispiece to Sprat's book, Francis Bacon (who had died forty-one years prior) points upwards to the instruments that surround the picture. Society President William Brouncker sits to the left of the image, whilst the bust of Charles II is 'crowned' with laurel leaves, an image with religious and classical allusions, and one that may have been used to encourage continued royal patronage.[125] According to Michael Hunter the engraving was 'designed' by John Evelyn, engraved by Wenceslaus Hollar, and intended for an earlier work than Sprat's, by 'John Beale of Somerset', who was a frequent correspondent to the Society.[126] Hunter's work is part of a recent, material and visual 'turn' in the scholarship of early modern science.[127] A number of surveying instruments, including quadrants and

[125] Patricia Fara, *Science – A Four Thousand Year History* (New York: Routledge, 2009), 149.
[126] See: Michael Hunter, *The Image of Restoration Science, The Frontispiece to Thomas Sprat's History of the Royal Society* (1667) (London: Routledge, 2016), Chapter 1. Hunter first accounts for this connection in his 1980s work*, Science and Society in Restoration England* (Cambridge: Cambridge University Press, 1983), 194-196. Sprat's frontispiece was the cover image of Hunter's own book at that time.
[127] A.M. Roos, 'Review - The Image of Restoration Science: The Frontispiece to Thomas Sprat's History of the Royal Society (1667), by Michael Hunter', *The English Historical Review* 133, no. 563, (2018): 952–953.

compasses, can be seen in the background of the Sprat frontispiece, along with books, a globe, a barometer and what appear to be maps. In the far sight of the image there is a large telescope, although it is partially obscured. The telescope's size may be the reason it appears in the background. The impression from this image, and Pepys' account, may provide us with a partial picture of how optical instruments were used and viewed during the 1660s.

Illustration 9: Frontispiece: Thomas Sprat, *The History of the Royal Society of London* (1667)

Bennett says that Hollar engraved the image without having knowledge, or even physical reference to many of the mathematical objects he included, and this may explain why he omitted the Society's cabinet of anatomical and biological curiosities.[128] Used for entertainment, pleasure and collecting, the purpose of the optical objects changed during the

[128] Jim Bennett, 'The Instruments' in *The Image of Restoration Science, The Frontispiece to Thomas Sprat's History of the Royal Society (1667),* by Michael Hunter (London: Routledge, 2016), Chapter 5.

period, and they came to circulate within social and cultural circles they had not occupied before. Indeed, by the early eighteenth century, the attitude towards the objects may be summed up by Robert Hooke, who complained that they had become little more than ‘play-things’, with Hooke known to have criticised how they came to be items for mere ‘pastime’ by the 1690s, not the serious application he advocated with the publication of *Micrographia*.[129] Telescopes, and microscopes, are mentioned in Sprat’s 1667 written account, but fewer than half a dozen mentions across the entire account. One notable example of the Society’s work in the area, however, was recorded by Sprat, who mentioned that work on a catalogue of natural observations in England had begun:

> ‘...They have suggested the making a perfect Survey, Map, and Tables of all the fix’d Stars within the Zodiac, both visible to the naked eye, and discoverable by a six foot Telescope, with a large aperture; towards the observing the apparent places of the Planets, with a Telescope both by Sea and Land. This has been approv’d, and begun, several of the Fellows having their portions of the Heavens alloted to them.’[130]

The size of this type of telescope meant it would not have been possible for everyone to own one. This activity is one this chapter will return to later. The makers and buyers of instruments in the mid to late seventeenth century were concerned with the production of optical devices for a range of different reasons. The evolution of the technology had been gradual and was still effectively ‘new’ by the 1660s. Optical instruments were made, bought and used, for a wider range of activities than their intended design: for either gazing at the

[129] David Carroll Simon, *Light Without Heat: The Observational Mood from Bacon to Milton* (New York: Cornell University Press, 2018), 130.
[130] Thomas Sprat, *The History of the Royal Society of London* (London: Printed by T.R. for J. Martyn at Bell, 1667), 190-191.

stars or observing miniscule organisms. In this period, the instruments also acquired some common purpose as collectable gadgets as their cultural value changed and they occupied domestic spaces, as well as institutional ones. The purpose of this chapter is to understand how this changing mind-set from the 1660s led to a dramatic increase in the production and sale of optical instruments in London, and to do so through the surviving instruments in the Science Museum collections. What were the dynamics that made this growth possible, and what conclusions can be drawn by observing the artefacts themselves in the twenty first century?

The chapter marks a contrast to the previous one on mathematical instruments during the period. Whilst a material cultural analysis of those objects reveals much about their makers, with optical instruments a visual and qualitative investigation can reveal more about their consumers. The distinction is a subtle one. With multi-faceted uses and a multitude of makers, materials and workshops, optical instruments were desirable objects of luxury, commodity and collection amongst a wider market than traditional instruments had been. Whereas mathematical items such as quadrants and protractors were objects made and used with precision and mathematical theory, telescopes and microscopes were routinely used for curiosity. As stated at the start of this thesis: the definition of 'instrument' changed during the period after 1650 and having assessed how the boundaries for mathematical instruments became less rigid, a material cultural study of optical instruments can support this.

This chapter therefore makes six points to support the thesis core claims. First, it reiterates that a material cultural approach is preferable for some early modern objects. Telescopes and microscopes especially have numerous component parts from many materials that reveal much about their creation, purchase, use and collection. Second, that a study of these materials demonstrates how, in contrast to other types of ‘instruments’, telescopes and microscopes became early modern items of luxury that were purchased and used for their novelty, their modernity, their curiosity and as entertainment. Third, that this meant their network of users expanded away from the traditional, niche network of users of ‘instruments’ for practical application in industry or education. Fourth, that the qualitative approach used to present case studies in this chapter enhances our present understanding of the world of seventeenth-century ‘science’ and where this took place: technological developments disseminated in early modern English society in ways otherwise overlooked. Fifth, that unlike the one-material mathematical instruments of precision, many of the telescopes and microscopes produced for a popular market, either on commission or bought off the shelf, cannot be considered ‘precise’ in the same way. Made from materials that were cost-effective, recycled, re-used, designed to emulate more expensive ones, optical devices were sometimes a part of a ‘make-do-and-mend’ culture in seventeenth-century craft. They sometimes too were used, as alluded to in the previous chapter, because it was more effective in terms of both time and cost to reuse materials rather than start from, or source, raw materials. Sixth, that this expansion in production, as well as change in meaning and alterations to what constituted an ‘instrument’ changed what a ‘maker’ was expected to do, and their social status.

The growth in the optical instrument trade in London (from the 1660s) was a consequence of a move away from experimentation and the popularisation of the objects for novel, curious reasons. This chapter considers a number of objects in the Science Museum that reflect individual object histories that are indicative of these patterns from the time. Each of these objects led to the most detailed, individualised findings that can most effectively lead to new deductions about the trade and use of the items. They were not included because they were typical or usual, or specifically because they were atypical, but because research into their makeup yielded the most information and new findings. Simultaneously, they demonstrate that the growth in demand across the seventeenth century resulted in the production of new instruments, made with multiple component parts and raw materials, and a likely shift in working practices. Early divisions of labour must be considered.

The chapter argues that the surviving instruments bear the characteristics of these movements in socio-economic circumstances and prompt questions to modern day observers. The objects and archive materials (such as accounts from the classified papers held by the Royal Society) are used to argue that the optical instrument trade centred on London because of landmark contextual events (such as the publication of *Micrographia*) that stimulated interest, appetite for consumption, with changes to working practices. The emergent 'hybrid' instrument makers in the previous chapter in mathematics therefore evolved into newer 'hybrid' makers who produced a varied range of instruments for a more diverse range of consumers. The calculated precision required to produce quadrants was rather different when used to produce all of the parts of optical devices, as the chapter will argue.

The expansion of thinking in material cultural studies since the emergence of 'new cultural history' in the 1970s and 1980s, means the approach used for observing, analysing, describing and understanding past objects is straightforward: to examine the objects, note, analyse and describe their physical characteristics and research based upon questions that arise from this visual analysis. The history of optical instruments can be aligned to the so-called 'Life History Approach'. This framework argues that '...the concept of material life is redundant since it is impossible to imagine a human life that is immaterial. Human interactions, human belief systems and human cultures require intimate ties to things'.[131] In order to understand the value and place of an object in past societies, the 'Life History Approach' may be helpful, especially as objects are accepted as undergoing a succession of logical phases that represent the universal '...sequence of interactions and activities...during its existence.[132] These stages appear below in flow chart form and '...include procurement, manufacture, use, maintenance, reuse, recycling, discard and post-depositional formation'.[133]

In the cases of telescopes and microscopes, these phases took place over the course of little more than a century. The history of optical instruments cannot be sequenced into these perfect, rigid categories, but these phases can be used to understand how the technology became embedded over time. After their early century 'invention', the objects went through the subsequent stages. To be clear, this framework is a useful benchmark to help explain the growth in the optical instruments trade. These successive phases cannot be applied in a rigid way either to objects in museum collections, but they can be used to describe broad changes that took place. As with similar use-life approaches to object study, the functional characteristics of the object are analysed, and more recent scholarship seeks to stress the social interactions rather than treat objects as 'passive'.[134] This chapter does not claim that the objects did this of their own 'agency', as argued by Pickering.[135] The purpose of this work is to analyse the human agents, the makers, consumers and users of optical instruments and this is achieved through a visual analysis and investigation of the materiality of the objects

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[131] Kacy L. Hollenback and Michael Brian Schiffer, 'Technology and Material Life' in *The Oxford Handbook of Material Cultural Studies*, ed. Dan C. Hicks and Mary C. Beaudry (Oxford: Oxford University Press, 2010), 313-332.
[132] Hollenback & Schiffer, 320.
[133] Ibid.: Schiffer first does this in *Behavioural Archaeology* (New York: Eliot Warner, 1976), where he argues that there is an inherent close relationship between human behaviour and the objects people create.
[134] Chris Gosden and Yvonne Marshall, 'The Cultural Biography of Objects' *World Archaeology* 31, no. 2 (1999): 169-178.
[135] Andrew Pickering, 'Material Culture and the Dance of Agency' in *The Oxford Handbook of Material Cultural Studies*, ed. Dan Hicks and Mary Beaudry, (Oxford: Oxford University Press, 2010), 191-208.

included. These objects did not move of their own agency but were the embodiment of human agency. This is rather different from the linear 'Life Cycle Approach'.

Optical instruments were assigned different meanings, purposes and were themselves refashioned by separate groups of people at different stages: the items made for observation were repurposed for entertainment, as desirable curiosities, and ultimately as museum artefacts. Whereas material histories of 'science' can focus on the significant objects (Hooke's microscope, Newton's telescope) for the discoveries, or work, that was made with them, this is only a portion of the story of early modern instrumentation.

For Bruno Latour, the 'manipulating' of objects in settings other than where they were created, means that new 'skills' are learnt by the user or owner, and a new value is assigned to the object accordingly.[136] Straddling the historiographical debate between 'internalist and 'externalist' approaches, Latour shows how the place (which in many cases he considers to be a 'laboratory') can lead to separate meanings, but that in many past cases, knowledge and skills were exchanged and then re-termed, or repurposed, in order to acquire new knowledge.[137]

The distinction between the technology as a whole and individual objects that can be accumulated as a 'collective formation' is a quiet but integral one to this chapter. The collective formation (with a range of meanings, values, histories) of objects into a group is argued to be the reason for their continued existence and dissemination. The 'everyday handling of technological things', as argued by Latour, is part of the 'processes of translation

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[136] Bruno Latour, *Give Me a Laboratory and I Will Raise the World*, (Paris: Ecole des Mines, 2014), 148.
[137] Adam S. Miller, *Speculative Grace: Bruno Latour and Object-Orientated Theology* (New York: Fordham University Press, 2013), 1-2.

and displacement'.[138] From their early use microscopes and telescopes had their values translated from their original ones, as their presumed purposes and functions became less rigid, more popularised, and less niche. This can only be understood and analysed by examining these objects, underrepresented in the existing literature.

In the scholarship on early modern instruments, it has become usual for telescopes and microscopes from the long eighteenth century to be classified together; Jim Bennett describes surviving seventeenth-century examples as unusual in comparison to mathematical instruments, and therefore groups them together as 'optical' instruments, rather different from other lens-based devices, such as spectacles.[139] Bennett is not alone in aligning the instruments in his research in this way. Alexi Baker's 2009 thesis, and Anita McConnell's monograph argue for the same approach.[140] The basic traits of the two different instruments are similar because their histories, design, initial makers and first users were linked. Makers of microscopes usually made telescopes, and users of microscopes often also used telescopes. Makers of instruments in the seventeenth century were both producers and sellers of mostly mathematical instruments. It was these objects that were in greater demand. Indeed, in the latter part of the period, the sale and consumption of optical instruments grew.

In the words of Maurice Daumas, the emergence of the telescope and microscope '…gave new life to the classical instruments…optical instruments suddenly offered an unexplored field in which it was necessary, in order to succeed, to give proof of theoretical knowledge

138 Henning Schmidgen, *Bruno Latour in Pieces: an intellectual biography* (New York: Fordham University Press, 2015), 4.
139 Jim Bennett, 'Early Modern Mathematical Instruments', *Isis* 102, no. 4 (2011): 697-705.
140 Alexi Baker, 'This Ingenious Business: the socio-economics of the scientific instrument trade in London, 1700-1750' (doctoral thesis, University of Oxford, 2010); Anita McConnell, 'A survey of the network bringing a knowledge of optical glass-working to the London trade: 1500-1800' (monograph, Whipple Museum of the History of Science, 2016).

which a simple workman could not always assimilate'.[141] The move towards mechanical objects as the first choice of the seventeenth-century instrument buyer was part of a wider evolution in instrumentation that moved increasingly further from the category of 'tools' with which they had previously been associated. The precision required to make and use the objects was fundamental to this change, as well as the considerable number of materials and components that represented a marked change from the single materials used to make instruments such as quadrants.[142] Antoni Malet places the growth of both optical instruments within the context of seventeenth-century contemporary conceptualisations of the purpose of using optical instruments, and he makes it clear that the emergence of these objects for sale (and use) was a distinct break from the earlier tradition of mathematical instruments (for doing) into a new category (for knowing), an idea that Bennett also advocates.[143]

The trade in microscopes and telescopes was popularised in London, as the objects became desirable, capable of being made with a relatively low cost, with efficient new working practices. The cases that follow are included as they reveal most about the maker, patterns of making, and material tastes. As well as bearing the characteristics of the changing nature of the status of optical instruments as a technology, their commission and their user can be deduced.

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[141] Maurice Daumas, *Scientific Instruments of the 17th and 18th Centuries and their Makers* (London: Batsford, 1972), 28.
[142] Liba Taub, 'Introduction: Re-engaging with Instruments' *Isis*, 102, no. 4 (2011): 689-696.
[143] Jim Bennett. 'Knowing and doing in the sixteenth century: what were instruments for?' *British Journal for the History of Science* 36, no. 2 (2003): 129-150.

A Brief History of Optical Instruments

The Telescope

In order to understand the complex factors that led to the dramatic growth in the trade in (and demand for) optical instruments it is important to ask 'why?' Why were these instruments being used at all, and from where did they come in the first place? Both types of optical instrument (unlike the sundials, quadrants and clocks and watches made at this time) had relatively short past histories as technologies, comprising decades. In the 1660s, when their production and sale in London soared, the technological history of the telescope stretched back to no more than seven decades. This had a profound effect on the number of instrument makers, and many optical instrument makers also produced other 'types' of instrument.[144] It is now widely accepted that the telescope was 'invented' in the first decade of the century, and emerged as a new object, in 1608 or 1609.

According to Huib Zuidervaart, it was not really an 'invention' in any conventional sense; instead, Western Europeans in the years 1608-1609 witnessed a rapid, widespread, 'recognition' of an object that many believed had enormous potential, initially in the realms of military surveying, transportation and war.[145] Zuidervaart claims that the telescope had 'likely' been around, in other guises, for '…some decades, as a kind of toy', highlighting its dual function as an object of fun and practicality, and this would become a key factor in its sale during the 1680s and 1690s.[146]

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[144] The number of makers in London was at least 30 in London in 1651. The number rose to 123 by 1701: Gloria Clifton, *Directory of British Scientific Instrument Makers 1550-1851*, ed. Gerard L'E Turner (London: Zwemmer,1995), xv.
[145] Huib J. Zuidervaart, 'The True Inventor of the Telescope. A survey of 400 years of debate', *Origins of the Telescope – Royal Netherlands Academy of Arts and Science* 1 (2010): 9-44.
[146] Ibid.

The evolution and change from plaything to functional instrument was ‘the first’ such change ‘…in Modern History’ and has been variously attributed, with cultural and historical nationalism, as playing an important part in the claims to invention.[147] Whilst in *Il Saggiatore* (1623) Galileo Galilei recounted how he had presented a telescope in the autumn of 1609 to the Doge of Venice, he also made clear that he was not the actual inventor of the object. Unusually, he instead preferred to describe himself as the ‘discoverer’ of the telescope, unlike with other ‘discoveries’ he claimed credit for.[148] A possible reason for this may have been that a significant number of people already knew that the object had been created, before it arrived in the Veneto. Galileo recounted that whilst in Venice:

> ‘…news arrived that a Fleming had presented to Count Maurice [of Nassau] a glass by means of which distant objects might be seen as distinctly as if they were nearby. That was all. Upon hearing this news I returned to Padua, where I then resided, and set myself to thinking about the problem. The first night after my return I solved it, and on the following day I constructed the instrument and sent word of this to those same friends at Venice with whom I had discussed the matter the previous day. Immediately afterward I applied myself to the construction of another and better one, which six days later I took to Venice, where it was seen with great admiration by nearly all the principal gentlemen men of that republic for more than a month on end, to my considerable fatigue. Finally, at the suggestion of one of my patrons, I presented it to the Doge at a meeting of the Council.’[149]

[147] Zuidervaart.
[148] Galileo’s ‘preoccupation with credit and control over his work’ is explored in the introduction to M. Biagoli, *Galileo's instruments of credit: Telescopes, images, secrecy* (Chicago: University of Chicago Press, 2007).
[149] Stillman Drake, *Discoveries and Opinions of Galileo: Including The Starry Messenger (1610), Letter to the Grand Duchess Christina (1615), and Excerpts from Letters on Sunspots (1613), The Assayer (1623),* (London: Domesday Books, 1957), 242.

The 'Fleming' Galileo described was Hans Lippershey, who first presented his device to the States-General in The Hague in 1608 with the hope of obtaining a lucrative patent for the design. This was almost a year before Galileo 'discovered' the telescope, in September 1609. Lippershey was paid three hundred guilders by the Dutch governors in The Hague, and instructed to develop more of his instruments for the military to use. Although he did not secure a patent, news of his object soon '…spread like wildfire'.[150] Whilst Lippershey was the first to apply for a patent, other makers in Holland came forward to claim that they were responsible. Zacharias Janssen and Hans Janssen are the two most famous examples of makers who made later claims to invention which have been the source of debate and discussion ever since.[151] Gerard L'E Turner asserts that the 'invention' of the telescope and the microscope should be attributed to Zacharias Janssen, who likely came up with the application of the instrument in around 1608, before Lippershey became aware of the object's importance and potential.[152]

Nonetheless, the telescope that Galileo used, first presented to the governors of Holland by Lippershey, became known as the 'Galilean' or 'Dutch' telescope, depending on the national perspective. It used a convex lens at one end, with a concave lens at the opposite. This produced upright images for the viewer, but with a smaller field of vision for the user in the centre.[153] Over the course of decades, changes to the lens shape to enhance the telescopic range led to the creation of the so-called 'astronomical' telescope. Developed first by Johannes Kepler in 1611 and intended to improve on the deficiencies of the object Galileo

[150] Zuidervaart, 12-16.
[151] Timothy C. Kriss and Vesna Martich Kriss, 'History of the Operating Microscope: From Magnifying Glass to Microneurosurgery', *Neurosurgery* 42, no. 4, (1998): 899–907.
[152] Gerard L'E Turner, *Scientific Instruments 1500-1900 – an introduction* (Cambridge: Cambridge University Press, 1998), 91.
[153] Albert Van Helden, 'The Telescope in the Seventeenth Century', *Isis* 65 (1974): 38-58.

used and described, the astronomical telescope used *two* convex lenses of equal diameter; this 'astronomical' telescope also came to be known as the 'Keplerian' telescope.[154] Kepler detailed this object and demonstrated his insight and understanding into the properties of lenses (a craft skill and knowledge that Galileo lacked) in his work *La Dioptrique* (1611). Kepler's telescope created a larger field of vision for the user but inverted the magnified image, instead of the smaller upright image that resulted from observations made with the Galilean telescope.

Typical of the terrestrial telescopes that continued to be made alongside the astronomical telescopes is an object held in the Science Museum collections, dated to the 1680s, and this makes it one of the earlier specimens in the Museum.[155] To the casual observer today, the lenses are not prominent, but they are central to the 'mechanics' of the object and the way that the astronomical and the terrestrial telescopes differed. The telescope has nine 'draws', sections that were elongated, in order to maximise the distance that could be viewed. Makers and users in the formative decades erroneously believed that the length of the objects and their tubes was critical importance, and the potential of the instruments was linked to this part.[156]

[154] Van Helden.
[155] 'Terrestrial Telescope by Yarwell, signed 'John Yarwell' (1928-920), Science Museum Group Collection, London.
[156] René Racine, 'The Historical Growth of the Telescope Aperture' *Publications of the Astronomical Society of the Pacific* 116, No. 815 (2004): 77-83.

Illustration 10: ‘Terrestrial Telescope by Yarwell, signed ‘John Yarwell, Fecit’ 1928-920, Science Museum Group Collection.

Illustration 11: Detail of the draw tubes (closed), ‘Terrestrial Telescope by Yarwell, signed ‘John Yarwell, Fecit’ 1928-920, Science Museum Group Collection.

This proved to be a falsehood, as philosophers later understood that all optical instruments had a natural limit to their range and magnification. The tube is made from pasteboard, and covered in vellum, which was dyed in a shade of green that was typical to similar items from the period in this, and other collections. John Yarwell was its maker, and it seems likely, given the fashion of printing and signing the name of the maker on to the instrument that gained currency in the 1680s and 1690s, that this example is particularly early. In size, design, style and general appearance, this is a good example of a terrestrial telescope that would have been sold in the late 1670s and into the 1680s, but smaller telescopes, cheaper and more portable, were also common.

Examples of smaller telescopes by makers whose works are held in the Science Museum (notably John Yarwell and rival John Marshall) comprise a sizeable collection compiled by the Louwman family in the Netherlands, and these are today held in a separate part of the privately-owned Louwman Museum in The Hague.[157] In Britain, the Whipple Museum of the History of Science (Cambridge), Museum of the History of Science (Oxford) and Wellcome Collection (London) each contain objects that include seventeenth-century optical instruments from makers such as Yarwell, Cock, Marshall, that are of comparable length and size.

Whilst the Galilean telescope was the dominant instrument to be produced for private and state use in the first few decades after its arrival, it was the Keplerian astronomical telescope that effectively 'emerged' as the standard type of telescope in the 1630s and 1640s, primarily

[157] A gallery in the car and transport museum that houses these instruments is described by the Louwman Museum as the largest single collection of historic telescopes in the world. 'Louwman Historic Telescopes', *The Louwman Museum*, accessed Dec 01, 2020, <https://www.louwmanmuseum.nl/Stichting-Louwman-Historic-Telescopes/Louwman-Historic-Telescopes.aspx>

in Italy and later elsewhere in Europe, although the users of these were usually astronomers and military surveyors.[158] Van Helden attributes this shift to the fact that early telescopes were used for naval and terrestrial observations, whereas the growth in popularity of the Keplerian telescope was a result of the increased interest in astronomical observation from the 1630s and 1640s; for which task an inverted image was of far less of an obvious disadvantage to the user, and could be easily corrected when drawing or sketching observations.

Rolf Willach cites ‘two astronomical waves of discovery’ that he asserts directly impacted the change in style of telescope more than anything else.[159] The first ‘wave’ took place between 1610 and 1611. For Willach, the two developments of greatest significance both had astronomical outputs. The first wave coincided with successive discoveries: of the moons of Jupiter, the topography of the moon, the shape of Saturn and the discovery of sunspots.[160] These observations were because of the telescope. The new technology was adopted at this time mostly within astronomical circles. Willach claims, however, that for the next few decades, the number of astronomical discoveries was slower than this initial burst.

Only from the 1650s until the 1670s was there a wave of second discoveries (including the observation of Jupiter’s bands, Huygens’ observation of Titan in 1656 and the regular discoveries made by Cassini at the Paris Observatory) that led to the increase in size and power of telescopic objects from ‘year-to-year’ in response to demand from astronomers and philosophers, until they reached their technological limit of magnification in around 1670.[161]

[158] Ibid.
[159] Rolf Willach, ‘The Development of Telescopic Optics in the Middle of the Seventeenth Century’, *Annals of Science* 58, no. 4 (2001): 381-398.
[160] Ibid.
[161] Willach, 381-382.

Van Helden is broadly in agreement with this point that the period 1650-1685 was the period when the application of the telescope for practical observations and astronomical discoveries was first utilised.

The Microscope

Unlike with its close cousin the telescope, in the early seventeenth century there was a '…curious lack of interest [by contemporaries] in the possibilities' that the microscope presented to philosophers.[162] There were very few serious applications of the microscope in the first part of the century, with most viewing the object as only a toy. The first to modify a telescope and use it for microscopic purposes was most likely Galileo. Similar to the telescope, the actual 'inventor' of the microscope is not without uncertainty.[163] In the second century CE, the thinker Ptolemy wrote in *Optica* that he had observed as part of a series of experiments and observations, that when he filled glass objects with water, it lead to the magnification of the image through it to the viewer.[164] Given the veneration attached to ancient thinkers in the early modern era, it is odd that no-one thought to build on Ptolemy's claims for practical ends for almost a millennium and a half to create an instrument devised on these principles.[165]

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[162] Clara Sue Ball, 'The Early History of the Compound Microscope', *Bios* 37, no. 2 (1966): 51-60.
[163] Ibid.
[164] Ptolemy, 'The Fifth Book of Ptolemy's Optics', in *Ptolemy's Theory of Visual Perception: An English Translation of the Optics*, translated by A. Mark Smith (Philadelphia: American Philosophical Society, 1996), 229-262
[165] David Bardell, 'Eyeglasses and the Discovery of the Microscope', *The American Biology Teacher* 43, no. 3 (1981): 157-159.

Whereas Galileo and others initially used their telescopes to point downwards, and effectively use them as cruder forms of what later came to be known as 'microscopes', when the miniaturisation and modification of the telescope led to a distinct instrument, the compound microscope, is not known. It is likely to have taken place between 1615 and 1620. Correspondence from William Borelius reveals that he was shown a compound microscope in 1619 by Cornelius Drebbel, a Dutch mathematical thinker and instrument maker, who also acted as an adviser to James I of England, and this is the earliest known account of a compound microscope being demonstrated.[166] Drebbel was known as a man of magic, and in early experiments with ice entertained the King by claiming he could change the summer to winter with the use of ice and salt, inside Westminster Abbey.[167] The combination of optical instruments and a person such as Drebbel, meant they were caught between knowledge and entertainment. Work by Vera Keller positions Drebbel as someone whose authority as an artisanal philosopher was embraced by many, and says he distinguished himself as a philosopher and was no mere magician.[168] This was similar to the later growth and change in the instrument trade in London after the 1660s where the serious application of instruments was blended with the novel.

The compound microscope used a biconvex eye lens to capture the light and a plano-convex objective lens for magnification. Amongst those to praise and consider the practical possibilities that optical instruments held was Descartes.[169] The compound microscope, first described in text in 1637, also matched the design of the instrument that Drebbel used some

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[166] Ball, 51.

[167] Steven Ashley, 'The Vulgar Mechanic and His Magical Oven', *Nautilus* no 12 (2014), accessed Jan 10, 2019, http://nautil.us/issue/12/feedback/the-vulgar-mechanic-and-his-magical-oven/

[168] This is outlined in: Vera Keller, 'Cornelius Drebbel (1572 - 1637): Fame and the Making of Modernity' (doctoral thesis, University of Princeton, 2008).

[169] Edward G. Ruestow, *The Microscope in the Dutch Republic: the shaping of discovery* (Cambridge: Cambridge University Press, 1996), 37-40.

two decades earlier and wrote about.[170] How Galileo and others used the telescopic apparatus as a crude early form of microscope was not quite the same as this: for the compound microscope, the eyepiece lens does not function to magnify the image as with a telescope, but rather to make parallel the rays of light for the image which reach the eye; its purpose could be described broadly as ‘lighting’ rather than ‘magnification’, a technical and technological difference that separates the two objects.

From the 1630s, the experimental and observational applications of the compound microscope grew and were recorded in print by thinkers across Europe. Two founding members of the *Academia dei Lincei* (Rome), Stelluti and Cesi, published an incomplete treatise entitled *Apiarium* in 1625, on their microscopic bee observations, but they referred to their instrument in Italian as the ‘Occhialano’.[171]

This is the earliest known written record of observations made possible due to the use of a microscope, although the work’s importance amongst biologists is still not widely recognised. A 1646 treatise by the Jesuit polymath Johannes Kircher (*Ars Magna Lucis Et Umbrae*) focused on magic lanterns, but Kircher was also an advocate of microscopes and is now thought to be one of the first people to observe microbes through an optical instrument. Another Jesuit thinker, Gaspar Schott, listed different types of microscopic lenses in *Magia Universalis Naturae et Artis* (1646); Schott believed that nature’s mysteries could be ‘illuminated’ through the use of such objects and, like Kircher, advocated their use.[172]

[170] Ball, 53.
[171] David Bardell, ‘The First Record of Microscopic Observations’, *BioScience* 33, no. 3 (1983): 36-8.
[172] Mark A. Waddell, *Jesuit Science and the End of Nature’s Secrets* (London: Routledge, 2016), 165-7.

In the 1650s, Peter Borel's work *De Vero Telescoppi Inventore* (1656) listed four different types of microscope and descriptions about how to use them. Borel's earlier treatise, *Historiaum et Observationum* (1653) included descriptions of blood capsules.[173] Why is this relevant? The history of the microscope, much like its cousin the telescope, followed a clear trajectory. This pattern answers why there was a supposed 'gap' between the emergence of optical instruments in the early century and their production and sale in greater number in London from the mid-century for a more popular clientele. Whereas the initial deployment of the instruments was for practical and experimental purposes, the growth in the trade after the 1660s moved beyond these closed circles of thinkers connected to universities or institutions like the *Academia* (such as Stelluti and Cesi). Instead, the instruments were made for novelty, status, entertainment, as curiosities and were subsequently made and marketed in a different way. None of the works alluded to however has attracted as much scholarly attention, much like at the time, as Hooke's 1665 work, *Micrographia*.[174]

Regardless, there is a clear, quiet but sustained pattern of natural philosophers becoming increasingly confident at turning to microscopes as mechanical devices with an important potential for practical use from the 1650s. The traditional view was that the first real 'scientific' application of the microscope to be documented in print did not occur until as late as 1661.[175] The Italian Marcello Malpighi published details of his microscopic observations after he put the dried blood of a frog under the most powerful microscopic lens he could source, and drew what he saw.[176] Clara Sue Ball is intrigued as to why there was a delay from the 'invention' of the microscope in the first decades of the century and the application of it

[173] Ball, 55.
[174] There are no known references in the scholarship to estimates on print runs or circulation, and consultation with the archivists at the Royal Society yielded no clear information on the subject.
[175] Ball, 58.
[176] Marcello Malpighi, *De Pulmonbus Observationes Anatomicae* (Typis Jo. Baptistae Ferronii: 1661)

for biological purposes such as this. When one considers that William Harvey's thesis on blood circulation was published in 1628, and that his theory would not be effectively 'proved' for another century and a half, the slow application of the microscope for biological observations seems strange.[177] The study of frog blood by Malpighi (and Nehemiah Grew) showed that a system of capillaries existed, and although neither he nor others realised this at the time, his observation effectively confirmed that blood circulated in a closed system.

Whereas the published observations from these instruments was sporadic, between the time of the object's first appearance in 1620 and the 1660s, the wider understanding of how important the application of the telescope was changed. Whilst these optical instruments become fashionable, useable and available, it was two landmarks in England that were of critical importance to the eventual growth in the trade of telescopes and microscopes. Whereas Borel, Kircher and Stelluti and Cesi, and many others, published works aimed at attracting the attention of their elite, educated audiences and patrons, it was the impact of a 1660s publication that had a greater effect on the dynamics of growth in the trade of microscopes and which was disseminated amongst a far grander readership. The foundation of the Royal Society in 1660 and the publication of *Micrographia* (1665) were events that took place initially amongst the closed circle of experimental thinkers. This meant that by the 1670s, London was in the process of acquiring its status that was cemented by the 1690s: as the world's dominant space for the production and sale of optical instruments.

As with other histories, this thesis accepts that the publication of *Micrographia* was a major publishing event in London, with Hooke's work causing something of a sensation. It may be an indicator for the reasons why London's trade in optical instrument making grew. Hooke's

[177] Ball, 58.

work may have popularised microscopic research, but within the closed circle of the Royal Society, his work was not the first. In 1661, Charles II was impressed with the engraved images of a flea and a louse that had been sent to him by Hooke's collaborator and fellow of the Society, Sir Christopher Wren, who had engraved them after his own observations.[178]

The book's popularity and circulation contributed to the drive in demand for optical instruments for pleasure, status, interest, curiosity. The published work in the 1660s by Hooke, but also Antoni van Leeuwenhoek, played a crucial conceptual role in the advancement of ideas on the interpretation of nature, as had been advocated earlier in the decade by thinkers including Bacon, Locke and Boyle.[179] Technical limitations to the possibilities of microscopes and telescopes stunted their evolution from the 1660s, and yet at this same time the Paracelsian worldview that the unseen or unexplained could be explained by the occult and magic began to decline.[180]

This is why the six themes and questions outlined at the start of this chapter are important and can be answered by and analysis of the objects. The reasons for the demand and growth in the trade were centred on replication: seeing or trying to see the same things that Hooke, and van Leeuwenhoek, had published, as well as the novelty that these items presented consumers with. The 'sudden fall' of the microscope is the focus of attention by early modern historians, but Luthy says that the instrument's zenith was reached only after the 1650s, the preceding decades for it were 'barren'.[181] Indeed, Fournier and others argue that the 'rise' of the

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[178] Jenny Uglow, *A Gambling Man: Charles II and the Restoration* (London: Faber and Faber, 2009), 232.
[179] Catherine Wilson, 'Visual Surface and Visual Symbol: the microscope and the occult in Early Modern Science', Journal *of the History of Ideas* 49 (1988): 85-108.
[180] Ibid.
[181] CH. Luthy, 'Atomism, Lynceus, and the Fate of Seventeenth-Century Microscopy'*, Early Science and Medicine* 1 (1996): 1-27.

microscope during its heyday had little to do with technological advance or application, but was the result of social circumstances.[182] The decline in use from the 1690s, when technical advances meant that the instruments were more capable and less prone to interference than ever before, paradoxically coincided with their decline in use.[183] This chapter will assess the reasons why this change took place. What drove an increase in use, away from the closed circle of thinkers and experimentalists, and how did this impact the eventual decline of optical instruments?

The Materiality of Early Modern Optical Instruments - Analysis

Studying the individual components on surviving instruments today can show how makers approached producing the instruments for sale. Unlike mathematical instruments, telescopes and microscopes were made from multiple, different raw materials, themselves created with a varied range of skills and for different purposes. For telescopes and microscopes, the lens type, size and quality were important, and yet still by the 1670s, the process of blowing glass into lenses and grinding and polishing these down on a lathe was an imprecise process.

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[182] Ibid.

[183] Marian Fournier, *The Fabric of Life: Microscopy in the Seventeenth Century* (Baltimore: John Hopkins University Press, 1996); See also: Ann La Berge, 'The History of Science and the History of Microscopy', *Perspectives on Science* 7 (1999): 111-142.

Although the glass was often sourced from Venice rather than blown in London, changes to the process of lens grinding was slow and the practice was unchanged until the nineteenth century when major improvements took place.[184] The glass lenses for telescopes and microscopes from the period are often scratched, missing, damaged, cracked, or later replacements. However, Bedini also said that towards the end of the seventeenth century, both English and French lens grinding and polishing had witnessed many improvements in apparatus and techniques.[185]

The precision used to engrave mathematical instruments was not comparable to the production of lenses for optical instruments. Without discerning features to indicate where they were made, when, and by whom, there are few clear or firm clues as to the origins, or histories, of individual objects. It seems sensible therefore to begin with the largest component part of optical instruments that does have such marks and characteristics, the tube that separates the two lenses. Many of the surviving examples within collections from the later seventeenth century were made from pasteboard, not the brass or copper that became more popular after this period.

Gerard L'E Turner advises that the first step after finding historic instruments is to 'go and look at them… there is no substitute for close examination', and that the starting point for any observation based study is the materials.[186] He continues that: 'for more than a century after the invention of the telescope and the microscope…the lenses were kept the required distance

[184] Silvio A. Bedini, 'Lens Making for Scientific Instrumentation in the Seventeenth Century' *Applied Optics* 5, no. 5 (1966): 687-694.
[185] Ibid.
[186] Gerard L'E Turner, 'The Annual Invitation Lecture: scientific instruments – why?', *Bulletin of the Scientific Instrument Society*, 76 (2003): 2-4.

apart by tubes made of wood or pasteboard covered with vellum or leather'.[187] In a 1966 study by the same author, seventy telescopes and microscopes made in England between 1660 and 1750 were examined as part of research into their outward decoration: all were made of pasteboard covered in leather or vellum and L'E Turner deduced that they were very likely made by similar tools and methods.[188]

Building on L'E Turner's quantitative conclusions, research for this thesis began with observation, and the recording, of materials, marks (and subsequent investigations) into what these can reveal about the early modern optical instrument trade in London. The following case studies, based on the original research undertaken during the course of the thesis project, have been chosen because they offer pertinent, tangible examples of typical, and untypical, material characteristics. The research led to new findings on some of the objects. In each of the following examples, analysis of the functionality, decorative aspects, damage, accessories, and the component materials is made.

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[187] Ibid.
[188] Gerard L'E Turner, 'Decorative Tooling on 18th Century Microscopes and Telescopes', *Physis. Rivista internazionale di storia della scienza,* 8 (1966): 99-128.

Culpeper Microscope (1913-274)

Illustration 12: Composite image showing parts of: 'Compound microscope by Culpeper', 1913-274, Science Museum Group Collection.

This compound microscope by Culpeper, has an optical tube made from pasteboard.[189] Pasteboard involved the gluing together of multiple sheets of paper to create a thicker, harder, 'board', which was then shaped into a solid object with the aid of moulds and presses. Early examples of a form of pasteboard production have been traced to ancient Tibet.[190] Commercial production of pasteboard in Europe likely began in the 1570s. Pasteboard should not be confused with papier-mâché, which despite its French name is not a term of French

[189] The formal term 'optical tube' is used interchangeably with 'tube' in this chapter.

[190] Pilvi Vainonen, 'Making Museum Collections: Missionary Hilja Heiskanen's Himalayan artefacts' *Studia Orientalia* 109 (2011): 163-182.

origin, but instead came from England when sometime after 1725, the method of 'chewing' paper, as its name suggests, began.[191] Papier-mâché became a popular, cheap and efficient material for furniture, across the eighteenth century. By the nineteenth century, the then out-of-favour pasteboard began to be known as papier-mâché and merely a method of the new form, but papier-mâché involved using pulped paper, which pasteboard did not.[192]

An 1840 encyclopaedia from London described the 'two modes' of creating papier-mâché as '1, By glueing or pasting different thicknesses of paper together; 2, by mixing the substance of the paper into a pulp and pressing it into moulds'; on the other hand, the entry also affirms that '...Papier-mâché, properly so called, however, is that which is pressed into moulds in the state of a pulp. This pulp is generally made of cuttings of coarse paper boiled in water'.[193] There is an apparent acceptance that pasteboard came to be known as papier-mâché as the former fell out of fashion in the eighteenth and nineteenth centuries, but that it was a technically different material, made in a separate process, that pre-dated papier-mâché made from pulped paper. In the case of telescopes and microscopes made during the period, their tubes were usually made from pasteboard, as L'E Turner shows.[194] The term papier-mâché is both too early and non-specific to use as a description.

Wooden tubed telescopes have not survived in as great a number, and they appear to have been made in fewer number than pasteboard objects. We know that contemporaries thought it preferable to use the sturdier wood. A rare example of written instructions on the production

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[191] D. van der Reyden & D.C. Williams, 'The Technology and Conservation Treatment of a 19th century 'Papier-mache' Chair', *Preprints of the American Institute for Conservation, 14th AGM, Chicago*, 1986: 125-142.
[192] For further context on the history of paper and print, see: Richard Leslie Hills, *Papermaking in Britain, 1488-1988: a Short History* (London: Athalone Press, 1988).
[193] *The Penny Cyclopaedia of the Society for the Diffusion of Useful Knowledge*, Volume XVII (London: Charles Knight publisher, 1840), 217.
[194] L'E Turner, 'Lens Making for Scientific Instrumentation in the Seventeenth Century' *Applied Optics* 5, no. 5 (1966): 687-694.

of optical instruments was written in Italy around 1670 by Giovanni Christoforo Bolantio. A 1995 translation and analysis of Bolantio by Silvio Bending and Arthur Bennett, entitled *Of the materials of the Construction of Tubes*, begins: 'The tubes are most often made of cardboard [modern translation], others are made of iron bands, but it is preferable to make them of wood, hollowed out and turned on a lathe. These are the best'.[195] Much of the chapter is taken up with calculations on length and magnification, which Bolantio may have done himself.[196] Wood was a well-used material that was more solid than pasteboard but may not have been used as much due to constraints on time and the fact that hollowing or engraving blocks of wood with a lathe or knife was costlier.

Despite the drawbacks of light infiltrating the tube and distorting the image to the viewer, and Bolantio's assertion that wood was the best of the three options, pasteboard prevailed for the first hundred years of the London production of optical instruments, perhaps due to being cheaper and quicker to produce. Metal tubes only replaced pasteboard in the middle of the eighteenth century, as makers sought to reduce the negative effects of light entering the tube. This was a considerable drawback of pasteboard, but one that must have been considered cancelled out by the low cost. This reflects the move away from the quest for precision instruments, and how the technology of optical instrumentation led to objects being individually constituted for purposes other than precise observation and experimentation, but instead as fashionable commodities to own.

[195] Silvio A. Bending and Arthur G. Bennett, '"A Treatise on Optics" by Giovanni Christoforo Bolantio' *Annals of Science*, 52 (1995): 103-126.

[196] See also: Fokko Jan Dijksterhuis, *Lenses and Waves: Christiaan Huygens and the Mathematical Science of Optics in the seventeenth century*, (Leiden: Kluwer 2005), 60-63.

It was a complicated task to exclude natural light from the pasteboard tubes. Whereas wood was used for the cap to hold the observing lens in place, and as part of the stand, the actual microscope tube is made from pasteboard, with the outer section covered in ‘fish skin’ for decoration, according to its documentation record in the Science Museum. The exterior section of the tube was covered in vellum, dyed green and stamped with gold embellishments.

Illustration 13: Component Part: ‘Compound microscope by Culpeper’, 1913-274, Science Museum Group Collection.

Blank paper was often used for pasteboard, although printed text can sometimes be observed on the inside of the tube, indicating that the paper was re-used or recycled, and this may have been a further cost-effective strategy. Recent research by Anna Reynolds on wastepaper shows that, prior to 1700, wastepaper was re-used for book binding, and this is evidenced today in multiple surviving early modern library collections including Bishop Cosin's Library, Durham and the Huntington Library, San Marino.[197]

The value of paper as a material that was available to be reused for other purposes is evident in many early modern tube-based instruments, where there are signs that the paper had previously been printed on. Recycling materials as products with additional or alternative purposes than their original ones was not an unusual practice in the seventeenth century. According to Simon Werrett, '...materials were repaired, reused, used by friends [...] or converted to new uses [...] scarcity, and to a lesser extent poverty, dictated that such activities were a matter of course'; in other words, the practice of 'making do' was a common strategy, particularly in book bindings.[198] From a modern perspective it may appear somewhat at odds with the stereotypical association of instrumentation and 'innovation'.

As new objects, '...many of the instruments used by philosophers were new, purchased from instrument-makers or made by hand, but these might incorporate old or cheap materials'.[199] This is why paper was used in place of the more expensive wood, and the more readily available metal that would become easier to produce on a wider scale from the nineteenth century. The early modern repurposing of materials to create objects with other means was a major part of the early optical instrument trade, but it had its origins in the earlier mathematical trade.[200] This is why astronomical implements such as astrolabes were

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[197] Anna Reynolds. 'Such dispersive scattredness: Early Modern Encounters with Binding Waste.' *Journal of the Northern Renaissance* 8 (2017): 1-43; Anna Reynolds, 'Privy Tokens: Wastepaper in Early Modern England, 1536-1680', (doctoral thesis, University of York, 2017).
[198] Simon Werrett, 'Recycling in early modern science', *British Journal for the History of Science* 46, no. 4 (2013): 627-646.
[199] Werrett, 633.
[200] Ibid.

sometimes made from the cheaper, quicker, paper, pasted to wood backgrounds, rather than engraved on the wood or metal.

The exchange of older goods, especially books, was a central component of the early modern network of transaction and exchange. It is possible that the paper used to make tubes for telescopes and microscopes came from exchanges such as this. Anna Reynolds' research examines the complexity of books becoming 'waste' as both texts and objects.[201] This could be down to innumerable reasons, including the creation of unauthorised editions of works. These were then printed, entered and subsequently undercut the market. This meant the editions created by the actual publisher struggled to sell. In many cases, it is possible to observe the remnants of pages and partially printed text when the caps are removed from the tubes. Furthermore, it is an excellent example of the 'make do and mend' mentality argued by Werrett, proving that this mentality not only applied to experimenters and philosophers, but extended across the network to include instrument makers as well.

As part of research into the collection of optical instruments carried out for this doctoral thesis, the possibility of finding the source of the paper used from a telescope or microscope was explored. This information could give an indication of the type of printed material used (whether it was a cheap thin pamphlet, or a more expensive book, is just one question) and provide evidence of the wider network of craftsmen and artisans in London, over different trades. The main challenge was to find a pasteboard tube with enough text to begin a fruitful search. From the Science Museum collections, this author identified the Edmund Culpeper compound microscope above (1913-274) as providing the best possible chance of

[201] Anna Reynolds, 'Privy Tokens: Wastepaper in Early Modern England, 1536-1680' (doctoral thesis, University of York, 2017).

investigating what this pasteboard tube may have been extracted from. Text observed on the inside of the tube was promising. Several lines of text were observed, photographed and enhanced with a computer and afterwards transcribed to give the following, partial, transcription, from which it was then hoped a list of possible materials could be drawn up:

‘About this time Fab----

the Priest

Off-- it fol---’

Illustration 14: Enhanced Image with text visible: Interior tube: ‘Compound microscope by Culpeper’, 1913-274, Science Museum Group Collection.

A computer enhancing programme was used, but little more than the text observable with the naked eye only could be found.[202] Even with enhancement, the amount of text visible offered little improvement on the original transcription. Research for the short, above, partial transcription therefore focused on *Early English Books Online,* the *Universal Short Title Catalogue*, and the *English Short Title Catalogue* as the starting points; other internet search engines including *Google Scholar*, and university library catalogues, including *YorSearch*, were also used.

Combinations of the known words from the transcription, as above (with the clear identifiable words: about, this, time, the, priest) often led to vast search returns: a search for the clear phrase 'about this time' on *EEBO* alone provided the staggering figure of 10,284 hits in 2,210 individual records; many arose because the phrase 'about time' was a very common occurrence.[203] Using the partial term 'fab' produced no positive results. It was therefore decided to focus on the opposite side of the internal pasteboard, which was also partially visible, but initially thought to be less promising than the fuller passage:

'...about the ex----

---ditions were, That after the...'

[202] In order to enhance the images, they were uploaded to the website, Fotor.com where the contrast and brightness was improved. See: https://www.fotor.com/features/one-tap-enhance.html/ Accessed Jan 10, 2019.

[203] The website has since changed, but the search was carried out in 2018 via *Early English Books Online*, Accessed Oct 1, 2018, www.eebo.chadwyck.com

Illustration 15: Enhanced Image with text visible: Interior tube: ‘Compound microscope by Culpeper’, 1913-274, Science Museum Group Collection.

The combination of words and letters did not first produce a sample of matches. Only completed words result in a return from the database. The final line was therefore altered, on the assumption that ‘ditions’ could be ‘conditions’. The line ‘...conditions were, That after the...’, was entered into *EEBO* and this produced a single hit.[204] The matching book on the database is a 1683 copy of *Plutarch’s Lives*, a classical work that was very popular in England over the course of the seventeenth century.

[204] Alternative possibilities for the word with the ‘-ditions’ suffix, such as ‘editions’ and ‘additions’ did not produce returns on the databases cited previously.

The passage comes from *Chapter V* of *Plutarch's Lives, (on Fabius).* The sections below that have been underlined show where the found match supported the original transcription from the pasteboard tube. It reads in full: 'The Senate on their part was offered with him for the bargain he had made with Hannibal, about the exchange of Prisoners, of which the conditions were, that after the exchange'.[205] The initial transcription corroborated the finding, and this was further proved, when compared with the fuller passage at the top of the next page in the sequence (in a similar positioning); it reads: 'About this time Fabius was called to Rome by the Priests, to assist (according to the duty of his office), at some their solemn sacrifices'.[206] This final part ('their solemn') showed that an error was made in the original transcription with the 'f' and 's' confused. Nonetheless, the matches underlined, their proximity, positioning, and similarity to the original analysis of the visible print means that the paper for the pasteboard was indeed made from a copy of this book or from sheets of individual paper. They are not a perfect match, and the positioning of the words on their lines is slightly different. The setting of the text on the microscope pasteboard differs from the setting of the page on EEBO. Tonson's work went through multiple reprints. It could be a reprint, or a translation by another author.

The edition on EEBO was published by Jacob Tonson (1665-1736), and numbered some six hundred and fifty-six pages, across five volumes, and this means a considerable amount of paper may have been purchased to create multiple tubes, if the entire work was acquired in a single transaction. Tonson was a well-connected author. A member of the 'Kit Kat Club', he had his portrait painted by the famed Sir Godfrey Kneller, an unusual accolade during this

[205] Correlation with this author's original transcription is underlined; *Plutarch's Lives. translated from the Greek by several hands ; to which is prefixt The life of Plutarch.*, (London: Printed for Jacob Tonson, 1683), Accessed 10 Dec, 2018, http://gateway.proquest.com/openurl?ctx_ver=Z39.88-2003&res_id=xri:eebo&rft_id=xri:eebo:citation:11244647

[206] Ibid.

time for a bookseller. Given Tonson's occupation and its typical social standing, his Society and social connections made him unusual. As Walker writes, 'booksellers were not among the class of people to have their portraits painted in the late seventeenth century by [...] expensive court painters'.[207]

Subsequent studies suggest Tonson was possibly the most influential publisher of the late seventeenth century in London.[208] The questions thus follow: was Tonson connected to Culpeper, and how did Culpeper come to use a Tonson book for his pasteboard tube? If they were connected, what part did this connection play in the making of Culpeper's optical instruments? These are questions for further research and documentary evidence for a business or working relationship between the two has not been found. Therefore, the possibility cannot be discounted that the book may have come from an exchange with a customer or supplier.

The book was '[p]rinted for Jacob Tonson, at the Sign of the Judge's Head in Chancery Lane near Fleet Street, 1683'. From 1700, Culpeper is known to have had his workshop at the 'Sign of the Cross Daggers in Moorfields', but according to Clifton, he had other workshops before this (the dates are uncertain) in the Moorfields area.[209] Given the proximity of their workshops, they may have been known contemporaries. Perhaps Culpeper acquired old, or unsold copies with the aim to make pasteboard for his instrument tubes. If he bought the six-hundred-page copy of *Plutarch's Lives*, the number of tubes made could have run into dozens. Whilst the monetary value of discarded books, reused as pasteboard, was relatively

[207] Keith Walker, 'Publishing: Jacob Tonson – bookseller', *The American Scholar* 61, no. 3 (1992): 424-430.
[208] See also: Kathleen M. Lynch, *Jacob Tonson – Kit Kat Publisher* (Knoxville: University of Tennessee Press, 1972); G.F. Papali, *Jacob Tonson, publisher* (Auckland: Tonson, 1968); Harry M. Geduld, *Prince of Publishers* (London: University of Indiana Press, 1967)
[209] Clifton, 70.

low, in conjunction with other assembled parts, the full instrument had a greater value and worth, as a microscope. It is impossible to see exactly how many pages were pasted together for pasteboard. However, if one takes account of the measured thickness of 2.5mm, an assumption can be made that approximately thirty to fifty pages must have been used for one tube. They could have been purchased as loose sheets, or as part of a book.

Why was this paper used if it did indeed come directly from Tonson's workshop, as either a purchase or a gift, and what significance should be applied to its use by the maker? It may have been that too many copies were printed. Stretching to six hundred pages, the book would have been slower and costlier to manufacture compared to shorter books and so this does not seem logical, although it is a possibility. If the copy in question came from 1683, and was not a pirated reprint, then this makes it a book printed during the early years of Tonson's career.

Tonson was admitted to the Stationer's Company in 1678 and set up premises near Gray's Inn, after serving his apprenticeship for seven years; in 1679 he secured the right to be John Dryden's publisher.[210] The first work of Dryden's published by Tonson was 1679's *Troilus and Cressida*. Described as one of the most influential early modern publishing relationships, it lasted into the early eighteenth century. The first seven years of this working partnership saw Tonson publish Dryden's translations into English of classical works: *Ovid's Epistles* (1680), *Plutarch's Lives* (1683), *Miscellany Poems* (1684) and *Sylvae, or the Second Part of Poetical Miscellanies* (1687) all established Dryden as an esteemed translator and provided

[210] Lynch, *Jacob Tonson – Kit-Kat Publisher*, 14-16.

Tonson with a reputation as a leading publisher of classical translated materials at a relatively early stage in his career.[211]

The *Plutarch's Lives* that was used for the Culpeper tube was first published in 1683, went through five editions over the next two decades, and after 1703 underwent many reissues.[212] The research into the pasteboard interiors of telescopes and microscopes in the Science Museum for this study has therefore been able to lead to a conclusion about the materials used for one of Culpeper's microscopes, and the book or sheets he used. It may well be that for the first time in three centuries, it is now known which book was used and some of the possible reasons why.

Culpeper's microscope has a metal tripod stand; this was a design his workshop became famous for in the early eighteenth century. Metal components were a constituent part of telescopes and microscopes from the seventeenth century, normally for the stands only, before metal (normally brass) was used for the tubes from the eighteenth century. These metal pillars are unbranded, unmarked and difficult to identify where they came from in most cases. Blacksmithing was a distinct trade from lens grinding, and it is not certain that the parts would have been produced in the optical instrument making workshop. As part of further research into the Culpeper microscope's materials and possible origins, John Davis of the British Society for Sundials was invited to the Science Museum in January 2019 to analyse materials on the microscope with the aid of an x-ray fluorescent analyser.[213] A breakdown of Davis' chemical analysis of the component parts is appended. For the Culpeper

[211] Stuart Gillespie, 'The Early Years of the Dryden-Tonson Partnership: The Background to their Composite Translations and Miscellanies of the 1680s' *Restoration: Studies in English Literary Culture, 1660-1700* 12, No. 1 (1988): 10-19.
[212] James Kinsley & Helen Kinsley, *John Dryden: The Critical Heritage* (London: TJ Press, 1971), 7.
[213] XRF can only measure elements from Sulphur upwards in the Periodic Table. Specimens which are basically organic (carbon based such as wood) cannot be measured.

microscope, the breakdown of elements for metal components led Davis to conclude that: ‘The amount of lead in the alloys, together with significant traces of tin, lead me to suggest that the items are castings finished off in a lathe (lead makes the liquid more fluid)’.[214] If the metal stands were indeed castings, then this means that they were routinely made, and effectively standardised to fit multiple instruments, rather than individualised component parts unique to a single piece.

John Davis was able to further conclude that the flat circular part of the gave different readings when compared to the three pillars: ‘the [zinc] level is higher and there is no [tin] which suggests that it is made from a sheet alloy, possibly contemporary but perhaps a later replacement […] it is not modern’.[215] Assuming that all parts of the metal stand and support were made by Culpeper’s workshop, the findings indicate that a further separation of materials and skills was present for even the same ‘part’, with various materials used. It is too early to say from this analysis of one object whether this meant that Culpeper’s famed tripod stands were produced along what in modern terminology would be called ‘batch’ production, but given the output of his workshop, this is a strong possibility and an intriguing question for further, more specialised, research.

There is no signature on the microscope, but other marks made by the users, or later collectors, are visible. In the case of the ‘*Plutarch’s Lives’* Culpeper microscope (1913-274), there are signs that the outer tube was inscribed after the item had left the workshop.

[214] In an email to the author dated 31 January 2019, John Davis gave a narrative summary of the findings of the observations made with a handheld XRF analyser, which quantifies almost all elements, when used to analyse a material.
[215] Ibid.

Illustration 16: Enhanced image showing inscription: Compound Microscope, 1913-274, Science Museum Group Collection.

The meaning of the phrase is not known, but the words ‘almost quite Home’ are visible near the top of the pasteboard tube when the outer case is removed, as shown above. The act of writing something on the object effectively marked the object as a personal possession, even if this did not record the name of the inscriber, or any clues to the circumstances. Such marks and scribblings are commonplace in early modern books and periodicals, where such ‘graffiti’ can be found in the marginalia and inside covers of many pieces. In the case of books, historians of the form seek to use such marks to put the reader, rather than the writer, at the centre of any study. Jason Scott-Warren writes that the book marks are ‘exasperating’, for whilst they were written by the reader, ‘...he or she is not reading, but doing something else entirely, something that appears to lead nowhere’.[216]

[216] Jason Scott-Warren, ‘Reading Graffiti in the Early Modern Book’, *Huntington Library Quarterly* 73, no. 3 (2010): 363-181.

Here is a comparable example: the microscope user (or consumer) has left their permanent mark on the object. These are evidenced, where their indelible mark has been left with the poetic, if inexplicable, words 'almost quite home'. We do not know who that user of the microscope was, and neither are we likely to find out much from these short, trite, words. Like the 'graffiti' Scott-Warren encounters in early modern books, the mark from the microscope user may be our only direct connection to him or her, but it oddly has been left by them not using the microscope for observation as its design intended. The act of writing on walls, on objects such as books and furniture, has come under the umbrella term of 'graffiti' in early modern historiography, partly because there is no comparable contemporary term to take account for that would today be understood by the phrase.[217]

Scarlett-Culpeper Microscope (1928-792)

A later example of a microscope in the Science Museum (from around 1730) is similar to the previous example (1913-274) with the use of shagreen as the main material used to cover the instrument (illustration below). The microscope was also made to the style fashioned as 'Culpeper type' but is attributed to Edward Scarlett, an optician who was also an instrument maker during this time.[218] Scarlett was an apprentice to the esteemed Christopher Cock during the 1690s and after 1705 operated at his workshop, when he became a member of the Spectacle-makers Company. He made and sold instruments from that point until his death in 1743. Scarlett is credited by some historians as the inventor of 'temple spectacles', but this is now thought to be incorrect and indeed he made no such claim during his own lifetime.

[217] Juliet Fleming, *Graffiti and the Writing Arts of Early Modern England* (London: Reaktion Books, 2001), 33.
[218] Scarlett-Culpeper Compound Microscope, 1928-792, Science Museum Permanent Collection.

Whereas he did market, and was the first person to advertise, such spectacles, which were known for their spiral terminals and rather short temple pieces, he likely did not invent them even though they are nonetheless still known as ‘Scarlett-type’.[219]

Scarlett was optician to George II and is known to have sold optical instruments, as well as barometers, camera obscurae and magic lanterns alongside his spectacles at his shop, the *Archimedes and Globe* near St Ann’s Church, Soho (1705-1743), and at an additional workshop during the 1720s, the *Archimedes and Globe* in Market Street.[220] The microscope provides another example where text from paper on the interior of the pasteboard can be observed once the cap of the microscope is removed.

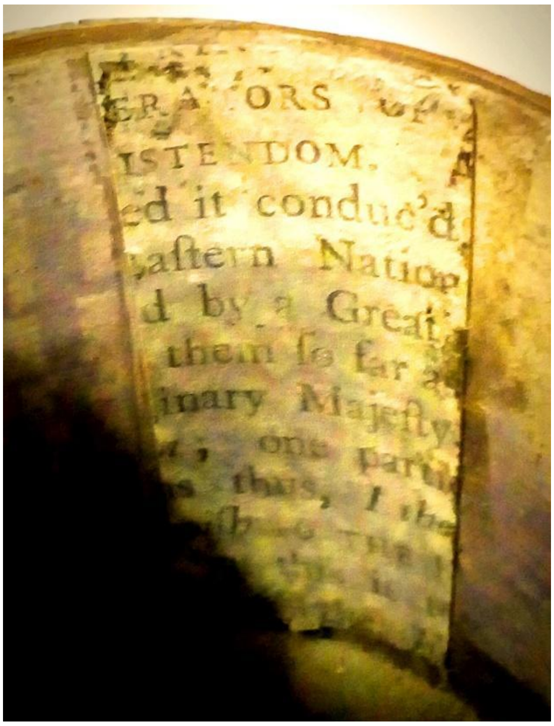

Illustration 17: Enhanced Image: Detail of pasteboard interior with text visible: ‘Scarlett-Culpeper Compound microscope’, 1928-792, Science Museum Group Collection

[219] ‘A Bit on the Side: the development of spectacle sides’, *College of Optometrists*, 2019, accessed 7 May 2019, https://www.college-optometrists.org/the-college/museum/online-exhibitions/virtual-spectacles-gallery/a-bit-on-the-side.html

[220] Clifton, 244-5.

Unlike with the earlier example, it seems plausible that this pasteboard was made to a different method. Instead of whole pages being used, it seems that in this case, smaller pieces of paper were cut and pasted together. Separate pieces of paper can be seen to the left and right of the text although on the left side the text is not visible, it seems that the obscured page underneath has been rotated forty-five degrees clockwise. Together this is indicative that smaller, partial pages were used for the creation of the Scarlett pasteboard tube. A potential match for a possible book that the above paper came from was not achieved, perhaps as only three full words are clear to the naked eye: ‘conduc’d’, ‘majesty’ and ‘Great’. Assistance with digital enhancement programmes, used for the earlier Culpeper piece, led to the following transcript:

-ERATORS of

-ISTENDOM. A

-ed it conduc’d.

[x]astern Nation

-d by a Great

Them so far as

-inary Majesty

[x] ; one partic-

The method set out to search for complete words as with the aforementioned Culpeper microscope was again followed, and when these failed to yield a suitable selection of possible matches, combinations of possible words from the above partial transcript were attempted.

For example, '-istendom' is likely to be 'Christendom' and '-astern' most likely is 'eastern' or a variant spelling of 'western'; but as the paper for that part of the pasteboard appears to have been cut or perforated entirely, this would probably not be uncovered by even invasive investigations. There is also no additional text for comparison on the opposite panel of the pasteboard or the adjoining sides, as was possible with research into the earlier Culpeper piece and the linking of its pasteboard to *Plutarch's Lives.* The work may now be lost. Uncovering further text on the other panels may be possible with advanced imaging technology.

What these glimpses into texts show is that pasteboard tubes were made from recycled materials, this was not due to any concern for the importance of the precision of the instrument from either the maker, or the consumer. If it had been, then Bolantio's advice that wood was the preferred material would surely have been used. Instead, the cheaper, quicker to mould, and more readily available material of paper was repurposed from its original intended, in the manner of the 'make do' mentality cited by Werrett. Investigations into the origins of these papers can uncover, as with the Culpeper piece, the intriguing fact that books, indeed very well received books such as Dryden's translation of *Plutarch's Lives* printed by Tonson, had a greater financial value to instrument makers when they were refashioned into component parts of optical instruments.

Illustration 18: ‘Scarlett-Culpeper Compound microscope’, 1928-792 Science Museum Group Collection.

The tubes of microscopes and telescopes were normally decorated. This microscope’s outer decoration is similar to the first example by Culpeper, in outward appearance. The colours, patterns, designs, and even outer materials pasted on to the tubes are further evidence that the purpose of the instrument sometimes was linked to its aesthetic appeal, with the look, feel and design of the instruments, important to consumers. In the case of the Culpeper piece that was made from *Plutarch’s Lives*, the tube was covered in ‘fish skin’ as previously alluded to, but other pieces were typically covered with vellum and leather which was dyed or patterned. Gold embellishments on these coloured pieces were common. Whilst the term ‘fish skin’ appears in this object's documentation record, and those of other instruments, the correct term for this seventeenth-century material is in fact 'shagreen'.[221] Shagreen was an unusual, and exotic material at this time. Normally made from shark (for a smooth surface) or rays (for a scaled surface) shagreen skins were often dyed.[222] The phrase 'fish skin' likely appeared from a later collector, as the term began to emerge in usage in England in the mid-eighteenth century. The 'trade card' of case-maker John Folgham provides an early example of the term's use.[223]

The material came to be closely associated with furniture, especially larger cases and cabinets, made in France, from the 1730s and 1740s; the nineteenth century witnessed the major growth in shagreen use for French cabinets, particularly by the famed cabinetmaker Ruhlman, who fashioned their use.[224] The material's use in Europe reached its peak in the latter two decades of the eighteenth century, as trade routes became easier, and it was used on many luxury decorative items.[225] However, the use of shagreen in more portable items in Holland and England began in the mid-seventeenth century, in order to cover '…small objects and cases rather than furniture [as later]' and Silverman further notes that its uses on microscopes and optical devices was because its texture could '…presumably [...] aid precise adjustment'.[226] It was in fact probably not to do with any benefits to the user in terms of

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[221] The details from the Documentation Record are replicated in their entirety online: 'Culpeper Compound Microscope by Scarlett, with accessories', 1928-792, *Science Museum,* accessed 10 Dec, 2020, https://collection.sciencemuseumgroup.org.uk/objects/co430474/culpeper-compound-microscope-with-accessories-by-scarlett-microscopes-compound-microscopes

[222] Cathy Silverman, 'Shagreen. The history and conservation of decorative ray skin in furniture' *Thirteenth International Symposium on Wood and Furniture Conservation* (2016): 63-73.

[223] Print, Trade Card, object number: Heal 28.66, British Museum Collection, Accessed 10 Dec, 2020, https://www.britishmuseum.org/collection/object/P_Heal-28-66

[224] Rudi Graemor and Marion Kite, 'The tanning, dressing and conservation of exotic, aquatic and feathered skins' in *Conservation of Leather and Related Materials*, ed. Marion Kite and Roy Thomson (London: Routledge, 2006), 170-183.

[225] Mathieu Willemsen, 'Shagreen in Western Europe: its use and manufacture in the seventeenth and eighteenth centuries', *Apollo* 145, no. 463 (1997): 35-38.

[226] Silverman, 67.

precision, but actually used as the decoration of favour by the consumer, or the maker. Used on other smaller objects from the 1600s such as watch cases, weapons, chests and luggage, there were practical advantages to shagreen such as the fact it was waterproof and made handling easier.[227]

Seventeenth-century shagreen, used in its commonest form from rays, was imported from the Far East, namely Japan, where the item was itself imported from India in vast amounts, having been fashioned as a desirable, luxury material by sellers and traders.[228] In the early seventeenth century, the Dutch East India Company imported shagreen to Europe, and by the 1680s, the British East India Company was also importing the material from India and China; it first appeared in the company's records between 1682 and 1694, then from 1724 in vaster numbers.[229] Recent work by Sachiko Kusukawa shows that shagreen was recorded in the list of 'things bought' by the late seventeenth century London collector William Courten, whose papers are held at the British Library, and this indicates it was possible to buy the 'raw' material in 1690s London, and that it was at this time still an unusual enough commodity that a collector of exotica such as Courten found its purchase attractive.[230] Despite this, shagreen was not imported in vast numbers into any European country until well into the eighteenth century. Guth believes that the use of shagreen for domestic cutlery (used from the 1720s) is evidence of the 'instrumentation' of the home.[231]

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[227] Christine Guth, 'Towards a Global History of Shagreen' in *The Global Lives of Things, The Material Culture of Connections in the Early Modern World*, ed. Anne Gerritsen and Giorgio Riello (London: Routledge, 2015), 62-80.
[228] Ibid.
[229] Silverman, 67-8.
[230] Sachiko Kusukawa, 'William Courten's lists of 'Things Bought' from the late seventeenth century', *Journal of the History of Collections* 29, no. 1 (2017): 1-17.
[231] Guth, 71.

A term with Persian origins, shagreen was prepared by skinning the ray (or shark) and then by resting the skin in tepid water for at least a week, removing any remaining flesh, and then leaving the skin to dry out.[232] The resultant shagreen was hard-wearing, but could be moulded with ease, especially if dampened with water again.[233] Culpeper, as well as fellow instrument makers John Marshall, John Cuff, and later Dollond, used shagreen to cover their optical instruments. The aesthetic appeal of the hundreds may explain its popularity for small, and then larger, decorative objects within a domestic setting, rather than any appreciable practical application when using the instruments themselves. From its early use, shagreen was dyed, often with a shade of green common to optical instruments.[234] This gave a 'two-tone effect at the surface': this resulted from the cartilaginous makeup of the skin itself.

In *Vermeer's Hat*, Timothy Brook uses the work of Johannes Vermeer and other painters from the Dutch Golden Age to examine global connections and how objects were produced.[235] The work argues that in the seventeenth century, the global economy's new trade networks meant that the cross-continental exchange of goods had a profound effect on patterns of consumption, fashion and taste. The work traces the journeys of many materials as they were traded internationally and reflects on the varied cultural and symbolic meanings different societies placed on them.[236] With the use of shagreen, seventeenth and early eighteenth-century optical instruments interacted with this new, globalised world of trade that Brook's work focuses on. The use of ray skin from the Far East, made with a skill and

[232] W. H. van Seters, 'Shagreen on old microscopes', *Journal of the Royal Microscopical Society* 71 (1951): 433-439.
[233] Recent accounts sometimes use the term 'aquatic leather', but this was not a contemporary phrase.
[234] Graemer & Kite, 174.
[235] Timothy Brook, *Vermeer's Hat: The Seventeenth Century and the Dawn of the Global World* (London: Profile, 2007)
[236] One example by Brook concerns the documented transaction between Dutch settlers and Native Americans, with the Dutch trading their abundant firearms, for the Americans' abundant rodent furs, with both believing they had acquired objects of greater value than the other.

knowledge that was abundant in China, utilised in Japan, but not known in Europe, means that the major aesthetic element of some microscopes was the result of transcontinental trade networks that grew across the seventeenth century. The shagreen travelled thousands of miles, for use as a material on early modern instruments, in ways the material's makers (and fishers) could not have known about or had in mind.

While shagreen was just one of innumerable new and exotic objects to enter European markets as a result of new trans-continental trade, something made possible by maritime travel, '…it is important to recognise that the acquisitive power of Asian societies gave them a key role in the emergence of a new global system of trade'.[237] In other words, whilst the use of the material in Europe was a result of the 'striking' phenomenon in the centuries after 1500 of a new, 'global economy' making more materials and objects accessible, the purchase of shagreen for use in England was part of a parallel economic pattern of increasing the purchasing power of peoples outside Europe and consolidating global networks of trade that had not previously existed.[238]

[237] Anne Gerritsen and Anthony McFarlane, 'Expanding Horizons' in *The European World 1500-1800 – an introduction to early modern history*, ed. Beat Kumin (Oxford: Routledge, 2014), 182-192.
[238] Humfrey Butters, 'Europe in 1800', in *The European World 1500-1800 – an introduction to early modern history*, ed. Beat Kumin (Oxford: Routledge, 2014), 403-412.

Illustration 19: Detail of shagreen outer with join visible: ‘Scarlett-Culpeper Compound microscope’, 1928-792, Science Museum Group Collection

Shagreen covers the tube of this microscope: the irregular size and shape of the scaled pattern is visible, as is the join where the sheet of shagreen has met once fixed around the tube. This would likely have been easier to cover with paper, but the delicate pattern of the shagreen was the reason for its demand and so the join remains visible. The surface is smooth and there is evidence that an earlier user or owner ‘polished’ the outer tube. The fact that the inner tube is green, and shagreen was normally also dyed green, means that the original colour effect of the outer tube has likely been lost over time. The smooth nature of the surface is at odds with accounts, such as Guth’s, that suggest the material was used on instruments to improve grip. It seems more probable the material was used for aesthetic reasons.

Compound Microscope by Culpeper (1928-782)

Aside from shagreen, the main materials used to cover the exterior surfaces of optical instruments were leather and vellum. There is often observable evidence of scarring, or hair, when these microscopes are themselves observed under a microscope, indicating that they were indeed made from animal-based product, and this was done with comparable objects in the Science Museum for confirmation. In one example, the use of leather and vellum was observed during the observation of a 1720s compound microscope, of Culpeper type, from the Thomas Court Collection but described as 'leather' in the object's description. It is described by the Science Museum as a 'very early' example of Culpeper's work with optical instruments in its record. Observation in the stores of the Science Museum with the employment of modern microscopes found that the red, dotted structure on the outside of the tube was inconsistent with the scarring and hair patterns that can be found with vellum or leather. This led to the conclusion that the tube materials were actually paper that was sculpted to give a leather style effect, but the material was clearly not leather.[239] It is not shagreen.

[239] Culpeper Microscope, (1928-782 pt 1), Science Museum Permanent Collection.

Illustration 20: ‘Compound microscope by Culpeper’, 1928-782, pt1/1, Science Museum Group Collection.

The tube in question was ‘tooled’ to give the appearance of leather or possibly of shagreen, which the small ‘scales’ can in some ways be equated with. The demands on time to make these individually would have been extraordinary and given that the material was likely used as a cheaper substitute for leather or vellum, the enormous cost in time that makes this seem illogical. A form of press or tool was most possibly used to give this effect to the paper. The microscope is unusual in that the wooden parts that surround both ends of the pasteboard tube show obvious defects. The ‘gap’ in the wooden support at the base of the tube indicates that the tube was marginally too big, but perhaps this was fitted anyway to save cost and time; the gap shows that two individual wooden parts were made but they could not be closed on either side, resulting in two small gaps of less than a centimetre in the circumference.

The opening may have occurred after the purchase of the object and the failing or fatiguing of an adhesive cannot be discounted. The damage could be evidence of a workshop defect, and perhaps too an indication that the finishing of this object was imprecise, rushed or part of an experimental new design. This may have been due to the fact that this is a 'very early' example of a Culpeper microscope, or again down to a desire to keep the cost for this particular instrument low, a demand that could have come at the request or commission of the buyer. It may also be that of multiple component parts ready to be fitted in the workshop, this was the best, if not a perfect, fit and so was applied; a further example of the 'make do' culture. Further examination of the microscope and its tooled leather effect outer board also showed that the material 'peels' away from the wooden parts of the instrument, again showing that this was a paper-based product, not made from the skin or hide of an animal, where such a thin 'peeling' would not occur.

Illustration 21: Detail of pasteboard tube showing a peeling of the outer material: 'Compound microscope by Culpeper', 1928-782, pt1/1, Science Museum Group Collection.

The thin material and the damage that can be seen is further evidence that the material was paper based, not leather, as erroneously described in its record. The microscope is accompanied by accessories. Within the drawer of the wooden stand at the base of the tripod there is a glass lens holder for the biological specimen to be placed on and observed through the lenses and tube by the user. The user of the instrument may have been unaware of the purpose of this glass plate, and by implication how to use the object. The glass is inscribed with guidelines on where to place it on the microscope and how to position the specimen. The guidelines have been measured and the glass is also inscribed on the left of the viewing side, with the phrase: ‘This glasse is to lay [th]e thyng on’.

Illustration 22: Glass plate: ‘Compound microscope by Culpeper’, 1928-782, pt1/2, Science Museum Group Collection.

Illustration 23: Detail of glass plate accessory with inscription visible: ‘Compound microscope by Culpeper’, 1928-782, pt1/2, Science Museum Group Collection.

The microscope is also accompanied by three further smaller glass lenses for the user to place at the top of the microscope. They also vary in thickness and magnification. These glass pieces appear to be original and unlike other optical instruments from the time, they remain in good condition, possibly as a result of the storage of the object in a case over a long period, although some scratches and marks (as above with the plate) are visible. It may also be further evidence that the microscope was not intended for practical, experimental use, but as a collectable accessory, and for the purpose of entertainment, rather than philosophical endeavour. It could be that the microscope was initially bought to be stored in a collection, or a private cabinet of curiosity, rather than regularly used by an experimenter or philosopher in an institutional setting. The inscription reads as an instruction, or commentary, and one that a user familiar with works on microscopy such as Hooke's, or familiar with lectures and demonstrations of the instrument, would probably not have required. Nonetheless, it is the use of a tooled paper in lieu of the more expensive leather or vellum that is the most striking aspect of this object's physical characteristics. The conclusion made by this author that the material is not leather poses further questions about the value of paper as a material; it may have been used as such to keep costs down for the maker, or the customer.

It is intriguing that the paper was manipulated to look like leather, and yet the creation of a patchwork of dots with or without tools or stamps, was a process that had purely aesthetic, results. The application of a tooled design like this would have been a longer process than dyeing a sheet of smooth paper in either one colour or to a pre-design. The possibility of a scarcity of leather seems unlikely as a reason for why this happened. Alternatively, the material attribution in the files for the object may have arisen from the original collector's own thoughts, or from a curator on its donation to the Science Museum in the early twentieth century. Additional examples of instrument tubes from this time 'tooled' to look like leather have not yet been identified. This may be because they were less desirable as cheaper objects, or they have fewer obvious signs than the above example that the material is not the same as the one it has been manipulated to aesthetically resemble.

However, it was the materiality of the instruments that helped establish optical instruments as desirable consumer items. Eighteenth century Britain became ‘transfixed’ on the technological improvements that ‘science’ afforded industry, and according to Larry Stewart this centralisation of science was integral to the Industrial Revolution.[240] In the early 1700s, public lectures popularised the new science to those outside the institutions and this, along with the new public sphere in coffee-houses, meant that there was a divergence of the public with private spaces.[241] Of course, these public demonstrations created a spectacle that aroused interest and in conjunction with other factors such as popularised works like *Micrographia*, the optical instrument production grew. The resultant ‘enthusiasm for useful knowledge’ was the direct result of the public and material nature of lectures, demonstrations and lectures in London that attracted hundreds and that promoted the use of new items including optical instruments.[242] But how had this situation arisen?

The answer comes back often to the Royal Society and whilst Stewart is right to argue that by the 1700s, doubt over the utilitarian ideals of the Society and its perceived lack of achievement and instead an emphasis on social convention, meant its influence waned, the place of the Society in the decades preceding this was crucial for the growth of the optical instrument trade.[243] Linda Levy Peck argues that the consumerist growth in luxury trades

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[240] Larry Stewart, ‘A Meaning for Machines: Modernity, Utility and the Eighteenth-Century British Public’, *The Journal of Modern History* 70 (1998): 259-294.
[241] Larry Stewart, ‘Other centres of calculation, or where the Royal Society didn’t count: commerce, coffee-houses and natural philosophy in early modern London’, *British Journal for the History of Science* 32 (1999): 133-153.
[242] Larry Stewart, ‘Public Lectures and Private Patronage in Newtonian England,’ *Isis* 77, no. 1 (1986): 47-58.
[243] Ibid.

began earlier in the seventeenth century, earlier than some economic and social historians believe. She highlights the dual relationship between the institution of the Royal Society and artisanal makers. Whilst the fellows of the Society 'transmitted knowledge' regarding new mechanical technologies that they had helped create, these endeavours also led to the 'nourish[ing]' of the market they had set in motion.[244] The formation of the Society, the growth in their activities and the publication and circulation of Hooke's *Micrographia* were combining factors that lead to a correlation between the growth in instruments, and the growth in interest of them. It also meant that the types of knowledge set out in the previous chapter and the agencies of the maker and consumer had begun to crossover.

Microscope by Marshall (1919-311)

The life of the objects did not end at the point of transaction. Moderations, repairs and additions to the objects continued for years, decades and possibly longer after their initial sale. The microscope below is very similar to the Culpeper piece made from *Plutarch's Lives*, with the same colour green used to dye the paper on the outside of the pasteboard tube, with the lower part covered in decorative fish skin. Thought to date from 1695 at the earliest, the microscope is attributed to John Marshall. Unlike the Culpeper piece, there is no gold stamp or set of markings to the green part of the tube.

[244] Linda Levy Peck, *Consuming Splendor: Society and Culture in Seventeenth-Century England* (Cambridge: Cambridge University Press, 2005), 340.

Illustration 24: 'Microscope by Marshall', 1919-311, Science Museum Group Collection. Image reproduced by permission of the Science Museum.

Illustration 25: 'Microscope by Marshall', 1919-311, Science Museum Group Collection.

The absence of gold stamps, with fleur-de-lys and royal arms, is intriguing, especially given John Marshall supplied the royal court. These were often included on items made by royal supplying workshops. Discernible ‘patterns’ between when, where and why gold stamps were attached to pasteboard tubes, has not been found and this may be an area for future research. The gold markings are often similar, but the variety of differing signatures often amongst individual makers means that patterns are much less obvious than monograms of makers like Hayes and Sutton discussed in the previous chapter. The accessories accompanying this object are the ‘rosewood stand box with a drawer’, and additional magnifying lenses attached to the brass pillar. Compared to the Culpeper piece, the stand’s appearance is more austere, less decorative and the different style, along with the inclusion of additional lenses mean this may be a later supplement. The use of brass for stands was an eighteenth-century addition.[245] The possibility the accessories that accompany the metal stand were later additions cannot be fully discounted.

Accessories are a complex part of the creation and consumption of many instruments. The inclusion of additional accessories for a range of optical instruments had been a part of their production and consumption since the growth in the London trade since the 1660s and may have been part of the appeal to collectors of curiosities. One ‘obscure’ 1660s reference to an accessory was referred to by Pepys, and others, as a ‘scotoscope’, and Pepys recorded purchasing one from Reeves in the summer of 1664 at the same time as he bought a microscope.[246] Nuttall discounts earlier views that the ‘scotoscope’ was likely a camera obscura and instead argues that the device must have been used to enhance the lighting in darkened rooms; something that he notes both Hooke and Pepys expressed difficulties with

[245] L’E Turner, *Scientific Instruments 1500-1900*, 93-4.

[246] R.H. Nuttall, ‘That Curious Curiosity: The Scotoscope’, *Notes and Records of the Royal Society of London* 42, no. 2 (1988): 133-138.

achieving.[247] Nuttall concludes that the scotoscope may have been the same device drawn and published in *Micrographia*, of a candle light. This was accompanied by a globe of water and attached to the tube near the field lens. Quite what the additional magnifying glass on the above microscope by Marshall, contained within the wooden draw, should be called is not clear. With the addition of a candle nearby to enhance the lighting for the user, it may be that this accessory was an evolution or continuation of the mysterious scotoscope.

Terrestrial Telescope (1927-2055/1) and Compound Microscope (E.2005.9.2)

Compared to the wood Bolantio recommended, or the brass tubes that would emerge in the following century, the use of pasteboard covered in vellum gave many of these instruments a structural disadvantage with light entering the tube and distorting the field of vision. Examination of a telescope by Christopher Cock shows that the pasteboard in this example came from blank paper and the tube's thin paper covering (in this case not vellum or leather) was pasted on the pasteboard. It is clear that the object has suffered damage to its exterior, which must have been a common problem for similar implements made from pasteboard, covered in paper (thinner and less durable than vellum) when used and transported. A pasteboard tube also made up the below compound microscope. Similar in pasteboard design is the below compound microscope. There is no name on the microscope.

[247] Ibid.

Illustration 26: Compound microscope A56281, Science Museum Group Collection.

One of the significant challenges in identifying the makers of early modern optical devices comes from the array of markings that can be found on a single set of instruments made by a single workshop. Unlike watchmakers from the time who followed Tompion’s 1680s practice of including serial numbers on their objects, optical instrument makers did not follow such a method. Whereas some telescopes and microscopes have gold stamped embellishments, others do not; whereas some items obtained by monarchs such as George III bear the royal coat of arms, not all do. This variety, multitude and inconsistency may have been a sign of the lack of business boundaries that a new trade like this had for its makers, or a further reflection of their status as objects of fun and pastime, rather than experimental application and observation. It could also be the result of a greater level of personalisation, as was the case in bookbinding, than is currently known.

On domestic items, particularly those made from metal such as tableware, hallmarks were a constant presence. In the seventeenth century, such ‘collective marks’ not only reassured the consumer about the quality, geographical origins and authenticity of a product, but also allowed powerful guilds to govern approved working practices and the workers, whilst also allowing the makers of smaller workshops to adopt their own best practices.[248] Optical instrument makers were not governed by such corporate and institutional hallmarking, and the inscribed name of the maker is often the best clue as to attribution. The numerous ways that individual makers have been recorded as engraving their names on telescopes and microscopes means that ‘authenticity’ of signature is highly complex to ascertain. The possibility that the names of makers were added in some cases later by the consumer, akin to the graffiti mentioned previously, provides one explanation for some of the more obscure signature examples. The point here is that the life of the object after it left the workshop contributed to its appearance today, and this should not be discounted. The histories of objects after they were purchased are more complex to research.

[248] Bert De Munck, ‘The agency of branding and the location of value. Hallmarks and monograms in early modern tableware industries’, *Business History* 54, no. 7 (2012): 1055-1076.

Microscope by John Mann (1928-772)

This early example of a compound microscope (1928-772) follows a typical green and gold design and is signed on the outer pasteboard tube cover, which separates fully from the piece, by London maker James Mann. A precise date is not possible, but the pillar side design of stand for which eminent suppliers (notably Yarwell) were known best for gives some estimation that it was later seventeenth century.[249] Little care appears to have been taken with the stamping of Mann's name, which in comparison to the stamping of the other gold design, is off-centre and is positioned at an angle of approximately thirty degrees, indicating that the name was stamped separately, possibly later, and may have been rushed. It further highlights the difficulty in analysing the positioning, significance and relevance of prominent signatures on instruments of this nature. James Mann was an optician by trade, a member of the Spectaclemakers Company from 1682 and known to have operated as an instrument maker between 1687 and 1718.[250] The styling of the instrument's pillar, its materials, and its aesthetic outward appearance mean that it likely originated in the late 1680s or early 1690s. It should not be confused with the work of either of his sons James Mann or John Mann, both of whom followed their father, and operated in London in the early decades of the eighteenth century.[251]

[249] Gerard L'E Turner, *Scientific Instruments 1500-1900,* 93-94
[250] Clifton, 176.
[251] Ibid.

Illustration 27: Detail of stamped signature: 'Microscope by J. Mann', 1928-772, Science Museum Group Collection.

The lenses in the Mann example remain in good condition. Lens grinding, as alluded to, remained an imprecise process until the 1800s and as a manual process was achieved through the care and experience of the maker. The engraving of the wood, moulding of the metal stands, grinding of the lenses, dyeing of the pasteboard and assembling of all of these parts required different skills and knowledge. With the production of microscopes and telescopes, the number of craft skills required to assemble a single object increased. It seems unlikely that all optical instrument makers therefore became the 'jacks-of-all-trades' that Evelyn recorded in his trades list; they took on apprentices and divided responsibility for component parts. Rob Iliffe says that historians ignore the role of what he terms 'technicians' during the 'scientific process' which might have included the assembling of mechanical instruments and objects.[252] One way this can be understood, is to study moderately later accounts, well after

[252] Rob Iliffe, 'Guest Editorial: Technicians', *Notes and Records of the Royal Society of London* 62, no. 1 (2008): 3-16.

the embedding of the optical instrument trades in early modern London, such as that of Richard Campbell from the 1740s, who wrote in *The London Tradesman*, his guide to the city's craft production industry:

> 'The Optical Instrument Maker is employed in making the various sorts of Telescopes, Microscopes of different Structures, Spectacles, and all other Instruments invented for the Help or Preservation of the Sight, and in which Glasses are used. He himself executes very little of the Work, except the grinding the Glasses. He grinds his Convex-Glasses in a Brass Concave Sphere [...] and his Concave-Glasses upon a Convex Sphere of the same Metal: His Plane-Glasses he grinds upon a just Plane, in the same Manner as the Common Glass-Grinder [...] He grinds them all with sand and polishes them with Emery and Putty'.[253]

This explains why many optical instrument makers were members of the Spectacle Makers Company: it was the grinding of the lenses that was thought the most important skill for the 'maker' to possess. Campbell's account suggests that by the 1730s and 1740s when he compiled his trade guide, a form of labour division existed in the workshops of optical instrument makers, with skills separated between workers, materials and the resultant component parts. All of those that contributed may not be known: 'The Cases and Machinery of his Instruments are made by different Workmen, according to their Nature, and he adjusts the Glasses to them'.[254] It seems most likely that this practice had begun with the emergence of the trade some decades earlier. The lenses of these objects may warrant a future research project through a minute quantitative analysis of their shape, condition and constitution.

[253] Richard Campbell, *The London Tradesman* (London: printed by T. Gardner, 1747), 254.
[254] Ibid.

Campbell may have exaggerated that it was only the lenses that occupied the 'makers' and indeed the situation could have been different in the late seventeenth century. It shows that optical instrument production required multiple hands, and multiple skills, to complete the necessary tasks. How these tasks were divided in workshops would have been specific to each maker. Campbell described the typical instrument maker as:

> '...a very ingenious and profitable Business, and employs but a few Hands as Masters [...] Such a Tradesman designed for a Master ought to have a pretty good Education, and a penetrating Judgment, to apprehend the Theory of the several Instruments he is obliged to make, and must be a thorough Judge of such Work as he employs others to execute'.[255]

When did this begin? Robert Hooke may be a good starting point. Although Hooke designed and used the microscope that he drew and described in *Micrographia*, he almost certainly did not 'make' it with his own hands alone, nor the other instruments he used. One of the makers this task has long been attributed to is Christopher Cock, who in the 1670s would become one of London's foremost optical instrument makers. Cock was one of a number of instrument makers who in the latter part of the seventeenth century operated in the St Paul's area of central London where his workshop was situated. Hooke's role in the technical side of microscopic instruments and their development has been the source of attention from some historians of science, who note his contribution to the public interest in the objects from his book but question his expertise in the lenses and their application.

[255] Ibid.

Gerard L'E Turner says that Hooke was not a 'serious microscopist' in the same manner as Malpighi and Leeuwenhoek, and that Hooke's place as the 'father of microscopy' is misplaced.[256] Perhaps the importance of Cock, and Reeves, has been missing in the historiography on Hooke's life, career and importance to the development of optical instruments. Clifton lists Cock as a member of the Turners guild from 1669, and a member of the Spectacle-makers Company from 1680/1.[257] Turning, the craft of creating 'turned' wooden bowls, containers and objects, had been regulated by the Worshipful Company Guild of Turners since 1295 but was granted a royal charter by James I in 1604, in part for its role in regulating the measurements of alcohol .[258] His two workshops (*The Two Twisted Pots* in Long Acre and *The Blue Spectacles* near St Anne's Church) are recorded as active in the 1690s, but details on his earlier career are sparse, and this may be due to the range of spellings his name is known to have used: Cockes, Cox, Coke, Cockes and even the forename Kit are listed by Clifton, but this may not be the sum total of variant spellings that he used during his lifetime.[259] His dates of birth and death are approximate, but Cock certainly had a long career in London. He was apprenticed to John Stonehall in 1657, received his freedom in 1669 and still worked three decades later.[260]

His son John Cock, also operated workshops in the Long Acre area, but his occupation was recorded in tax records from the time as 'prospective glass grinder'.[261] Making telescopes and microscopes was a new trade and in the strictly regulated world of seventeenth-century

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[256] Gerard L'E Turner, 'The Impact of Hooke's Micrographia and its Influence on Microscopy', in *Robert Hooke and the English Renaissance*, ed. Paul Welberg Kent & Allan Chapman (London: Gracewing, 2005), 124.
[257] Gloria Clifton, *Directory of British scientific instrument makers*, 1550-1851 (I.B. Tauris: London, 1998), 59.
[258] 'Company History', *The Turners Company*, accessed Dec 1, 2018, <https://turnersco.com/company/company-history/>
[259] Clifton, 59.
[260] Ibid.
[261] Clifton, 60.

London, where guilds and companies governed the majority of trades, there was no immediate natural group for makers such as Christopher Cock, nor any ready job description, but the grinding of glass lenses was clearly believed to be the most important part of his occupation. The specialisation that his occupation indicated, was a sign that the trade had evolved quickly by the 1690s, and that the complexity of individual component parts meant a change in prescribed roles and resultant working practices.

John Yarwell, famed as one of the leading instrument makers of his day, was also a member of the Spectaclemakers Company. His rival John Marshall was not a member of the Spectaclemakers Company, but was a member instead of the Turners. Edmund Culpeper, who was most active as a mathematical instrument maker in the first decade of the eighteenth century, and who took over the business of Walter Hayes following an apprenticeship, belonged to the Grocers Company. Culpeper's own rivals, George Willdey and Timothy Brandreth, were members of the Spectaclemakers Company. This points to something of a fluid, evolving setup for instrument making by the 1690s, when the trade was still only a few decades old. When optical instrument making became a main line of business, as the evidence from 'trade cards', newspaper articles (as a later chapter argues) and other printed ephemera shows, it seems that there was no 'instrument makers company' on the horizon, or forthcoming, at this time.[262]

Without this body the makers occupied a socio-economic position that meant they were the 'hybrid' makers that the previous chapter argues first emerged amongst the mathematical makers. The multiple parts meant they were knowledgeable about many different materials,

[262] The Worshipful Company of Scientific Instrument Makers, which exists today, was only founded in 1956 and granted its present status by charter from The Queen in 1964.

and processes such as lens grinding. However, the Clockmakers Company was founded during the 1630s, so why did instrument making not coalesce around a new organisation, like the clockmakers in London had?

It is widely agreed that the power of craft guilds in Western Europe declined after their peak in the Late Middle Ages.[263] Certainly, none of the makers mentioned above would have been permitted to make instruments and trade without their membership of a company or without having served an apprenticeship. Ogilvie concludes that after 1600, the power of the guilds was retained only in borough towns where the economy had stagnated and they would continue to decline until their demise during the Industrial Revolution.[264] Research by Patrick Wallis shows that from 1650, the rules and regulations of guilds and companies in London were routinely ignored. In an examination of 1695 tax records, he shows that a significant number of apprentices left their masters over the course of their seven-year term, some as early as within the first year, although the reasons for this were mixed.[265]

There is no consensus amongst economic and social historians on the precise structure of apprenticeship, or how craftsmen came to be a member of a company that was sometimes not directly connected to their eventual occupation. The working patterns of individual instrument making workshops can be theorised from analysis of the objects, and by comparison with the few written accounts. When mathematical instrument makers migrated to London from continental Europe in the mid sixteenth century, they were soon made aware by the city's authorities that legislation mandated that they joined a guild. No specific group

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263 Sheilagh Ogilvie, 'The Economics of Guilds', *Journal of Economic Perspectives* 28, no. 4 (2014): 169-192.
264 Ogilvie, 172.
265 Patrick Wallis, 'Apprenticeship and Training in Premodern England', *The Journal of Economic History* 68, no. 3 (2008), 832-861.

existed for their trade; subsequently they were permitted to join a company of their own choosing or preference under the 'Custom of London'.[266] This was a fundamental part of the economic and political dynamic that allowed the growth in trade for telescopes and microscopes; this also would not been possible a century before the emergence of the mathematical instrument trade.

Part of the complexity by the late seventeenth century was the number of differing component parts, and skills required to make them, that telescope and microscope making necessitated. The process of designing, building and selling telescopes and microscopes was not a linear process. Every component affected the quality and use of the instrument, and all of these components and accessories were the subject at one time of adjustments, refinements and in some cases improvements, by the makers and artisans themselves.

Part of the challenge for historians in the field is the aforementioned absence of detailed, written, textual evidence that sets out how makers began to create and assemble the optical instruments. The trade in these new instruments had no institutional foundation, as with other skilled and regulated trades, that were governed by livery companies and guilds. Telescope and microscope makers belonged to some groups that at first glance may not have seemed their natural home (such as the Clockmakers Company), but this was part of the effect of the trade being novel and new. The dynamics of collaboration were built on this novelty, and it is well-known amongst historians that instrument makers, particularly of optical devices, 'borrowed techniques' from a host of sources including locksmiths, clockmakers and others,

[266] Joyce Brown, 'Guild organisation and the instrument-making trade, 1550-1830: the Grocers' and Clockmakers' Companies', *Annals of Science* 36 (1979), 1-34.

where they '…followed the evolution in applied mechanics' that these trades had come in recent decades to typify.[267]

Terrestrial Telescope by Christopher Cock (1919-312)

Why did makers inscribe their names on the pieces they created? A nine-drawer terrestrial telescope is also held in the Science Museum collections and accredited to John Marshall (below). Again, the exact year of production for this instrument is uncertain; the Science Museum approximates it as 1675-1700c.[268] Made of vellum and pasteboard, it is similar to the unusual 'blotched' style of design. The wood is rosewood, a similar material to mahogany. An intriguing characteristic of the Marshall telescope is that it does not include an engraved signature on the outer case of the tube, as one might have expected. The telescope is stamped in gold (although faded), as other optical instruments routinely were, but the identification of the maker's name, may not necessarily signify a form of early modern 'branding'.

[267] Maurice Daumas, *Scientific Instruments of the 17th and 18th Centuries and their Makers* (London: Batsford, 1972), 2.
[268] Terrestrial 9-draw-tube telescope, 1937-602, Science Museum Group Collection.

Illustration 28: ‘Terrestrial 9-draw-tube telescope’, 1937-602, Science Museum Group Collection.

The stamping or engraving the name of the maker and its prominence may well explain much about the individual maker’s own advertising and sales techniques.[269] It is conceivable that the range of different signatures, often amongst items purportedly by the same maker, demonstrates that they were individual to the created piece, rather than the maker. It seems

[269] The next chapter explores these sales and advertising techniques in detail.

that later on, Marshall's attitude to this was different. A later example, perhaps best considered as a cousin to the telescope above, and also by Marshall, is engraved with his name. The telescope in question is believed to be from the early 1690s. It is very similar in style and size to the terrestrial telescope above, but in a poorer condition. The painted vellum has faded to a greater extent, possibly as it was long positioned near a window or light, and there is damage consistent with the telescope being kept for a long period on top of a surface.

Illustration 29: 'Terrestrial 7-draw-tube telescope', 1919-312, Science Museum Group Collection

Illustration 30: 'Terrestrial 7-draw-tube telescope', 1919-312, Science Museum Group Collection

'Branding' is a concept with a long history. There are accounts of marking humanmade objects to indicate who, or where, they were produced that stretch back to ancient times. Modern 'branding' strategies emerged in the nineteenth century, after the onset of Industrial Revolution.[270] Therefore, the signatures of the maker in earlier periods were not always consistent. It is a result of the individual nature of the objects that makers such as Cock created both to commission and 'off-shelf' items, and the markings and signatures on each were therefore also individual. This was moderately different from other fields in early modern 'science', notably quackery and medicine, where packaging is known to have functioned as active sales technique.[271]

[270] Adrian Room, 'A History of Branding', in *Brands: The New Wealth Creators*, ed. Susannah Hart and John Murphy, (London: Palgrave-Macmillan, 1998), 13-23.
[271] John Styles, 'Product Innovation in Early Modern London', *Past and Present* 168 (2002): 124-169.

Purchase and Consumption - Evidence of Royal Society Purchase

The consumers of these instruments comprised a more diverse range of people than Robert Hooke and the Royal Society. The mixture of buyers of telescopes and microscopes in seventeenth-century London became eclectic, diverse and by 1700 crossed social boundaries. But institutional consumption was a major part of the consumption pattern. These institutions included the Royal Society. The cataloguing the Society's papers began in the 1950s for the institution's tercentenary.[272] The papers that survive from the early years represent an unusual collection of surviving materials.[273] As part of archival research for the thesis, the Classified Papers in the Royal Society's archives, from the years 1660 until 1720 were researched. Two volumes of Classified Papers were judged to be of more importance for understanding the growth in trade of optical instruments in early modern London: account books, and a volume entitled 'mechanical' papers, cover a wide variety of the fellows' early work.

It is well established that the Society's early decades centred on the collection of domestic and international correspondence and much of these contained references to the natural, or biological world.[274] The Classified Papers of the Society's business also prove to be illuminating for the activities of the fellows, although a detailed survey of the years 1660 to 1720 shows that whereas the first fifteen years of documentary accounts are typified by careful and precise note-taking for finances and committee minute purposes, the care and due diligence of recording the business of the Society soon became more haphazard in nature; the

[272] R. K. Bluhm, 'A Guide to the Archives of the Royal Society and to Other Manuscripts in Its Possession', *Notes and Records of the Royal Society* 12, no. 1 (1956): 21-39.

[273] One of the more intriguing entries in the classified papers show that the Royal Society in the 1690s came to purchase animals including alligators and an eagle, and foods for them, although why or for what purpose has not been found. More precise details about the animals, and their foods, were found in these records from this time, than on the nature of instruments the Society purchased.

[274] William Bragg, 'History in the Archives of the Royal Society', *Science*, 89, No. 2316 (1939): 445-453.

Classified Papers of the 1680s and 1690s are mixed. Written in haste with noticeable gaps in chronology, they provide a snapshot of the Society's early work. The Society's first treasurer, William Balle, kept the accounts of the Society in the standard method of double entry bookkeeping in the first decade from 1660, but after three years of meticulous entries, the accounts become less detailed and more entries use the umbrella phrase 'bills paid', which was routinely used for entries between 1664 and 1667, with only generic references to items such as 'the operator's bill' becoming the norm. By the 1670s the detail varies, with the pages for the year 1674 left completely blank.

The first reference to any optical instrument in these accounts was made on 4 August 1663, with treasurer Balle recording that the Society paid the sum of ten shillings to '…Mr Hook for a Book for his Microscopical Pictures'.[275] This was two years prior to the publication of *Micrographia* and it is likely that this was a financial contribution towards the completion of the work to satisfy Charles II's aforementioned desire that Hooke's collaborator Wren produce an encompassing work on all of nature. It shows the Society's early interest in the use of optical instruments and their willingness to commit their finances, known to be scarce for much of its early life, to this cause. However, the accounts in the Classified Papers of the Society do not contain any further entries for optical devices for the next six years after this, well after the publication date of *Micrographia*.

There is no further mention in the accounts after the ten shillings for Hooke's 'book' until the autumn of 1669, by which time the recording of exact dates for the paying of accounts had been dropped. This may be because less money was being spent by the cash-strapped Society: Hooke complained in his Diary that his stipend payments as Curator of Experiments

[275] 4 August 1663, Classified Papers: AB/1/1/1, Royal Society, London.

were late, although sometimes he agreed only to dispute them later, as in the case of the Cutler Lectures fees of 1666/7.[276] In an entry for the 'year ending November 1669', where all of that year's payments are listed, it is documented that the large sum of ten pounds was: 'Paid to Chr: cox for the Large Microscopes'.[277] Christopher Cock is one of the few named suppliers in the Royal Society's accounts from the period, but he was not a fellow of the Royal Society. From the mid-1660s, common entries that named people include those for Hooke's and Henry Oldenburg's salaries: for example, thirty-seven pounds and ten shillings was '…Paid Mr Hook his Sallary for one year & 1/4 end: Lady Day 1670'.[278] Cock's name was recorded more than once, but his inclusion as slightly unusual and likely indicative of the importance of this purchase or line of work. It implies, on the other hand, that Cock was a supplier to the institution, rather than to Robert Hooke as an individual. This is because the Royal Society paid the invoice, not Hooke.

The years 1671 and 1672, after Balle's term as treasurer ended, are not dated in the accounts, other than by year. Cock appears twice in these years. In 1671, the accounts show that the Royal Society '…Paid Christo Cox in full for Specular Metall' the sum of five pounds, whilst the following year, the sum of one pound is paid to '… Christopher Cox for work about Opticks'.[279] The 'specular metall' was likely a form of mirror, possibly for optical observation works. It is known that Hooke and Cock were collaborators, and it is possible (given Hooke's role as curator of experiments) that Cock was employed for goods and services by Hooke, on behalf of the Society. The accounts hint that they worked together for experiments; Balle's successor as treasurer Daniel Colwall recorded in the winter of 1672

[276] Robert Purrington, *The First Professional Scientist: Robert Hooke and the Royal Society of London* (Boston: Birkhauser, 2009), 53.
[277] November 1669, Classified Papers: AB/1/1/1, Royal Society, London.
[278] 1 May 1670, Classified Papers: AB/1/1/1, Royal Society, London.
[279] 1671-1672, Classified Papers: AB/1/1/1, Royal Society, London.

that the Society: 'Paid Mr. Hook what he paid for brass-grinding plate for Glasses' the sum of two pounds and nineteen shillings.[280] A month later, Colwall recorded that a payment of one pound was made to '…Cox in further part of a Grinding plate'.[281] It seems logical to suggest that Hooke and Cock were working together on grinding lenses for an optical instrument for an experiment he would perform for the Society. Whilst the first payment was made to Hooke as reimbursement for costs that he incurred in paying Cock, the second was paid directly to Cock from the Society. This indicates that a form of contracting out of the physical work had taken place before Cock supplied the Society directly.

Hooke's diary entries only reveal so much about these account payments, but frequent references in the winter of 1672-1673 are made to 'Cox' and on 22 January 1672/3, when Cock was paid by the Society for the grinding plate, Hooke wrote in his diary: '...Cox a warrant signed and payd for 20sh. upon Speculum'.[282] Interestingly, it is not until the summer of 1673 that Hooke's diary touches on the grinding of lenses, which the purchase by the Society of 'grinding plates' indicates happened earlier. On 11 August 1673, Hooke wrote that 'Cox sent home new concave [lens]', the next day he recorded that he 'Calld at Coxes about new concave, told him my way of polishing', whilst on 14 August he wrote that he had '...sent Harry for Cock. Found out yesterday the new way of polishing glasses by a small gage or tooth'.[283] This new polishing method could have come from Cock, but the entry is vague. If it did, it is an example of the knowledge that makers at this time exchanged.

[280] 4 December 1672, Classified Papers: AB/1/1/2, Royal Society, London.
[281] 22 January 1673, Classified Papers, AB/1/1/2, Royal Society, London.
[282] 22 January 1673, *The Diary of Robert Hooke* (London: Wykeham Publications, 1968), 23.
[283] 11 August 1673, 12 August 1673, 14 August 1673, *The Diary of Robert Hooke*, 54-55.

The 1669 references to Christopher Cock and ‘large microscopes’ may not be as straightforward as they first appear. It is possible that, as microscopes did not vary in size in the same way as telescopes did, that the entry should refer to ‘large telescopes’ and may have been written as ‘microscope’ in error by the treasurer. It could have been a microscope, but it is unusual for the size to have been included. Furthermore, Cock was well-known for producing telescopes, and his work on microscopes was the lesser of the two parts of his instrument making. The sum of ten pounds was one of the largest sums paid out during the period to a contractor in that decade. Indeed, in a survey of the accounts no other payments made for an object were at this high a level. On the assumption that this is a reference to a telescope, what sort of telescope would Cock have supplied to the Society and why?

A Hooke sketch stored in the Royal Society, details his method for positioning an enormous astronomical telescope in the quadrangle of the old Gresham College, where the Society was situated, prior to the Great Fire of London.[284] The drawing dates from 1664, almost a decade prior to when the Society’s account books mention Christopher Cock. It is a sign that the use of astronomical instruments was a key part of the Society’s activity from its early years. The refracting telescope in question was thirty-six feet in length and suspended by a pole, with a tri-corner foundation at its base. Since the 1650s, Richard Reeves (named in Hooke’s *Micrographia*) had supplied microscopes and telescopes to Christopher Wren, in order for Wren to carry out his experimental and observational work.

In the early 1660s, one of these large telescopes, built first for astronomical purposes, was remounted by Hooke, in his capacity as Curator of Experiments at the Society’s Gresham College base, in the forecourt. Reeves was an active instrument maker until his death in 1680,

[284] RS.12572, Classified Papers. Royal Society, London.

although his association with Hooke seems to have dissipated somewhat by the time the latter decided to keep a daily diary, from 1672. Nonetheless, this is the sort of 'large' instrument that the Society had sought to own and use at an earlier point and came mostly through Hooke's own connections. It seems unlikely that the 'large microscopes' the account books mentioned that Hooke and Cock were involved in designing and making were on a comparable scale to the telescope erected in the old Gresham College almost a decade earlier. The description highlights the difficulties in understanding early modern accounts of this sort. But it may have been a 'large' telescope of the sort (and scale) that is pictured below:

Illustration 31: 'Telescope, 5-draw with terrestrial eyepiece', 1926-419, Science Museum Group Collection.

Illustration 32: Detail of signature, ‘Telescope, 5-draw with terrestrial eyepiece’, 1926-419, Science Museum Group Collection.

The acquisition of optical instruments by organisations such as the Royal Society wase not an isolated example of institutional purchase. The royal coat of arms can be visible on surviving examples, such as Cock’s (above). This one is dated 1673, meaning that it was made around the same time that he was known to be in regular contact with Hooke. It may be that this is the length and size of the ‘large’ instrument that the Society sought to acquire. Its dimensions when all the five draw tubes are closed fully is 530mm by 70mm, making it a larger telescope from the period. Six years after Sprat’s account, it may be the similar to the telescope that the Society sought to obtain for the astronomical survey detailed in his *History of the Royal Society* (1667). This may be the reason that the purchase of so-described ‘large’ instruments appears in the Royal Society account books.

As a supplier to Charles II, Cock, as others did later, used the royal crest to indicate his workshop’s prestigious connection. This was stamped on the outer of the main pasteboard tube as above and was normally made in gold. The inclusion of Charles II's coat of arms in this way was a sign to buyers and users that Cock was a supplier to the King, in a similar way that royal crests are used by suppliers to Buckingham Palace in the modern day.[285] The inclusion of the King's coat of arms in this way does not mean it was necessarily made with him, or his household, in mind.[286]

The telescope is accompanied by a microscope which is referred to as the 'Hooke type' microscope. This is thought to have been made by Cock, although the item is unsigned and undated. The microscope is made of boxwood, copper alloy, glass (for the lenses), iron, leather, mahogany, and rosewood. The style, dating and design (from Hooke) make this likely a microscope that the Society purchased for their curator, as with the previous telescope. The reference in the accounts to the items commissioned being 'large' is also indicative of the sort of instruments that the Society sought to acquire. The end tube cap is missing and there are noticeable cracks to the surviving cap's mahogany.

Within the line of tube drawers, the name of Cock is signed, in rather larger letters than later and comparable pieces and around the circumference of the tube. The full inscription reads: 'Christopher Cock Londini: 1673'. Again, with optical instrument makers, it was sometimes engraved, but often was missing from the inscription. In this instance, 'fecit' is absent, but London is included and so, unusually for a telescope or microscope, is the year. It could be that the name of the maker indicated that they had assessed the quality of the instrument that others in their workshop had put together, as Campbell asserted was happening by the 1740s.

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[285] 'Granting of Arms', *College of Arms*, accessed Dec 10, 2018, <https://www.college-of-arms.gov.uk/services/granting-arms>

[286] The George III Collection of instruments includes many examples of objects made for the King and royalty that omit the coat of arms and this was considered common practice.

As there is little consistency in the way that signatures were applied by optical instrument makers from this time, especially when one compares this to the earlier Christopher Cock telescope, where the signature was smaller, and positioned on the outer tube, rather than an inner draw.

Illustration 33: 'Compound Microscope', A56280, Science Museum Group Collection.

These items were styled in ways to appeal to the increased wealthy tastes that consumption patterns fuelled. The above compound microscope dates from the late seventeenth century and is on long-term loan to the Science Museum from the Wellcome Collection.[287] The object is similar to other, similar, compound microscopes from the period. The tube is made from pasteboard, covered in vellum. In the object's documentation record, it is noted that the microscope in question originally belonged to Pope Benedict XIV (1675-1758). Benedict was a famous sponsor of anatomical models and waxwork models in Bologna by famed makers Anna Morandi, Giovanni Manzolini and Ercole Lelli during his pontificate, and the city became part of the Grand Tour as a result of its connections to early modern 'science'.[288] The microscope in question was made in London, but the maker was not recorded. This may seem unusual, that an instrument with such connections to the Holy See contained no name engraved or stamped on it. It may not have been commissioned by the Pope, but instead bought 'off shelf' or from a third party.[289] It would be incorrect to claim that the only buyers, users and consumers of optical instruments were the governing or ruling elites, although the evidence suggests that since Lippershey's day, the objects had attracted the understandable attention of the governing elites in Western Europe especially. In this case, Benedict may have acquired the instrument for what it did, rather than who it was made by. It is further sign that the objects were considered desirable and collectable items.

In the eighteenth century, the trade in instruments in London was the '...largest in Europe', and arguably the world, with many 'driving forces' for London's dominance, especially after the 1750s, some decades after the focus of this thesis.[290] Sorrensen contends that one of the

[287] Compound Microscope, A56280, Science Museum Group Collection

[288] Lucia Dacome, 'Waxworks and the performance of anatomy in mid-18th-century Italy', *Endeavour* 30 (2006): 29-35.

[289] It is still not known why signatures were applied on some objects but not others. Similar items made for monarchs, including those in the George III Collection, often do not contain the name of the maker on the instrument.

[290] Richard Sorrensen, 'The state's demand for accurate astronomical and navigational instruments in eighteenth-century Britain' in *The Consumption of Culture 1600-1800: Image, Object, Text: The Image, Object, Text (Consumption & Culture in 17th & 18th Centuries),* ed. J. Brewer & A. Berningham (London: Routledge, 1997), 263-271.

many complex socio-economic factors for the trade's success during the century was the '...easily availability of popularized natural philosophy, which instrument makers understood and made use of'.[291] This chapter argues that the popularisation of the telescope and microscope was fundamental to the growth in the trade. As expensive and luxury items, it is no real surprise that the evidence of early modern purchase is normally to be found connecting the instruments to institutions such as the Royal Society, or powerful figures such as Pope Benedict.

The New Consumer: Instructions for Use

When telescopes and microscopes were sold, the nature of the new technology meant that users were not experts but handling items that they may have had no prior knowledge or experience of. Similar to the engraved instructions on the glass plate mentioned earlier, instructions for use would have been included with the object at the time of purchase. The 'trade card' by Culpeper contains a set of instructions on how to use the microscopes that were sold from his workshops. Interestingly, the paper that was used as the 'cover' for the mini booklet of microscope instructions is similar to the paper on the pasteboard of the anonymous microscope (see below) where the dotted circumferences can be seen; a composite image for comparison is below.

[291] Ibid.

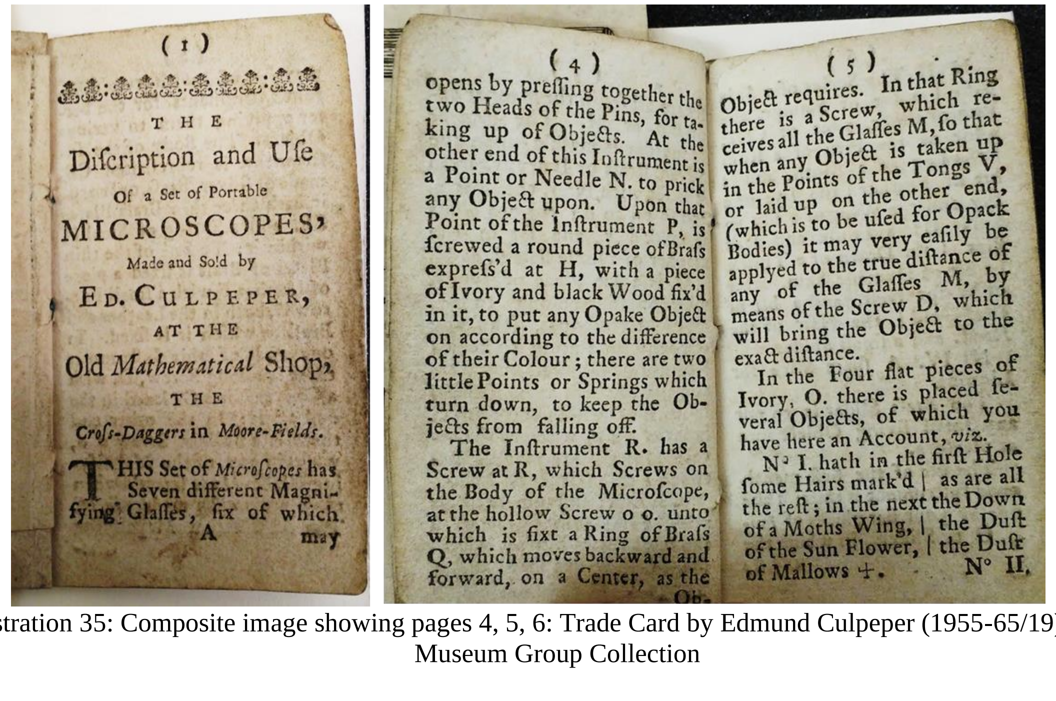
Illustration 34: Composite image showing (left) cover to book of instructions by Culpeper: Trade Card (1955-65/19); (right) detail of compound microscope (E.2005.9.2), Science Museum Group Collection

In the instructions book, Culpeper makes clear how the users of his instruments could get the best of their purchases from him. This is somewhat helpful to material cultural historians as he names some of the materials that were used to make the instruments: 'ivory, silver, brass'.[292] The mini booklet is sixteen pages in length and with links to the visual depiction of the pieces on the larger part of the 'card' to which the booklet is attached, gives an overview of microscope use. On the section about adjustment, Culpeper provided a small, written lesson on how the user should proceed:

> '[…] while you are looking through your Magnifying Glass upon the Object, you are to Screw in or out, the long screw […], in the other end of the Body of your Microscope, till you bring your Object into the true distance, which you will know [when the object appears] clearly and distinctly'[293]

[292] Ivory was sometimes used for sliders, but glass is more prevalent amongst surviving seventeenth and early eighteenth-century examples.
[293] Pages 5-6; Booklet: Trade Card by Edmund Culpeper, 1951-685/19, Science Museum Group Collection.

Culpeper does not mention guiding marks and instead his account suggests that the user would know when the magnification was correct based on their own judgment of sight. Part of the attraction of a new optical instrument such as a microscope was its novelty, its newness and the ‘experience’ for pastime and knowledge, that the instrument would provide its user. In order to match some of the experiences that users may have read about in microscopic accounts like Hooke’s, Culpeper advised that blood was a good biological specimen for use on the microscope, with ‘nutes’, ‘small fish’ and ‘frog’ mentioned as the best types to use. On the topic of lighting, Culpeper said that ‘clear Sky Light or where the Sun shines on any white thing’ are both preferable to candlelight, and that ‘One ought to be careful not to hinder the light’. The effectiveness of the elusive ‘scotoscope’ must have been minimal for the accessory not to catch on, and for Culpeper to explicitly advise against candlelight.


(1)

THE

Diſcription and Uſe

Of a Set of Portable

MICROSCOPES,

Made and Sold by

ED. CULPEPER,

AT THE

Old *Mathematical* Shop,

THE

Croſs-Daggers in *Moore-Fields*.

THIS Set of *Microſcopes* has Seven different Magnifying Glaſſes, ſix of which

A may

(4)

opens by preſſing together the two Heads of the Pins, for taking up of Objects. At the other end of this Inſtrument is a Point or Needle N. to prick any Object upon. Upon that Point of the Inſtrument P, is ſcrewed a round piece of Braſs expreſs'd at H, with a piece of Ivory and black Wood fix'd in it, to put any Opake Object on according to the difference of their Colour; there are two little Points or Springs which turn down, to keep the Objects from falling off.

The Inſtrument R. has a Screw at R, which Screws on the Body of the Microſcope, at the hollow Screw o o. unto which is fixt a Ring of Braſs Q, which moves backward and forward, on a Center, as the Ob-

(5)

Object requires. In that Ring there is a Screw, which receives all the Glaſſes M, ſo that when any Object is taken up in the Points of the Tongs V, or laid up on the other end, (which is to be uſed for Opack Bodies) it may very eaſily be applyed to the true diſtance of any of the Glaſſes M, by means of the Screw D, which will bring the Object to the exact diſtance.

In the Four flat pieces of Ivory, O. there is placed ſeveral Objects, of which you have here an Account, *viz.*

N° I. hath in the firſt Hole ſome Hairs mark'd | as are all the reſt; in the next the Down of a Moths Wing, | the Duſt of the Sun Flower, | the Duſt of Mallows +. N° II.

Illustration 35: Composite image showing pages 4, 5, 6: Trade Card by Edmund Culpeper (1955-65/19), Science Museum Group Collection

The booklet provides an unique insight into the challenges and pitfalls that the new microscope user of the late seventeenth century faced. Much like modern instructions for toys or electronic gadgets, the inclusion of instructions by Culpeper was to make sure that the consumer (not an expert like Hooke or Isaac Newton) could have the best possible experience with the optical device they had purchased, which was, after all, its main purpose: to provide a new, sensory experience.

Conclusions

This chapter argues that the materiality of optical instrument artefacts in the Science Museum collection consists of a long, intriguing and revealing range of characteristics that remain observable today. They reveal much about the trade in telescopes and microscopes from the mid-seventeenth century onward. The technology was a new one. From a short history, the telescope and microscope were used for successive observations and experiments, especially in Italy and the Netherlands from the 1610s. Two 'waves' of discoveries shaped the use of the telescope, and major findings were made early on too with the use of the microscope, before the 1660s. However, these experiments, and subsequent papers, circulated amongst institutions, universities and those connected directly to the new science. From the 1660s, the instruments became popularised. The publication and circulation of Hooke's *Micrographia* coincided with a growth in the production of optical instruments in London that meant the city became the world's leading producer of telescopes and microscopes.

Following Hollenbeck and Schiffer's 'Life Cycle Approach', the observation and analysis of these instruments demonstrates that the dominance of the London trade experienced clear and visible changes, but that the successive phases in the cycle took place relatively quickly. Whilst the materiality of the objects and those materials' origins provide clues to the network, the practice of the maker, and the desires and demands of the consumer, they also provide the missing link in our understanding of the subject, namely the lack of written evidence. Without detailed receipts, or documents and written accounts (Campbell's trade account is relatively later compared to the objects included in this chapter), the objects, and investigations into their materials and composition reveal that the items were positioned as luxury commodities. Despite this, they were often made in ways to keep costs in time and money low. They were sometimes, marked and signed, giving prestige to the objects for the consumer and this acted as a form of quality control. Their creation was part of a pattern of 'making do' in early modern science, where cheaper, reused materials were used in conjunction with more expensive exotica such as shagreen. In this sense, they were global objects: based on a Dutch inspired technology, made famous in Venice, popularised in London and made with materials in some rare cases from thousands of miles away in Asia.

It is said that people such as Hooke (and others connected to the Royal Society) by the 1690s complained that optical instruments had become little more than objects of fun and pastime, but this is not an accurate reflection of the trade. Their creation and use meant that from the first time Pepys recorded using one to leer at women during Sunday sermon, when the Society's philosophical outlook was coalescing around Sprat's manifesto, telescopes and microscopes were marketed towards a wide range of consumers as desirable, quirky, interesting, but prestigious objects of luxury and curiosity. Early collections such as Hans Sloane's included technological items such as telescopes, alongside biological specimens, indicating they had a long-held attraction to collectors.[294] If all buyers of telescopes and microscopes had used them for the 'serious' application that Hooke advocated, then the waves of discovery in astronomy and biology may have continued at the same pace. This did

[294] Edward P. Alexander, 'Early American Museums: from collection of curiosities to popular education', *The International Journal of Museum Management and Curatorship* 6, no. 4 (1987): 337-351.

not happen, and instead the objects (as their aesthetic and physical qualities show) were used as novel, luxury items of curiosity, fun and collection, likely for a range of reasons.

That this happened is not to diminish or dismiss the instruments of the period as somehow not of 'science' or not worthy of study. Still a relatively new technology, they instead demonstrate an exciting and rather hidden aspect of early modern English urban life: that instruments caught the attention and attraction for a far wider section of the population than the niche consumers and users of mathematical objects used for surveying, calculation and other functions, that required specialised education, training and knowledge. The London makers in this chapter produced long surviving, durable, available, usable and desirable objects that fuelled demand, interest and use of their objects and the popularisation of the Royal Society's observational philosophy.

Microscopes and telescopes were used for popular purposes (pastime, fun, entertainment, collection) meant that the technology continued and survived; an idea advocated by Latour. The displacement of these objects away from the usual locales and into homes, and the hands of collectors and non-philosophers, is a fundamental part of the history of these objects. Indeed, most surviving examples (as all in this chapter) were a part of this refashioning and translation of value. The analysis of these material features provides a useful corrective to the history of early modern optical instruments, where the networks can be better emphasised. This thesis will now consider the role that makers themselves played in marketing their creations to consumers of all types and evaluate how effective these efforts were.

4

‘Paper Merchants’? The role of portable printed advertisements in seventeenth century London

Introduction

> ‘Made and Sold by John Yarwell at the Archimedes and 3 pair of Golden Spectacles in Ludgate-Street, the Shop next Ludgate, London. Exactly ground on Brass Tools, after a new manner, approved by the Royal Society, and the best skill’d in Opticks, which true Spectacles preserves the Eyes, either of Young or Old, so much that any Person of Sixty years of age, may see to Read the smallest Print as well as one of Sixteen;’[295]

This is not a speech, nor the opening lines from a book. The words appear on a three-hundred-year-old piece of paper. Written by optical instrument maker John Yarwell, they convey an acute sense of market awareness and a desire to appeal to customers. They explain what items he sold. The ephemeral piece comes from 1697 and is an item that is often described as a ‘trade card’. The poetry of the lines on this little piece of paper makes for intriguing reading. If spectacles did not appeal to the potential consumer, then Yarwell was happy to also inform the recipient that there were many other possible items that may be of interest:

> ‘Also Telescopes of all Lengths for Day and Night; Perspectives great and small; a new double Microscope Invented by the said Yarwell, fitted for all uses, particularly

[295] Trade card for John Yarwell, optician, London, England, 1697. 1951-685/88. Science Museum Group Collection.

> that admirable Curiosity of seeing the Circulation of the Blood in small Fishes, and other Animals'.

At the end, Yarwell listed the other types of objects he offered for sale:

> 'Magnifying, Multiplying and Weather Glasses; Speaking Trumpets, Reading glasses of all sizes, with all other sorts of Glasses both Concave and Convex, of the newest and most useful Invention, all made by the above named
>
> John Yarwell'

No prices, no conditions nor no recommendations are included in Yarwell's upbeat invitation to buy his instruments, which appears on a 1697 'trade card' held in the Science Museum Permanent Collections, which gives space and prominence to his name. Yarwell was one of the earlier instrument makers in England to use small, printed pieces of paper to advertise his goods and services to a selected clientele in this way.

The way that he, and others, achieved this in the growing luxury market of early modern consumption, namely London, gives us an unique way of analysing how makers presented and idealised themselves and their business. This chapter presents a series of case studies of the Science Museum collections of 'trade cards'. It explores how makers presented themselves and considers the nature of the transaction of goods at this time. It makes these assertions: first, that these portable prints reveal much about the identity of instrument makers. These identities demonstrated surprising degrees of similarity. Second, that it is incorrect to describe 'trade cards' as the same as all other forms of advertising, as this hinders the assessment of their function as objects of communication and transaction. Unlike advertisements printed in newspapers they undoubtedly acted as physical objects. By comparing their content with newspaper advertisements from the same time, the two complementary mediums had moderately different purposes. Third, that this exchange element meant that they fulfilled a function that was similar to an early modern form of ticketing, by completing the transaction and acting as personal souvenirs of the buying experience. Fourth, that the cultural meanings in text and imagery of each are emblematic of the growing 'business of science' in early modern London. This demonstrates that a discernible customer base was attracted to buying optical and mathematical objects.

As Jeffrey Wigelsworth rightly notes in *Selling Science in the Age of Newton* (2010), whilst it is routine for advertisements to be '…most often employed as supporting evidence…[t]he major exception is trade cards, which have been the subject of several articles in specialist journals'.[296] There is evidence that the makers positioned themselves as the 'hybrid' authorities mentioned in previous chapters, and marketed their businesses as offering premium, desirable items.

Defining 'trade cards'

The term 'trade card' is flawed. As early as 1925, the noted collector of trade cards Ambrose Heal noted that the phrase 'trade card' was '…not altogether a satisfactory term'.[297] For Heal, the items were not exclusive to tradesmen, so 'trade' should be discounted from their description. Neither were they made of card. Most were made from thin paper and many of folio size.[298] The phrase was not in contemporary usage in the eighteenth century when they

[296] Jeffrey Wigelsworth, *Selling Science in the Age of Newton – advertising and the commodification of knowledge* (Farnham: Ashgate, 2010), 3.
[297] Ambrose Heal, *London's Tradesmen's Card of the XVIII Century – an account of their origin and use* (New York: Dover Publications, 1968), 1.
[298] Ibid.

first appeared in great number, at least if the surviving collections are anything to go by.[299] Alternative contemporary phrases such as 'Shopkeepers bills' have been put forward as alternatives, but this is not a solution.[300] For example, the printed pieces of paper that make up these collections were not exclusive to shopkeepers, some were owned and exchanged by travelling tradesmen, journeymen or itinerant traders. Many advertised services, rather than shops and goods.

It is also not the case that they were used dually to advertise and as receipts. Later ephemeral pieces evolved in the eighteenth century for this purpose, with blank spaces for writing. The collections of ephemeral print in private and public collections, comprise a wide variety of mostly portable pieces of thin paper that were printed from the seventeenth century.

These were used to advertise goods and services by combining text and image, and sometimes visual reference alone. The collections in archives and museums often span trades, occupations, and nations, making them eclectic, diffuse and rather difficult to adequately describe and define. In her study on the Waddesdon Manor collection of trade cards, Katie Scott does what few others in this area have, and considers what those at the time thought and looks at an eighteenth-century writer: Jacques Savary des Bruslons, publisher of the *Dictionnaire universel de commerce* (1723-1730).[301] He described how the ephemeral prints given at the point of purchase acted as aide-memoires, receipts and also souvenirs for the purchase of what were undoubtedly luxury and novel items.[302]

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[299] Ibid

[300] Heal, 1; N. McKendrick, J. Brewer & J.H. Plumb, *The Birth of a Consumer Society* (London: Harper Collins, 1982), 84-85.

[301] Katie Scott, 'Archives and Collections. The Waddesdon Manor Trade Cards: More Than One History', *Journal of Design History* 17 (2004): 91-104.

[302] Scott, 97.

Scott concludes that the terms that Savary des Bruslons described (cards as souvenirs) is evidence of the ‘comparative novelty of shopping in the eighteenth century, or shopping of a particular kind at least’; shopping for scientific instruments is no exception.[303] However, Scott applies her own caveat to Savary des Bruslons’ categorisation of what a trade card in the eighteenth century both was and was not: she writes that between ‘...merchants and tradesmen, trade cards served, *pace* Savary, simply as advertisements, as a trade in information’.[304]

As objects handed over and exchanged between people, ‘trade cards’ had a cultural meaning and function; their role in ‘advertising’ was confined to the closed network and the exchange of information between traders. Later prints included space for writing, most likely receipt of payment or bill for the account, but earlier pieces, that this study focuses on, did not contain these blank spaces. The term ‘shopkeeper bills’ was a distinct eighteenth-century creation and is therefore also unsuitable as a term.[305] It was the result of their practical use, peaking between 1730-1770, when the term ‘trade’ evolved, most likely due to unfavourable connotations that the term ‘shopkeeper’ had.[306]

Josiah Wedgwood (1730-1795) is noted to have remarked that the reason he produced no such prints was that, to his in disdain, they were ‘…common to shopkeepers’.[307] Yarwell’s ‘card’, along with others in this study, dates from before all this. His ‘trade cards’ were not

[303] Ibid.
[304] Scott, 98.
[305] Philippa Hubbard, ‘The Art of Advertising: Trade Cards in Eighteenth-Century Consumer Cultures’ (doctoral thesis, University of Warwick, 2009), 11.
[306] McKendrick, Brewer & Plumb, 85.
[307] Nancy Cox, *The Complete Tradesman – a study of retailing 1500-1820* (Farnham: Ashgate, 2000), 110.

‘shopkeeper bills’ and they cannot correctly be described as ‘cards’ of any sort. This came from the nineteenth century too, when collectors began mounting them to pasteboards or cards, and this explains the use of the term.[308] Evidence for this anomaly is amplified by a routine search of historical resources such as *Early English Books Online* (EEBO): a request to search ‘advertisement’ returns 4,456 items for the years 1630-1777, conversely the term ‘trade card’ returned zero matches when searched in 2018.

One solution may be to move away from a rigid use of the term ‘trade card’, in favour of thinking about the objects as portable pieces of a print and describing them as prints, or papers. They were handed over, in the same manner as tickets. To label all items as ‘tickets’ would be imperfect, but in terms of function and status, it can provide an improved equation with how they functioned within transaction and exchange. As a practice, ‘ticketing’ amply describes their purpose, and over the course of this chapter will be demonstrated to be an effective comparison.

The word ‘ticket’ originated in the early sixteenth century from Old French, and was linked to ‘etiquette’, its early usage referred to tickets being ‘short, written notes’. According to the *Oxford English Dictionary* its definition of a noun is recorded as: ‘[a] piece of paper or card that gives the holder a certain right’ and also as a ‘...receipt for goods that have been received’.[309] It is therefore better to consider the pieces ‘portable prints’ and think about their function as similar to a form of ticketing. The size of these specimens was deemed to be important, with the portability of prints stressed as an effective strategy of sale, by John

[308] Heal, 1;
[309] *Oxford English Dictionary*, (Oxford: Oxford University Press) s.v. ‘ticket’.

Castaing, in advertisements for his own portable book on interest calculations, that he published in 1700.[310]

Considering these pieces as 'tickets' builds on the earlier research of Sarah Lloyd, who argues that in the seventeenth century'[…] the paper object mattered, with a watershed in the multiplication of paper tickets for admission, pay, lottery, information, all beginning around 1700.[311] Lloyd argues that 'tickets' came to incorporate a long list of different functions for small pieces of paper that contained implicit and explicit meanings between recipient and ticket-er. As well as lottery, pay and admission tickets, they also asserted trust, and through their physical presence had a social meaning and function that garnered '…aesthetic, sensory and emotional response, or held a memory of a sense of self in addition to any monetary or practical value they held'.[312] Coffee-houses specialised in ticket distribution and the social interactions surrounding print led to a proliferation in printed ephemera.[313] They were, unlike printed advertisements, individual, personal and owned objects.

This chapter argues that the papers associated with instrument makers such as Yarwell and his competitors were different from printed advertisements by the same makers. They differ in subtle ways in their content and function. This chapter accepts the term 'trade cards' as the conventional description of the items and uses a range of terms to describe the 'cards 'and argues the objects were exchanged in the form of 'ticketing'. The descriptions 'prints' and 'printed ephemera' are used to refer to these items. This is a deliberate attempt to highlight

310 Natasha Glaisyer, 'Print Culture, Trust and Economic Figures: early eighteenth-century England', *The Economic History Review* 60, no. 4 (2007): 685-711.
311 Sarah Lloyd, 'Ticketing the British Eighteenth Century: 'A thing…never heard of before', *Journal of Social History* 46, no. 4 (2013): 843-871.
312 Lloyd, 859-861.
313 Lloyd, 852.

the varying functions, use, and origins of the 'trade cards'. The long history of collecting, museum cataloguing and much excellent recent research in the area, as the next section will analyse, mean the term cannot be sensibly ignored entirely. Its use has caused comment and critique since its emergence over a century ago.

Historical accounts of trade cards provide much of our understanding of how and why the pieces were created and later collected**.** Historians since Heal agree that the eighteenth century was the period when 'trade cards' flourished. Heal even homed in on a closer date range than collections usually specify, describing the period between 1720 and 1770 as the 'palmy days' of production.[314] His 1925 work, the result of his own long-standing collecting of ephemeral prints, can perhaps be best regarded as the first published authority on 'trade cards'.[315] Heal saw the prints as forms of advertising and thought the distinction between 'trade card' and 'billhead' was rather blurred, but this is because of the ways that ephemeral collections were accumulated.[316]

For Heal, 'trade cards' were also the physical, printed reincarnation of shop signs.[317] In a later published work on shop signs (1947), he again links them to 'trade cards', pointing out that without them our knowledge of how signs looked would be absent.[318] Heal describes the term as a 'misnomer' and points out that whilst some 'cards' were likely used as 'handbills', they must not be confused with 'billheads'.[319] Heal's observations are emblematic of the unstable

[314] Heal, *London Tradesmen's Cards*, 11.
[315] One of the two major collections of 'cards' at the British Museum were donated by Heal.
[316] Heal, *London Tradesmen's Cards*, 3-4.
[317] Described as a 'simple rendering of signs': Heal, *London Tradesmen's Cards*, 14.
[318] Ambrose Heal, *The Signboards of Old London Shops* (New York: Blom, 1972), 4.
[319] Heal, *The Signboards of Old London Shops*, 4-5.

conception of what a 'trade card' is. Although the term has entered usage among historians, it does not accurately reflect the purpose of the objects.

References to 'trade cards' in accounts of advertising are common, but M.A. Crawforth's work focuses on the 'scientific instrument industry'.[320] Looking at 'cards' from a vast date range (1670-1900), Crawforth uses 'trade cards' to date shops and businesses. He also uses them to chart early modern business practices, using the text and imagery of the prints, and considers them as 'portable advertisements'.[321] Crawforth gives an overall account of what these objects were created for, and how they have been best understood by historians. He takes a three-fold approach: first, understanding the role of 'trade cards' to be a form of advertisement. Second, Crawforth looks at the images and draws parallels between designs to show that in many cases templates were re-used by engravers for multiple makers. Third, that as sources, the collections can be used to understand how makers of instruments presented themselves, self-identified, and presented their creations.

A 1971 guide by Calvert on the Science Museum's 'trade cards' acts as a catalogue of the collection, with history of the collectors themselves noted, and this is used as the basis for some understanding of the history of the Science Museum collection.[322] Another 1980s work, by Michael Snodin of the Victoria and Albert Museum cites both its nineteenth-century origins and the fact they were paper, never card, as problematic.[323] Snodin echoes Heal: the collector's focus is likely to be on the aesthetic appeal. The 'ornamental engraving', and the

[320] M.A. Crawforth, 'Evidence from Trade Cards for the Scientific Instrument Industry' *Annals of Science* 24, no. 5, (1984): 453-544.
[321] Crawforth, 454.
[322] H.R. Calvert, *Scientific Trade Cards in the Science Museum Collection* (London: HM Stationery Office, 1971)
[323] Michael Snodin, 'Trade Cards and the English Rococo' in *The Rococo in England – a symposium,* ed. Charles Hind, (Victoria and Albert Museum: London, 1986), 82-107.

artistic qualities are central to Snodin's analysis, whose admiration for the aesthetic form is the basis of his account, in contrast to historians and a natural preference towards the considerations on function, and the meanings that can be analysed and understood from them.[324] Snodin's distrust at how historians view 'trade cards' is obvious, and this may be as he was a curator at the Victoria and Albert Museum:

'Unfortunately, the real importance of the trade card as a type of engraved ornament has been very largely obscured by the work of Sir Ambrose Heal and other historians of the form, who tended to concentrate on its social and historical aspects'.[325]

Katie Scott and Maxine Berg, Helen Clifford and Philippa Hubbard, have brought 'trade card' study up to date with more recent historiographical trends in social and cultural history. Scott's 2004 study centres on the collection of over five hundred ephemeral prints at the Rothschild owned Waddesdon Manor in Buckinghamshire.[326] Scott confirms that 'trade cards' replicated shop signs and part of their function was for buyers to record or recollect their experience or purchase and that they were more akin to aides-memoires than the emerging practice of printed advertising.[327] Scott's study revolves around a single collection, much like Heal's (his own collection, which he later donated to the British Museum), Calvert's (in the Science Museum), Crawforth (Scientific Instruments 1670-1900) and Snodin (the Victoria and Albert Museum's collection of Rococo style 'cards').

[324] Snodin, 82.
[325] Ibid.
[326] Katie Scott, 'Archives and Collections. The Waddesdon Manor Trade Cards: More Than One History', Journal *of Design History* 17 (2004): 91-104.
[327] Scott, 91-104.

The long date ranges for many collections mean there are obvious dangers that meanings can be misattributed. They are also more prone to be connected to the personal taste of the collector. We know this as many focus on specific trades, rather than eras. The research of the Berg and Clifford links wider pattern of identified changes to consumption and shopping: the 'cards' are rightly described by them as '…one of the most common, yet overlooked, forms of early advertising'.[328] Focusing on the collections at the Bodleian Library, Oxford and Waddesdon Manor, Buckinghamshire, Berg and Clifford use 'trade cards' to argue that advertising was not 'primitive' prior to the nineteenth century, and that 'trade cards' were part of a broad, informal collection of activities that constituted 'advertising'.[329] Philippa Hubbard contextualises the 'trade card' from the eighteenth century to the wider, growing sphere of commercialisation, professionalisation and consumption in early modern London. She connects them to other forms of advertising to show that the cards acted as 'instruments of ambition' and were designed to promote and expand businesses.[330]

Hubbard examines them as objects handled at the point of transaction and exchange and this is different from other histories. She makes clear that these should not be considered as mere engraved illustration, but instead for their physical role as objects. They were not mass advertisements in the same way as newspaper advertisements. Instead, they were 'selectively distributed to a known or anticipated customer base'.[331] The three historians each point to trade cards' mixed uses as billheads, receipts, souvenirs. Often this is evident from examples dating from the mid-eighteenth century, where blank spaces for writing can be observed, earlier pieces from instrument makers held no such space for writing and instead were likely

[328] Maxine Berg & Helen Clifford, 'Selling Consumption in the Eighteenth Century', Cultural *and Social History* 4, no 2 (2007): 145-170.
[329] Ibid, 146.
[330] Hubbard, 'The Art of Advertising', 1.
[331] Ibid, 2.

used for a slightly different purpose, although some have writing on the reverse, as one of the case studies will show.

Science Museum Collection

Before explaining the justification for the case studies selected for this chapter and the research that led to their selection as suitable and reflective of the practices of instrument makers in late seventeenth-century London, it is necessary to place these prints within the history and context of the collection from which they are found. How the collections are stored by different institutions gives us insight into the complexities of archiving, storing and classifying these pieces. All ‘objects’ held in the Science Museum, as with other national and most museums, have a ‘Documentation Record’ attached to them. These files contain information from the time when the object came into the possession of the Science Museum, how it came to be in the collection, records of curatorial research and historical display, as well as background to the piece. As part of research into how these ‘cards’ were collected, these records were studied. In the case of the papers labelled as ‘trade cards’, no files exist in the registry and there is no evidence on the online database MIMSY for such files at the Science Museum, which is unusual, although may point to a longstanding uncertainty with how to categorise them.[332]

In a Museum wide collection of over a quarter of a million objects, the number of ‘trade cards’ at the Science Museum is 3,592, which amounts to less than two percent of the total

[332] The request was made by and responded to the Museum’s Corporate Information Officer in April 2018.

object collection.[333] According to Calvert, the bulk of the collection came from two private collections donated to the Museum prior to the Second World War; one from Thomas Court, and a second from George Gabb; Calvert describes them as ‘well-known collectors’ of instruments and related ephemera, including advertisements cut out from books and newspapers.[334] Little else is known about how Gabb compiled his collection, but much is known about Court’s. The Museum still lists both collections by the names of these collectors.

At the British Museum, over sixteen thousand ‘trade cards’ are stored, out of the Museum’s total collection of four million objects, the largest number of ‘trade cards’ at any institution worldwide, and this is from over one million printed objects. They are therefore a comparatively rare category of object. The overwhelming majority of these ‘cards’ came from two private collections, just like at the Science Museum, namely Joseph Banks and Ambrose Heal.[335] The collection at the Bodleian Library, Oxford, comes mainly from the collection of John Johnson, whose pieces also make up part of the Victoria and Albert Museum collection. There are other sizeable collections at Magdalene College, Cambridge, and the British Library, where the earliest examples come from the collections of Samuel Pepys, who described them as both ‘relics’ and ‘vulgaria’.[336]

In his 1971 account, Calvert categorises the Science Museum ‘trade cards’ into four, informal groupings: first the ‘trade cards’ and bill-heads, second the ‘useful and informative

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[333] It is possible to search the entire catalogue online: http://collection.sciencemuseum.org.uk
[334] Calvert, 9.
[335] Hubbard, 12.
[336] Hubbard, 12-13; ‘The Ephemera of Trade - Trade Ephemera as a Resource’, *Bodleian Libraries, University of Oxford*, accessed 1 May 2018, https://www.bodleian.ox.ac.uk/johnson/online-exhibitions/a-nation-of-shopkeepers/the-ephemera-of-trade/

advertisements' taken from cuttings, third the 'second rate material' in the form of photographs, and finally, facsimiles and any without 'scientific' interest.[337] These categories highlight the highly unstable and comparatively undefined category of what a 'trade card' in a Museum collection constitutes, and a sign that collectors who donated their pieces to Museums had imprecise boundaries over what to include.

This chapter examines examples by the following instrument makers: Walter Hayes, John Marshall, John Yarwell, George Willdey, Timothy Brandreth and Edmund Culpeper. The examples were selected because they typify the fluid, multi-faceted and broad way that the items were created, used and later classified. There has been little change since Heal noted the 'scarcity' of seventeenth century examples in 1925; and pieces from before 1720 remain 'exceedingly rare'.[338] The case studies are presented chronologically, to demonstrate both the evolution of the pieces during the late seventeenth century and the ways this affected collecting, and subsequent curatorial and historical approaches.

The text, imagery and purpose of each of these prints is evaluated, compared and analysed. Where possible, comparisons are made to other forms of print, such as classified advertisements. The four categories that are identified by Calvert, are mentioned throughout as a benchmark, although they are challenged. The first case is a mathematical instrument maker mentioned in a previous chapter: Walter Hayes.

337 Calvert, 9.
338 Heal, *London Tradesmen's Cards*, 9.

The Case Studies: Walter Hayes

Few details on the life of instrument maker Walter Hayes are known for certain, although he is referenced in the Diary of Samuel Pepys. On 16 September 1664, Pepys described him as the 'mathematical instrument maker at Moorefields'.[339] The dates of his birth and death are thought to be 1618 and 1692 respectively, and he is known to have been most active as an instrument maker from the 1650s until the 1680s.[340] Hayes' 'card' is one of the most illuminating examples of the unstable, broad category of 'trade card' previously mentioned and shows us the how collectors have contributed to the issues of understanding what object this 'trade card' actually is. For Hubbard, they '… were single-sheet advertisements freely distributed to provide consumers with information on the nature and location of individual businesses'.[341] This is true in many cases, but not in the case of the Hayes example.


Whoso Ever hath or Shall have Occation
for all or any of these Instruments
Mentioned in this Booke or any Other
for the Mathematicall Practice Ether in
Silver Brasse or Wood may Bee Exactly
furnished by Walter Hayes At the
Crosse Daggers in Moore fields Neere
the Popes Head Tavern London

Illustration 36. Trade card: Walter Hayes: Moore Fields, Bethlem Gate, London, 1934-122/17, Science Museum Group Collection

[339] '16 September 1664', The *Diary of Samuel Pepys*, ed. Robert Latham and William Matthews (Berkeley: University of California Press, 1971)

[340] H.K. Higton, 'Walter Hayes', *Oxford National Dictionary of Biography,* accessed April 20, 2018, <https://doi.org/10.1093/ref:odnb/60155>

[341] P. Hubbard, 'Trade Cards in 18th-Century Consumer Culture: Movement, Circulation, and Exchange in Commercial and Collecting Spaces', *Material Culture Review* 74-75 (2012): 30-46.

Comprising eight lines of printed text, the first three are highly revealing of the origins of this piece of ephemera: ‘Whoever hath or shall have Ocation for all or any of the instruments mentioned in this book […]’. This advertisement was not originally a single sheet, but instead part of a different style: a printed advertisement from within a book. Its later categorisation as a ‘trade card’ likely came from its original collector, although the definition is not changed or commented on by Calvert in his catalogue of the pieces from 1971. Despite setting out four parts to the ‘trade card’ collection, Calvert did not assign those on his list to one, but it is evident that this piece from Hayes most appropriately falls into the second category: ‘...useful and informative advertisements, many of them newspaper *cuttings*’.[342] Mounted, but not glued, to cardboard, the reverse of the piece contains inscriptions written in ink.

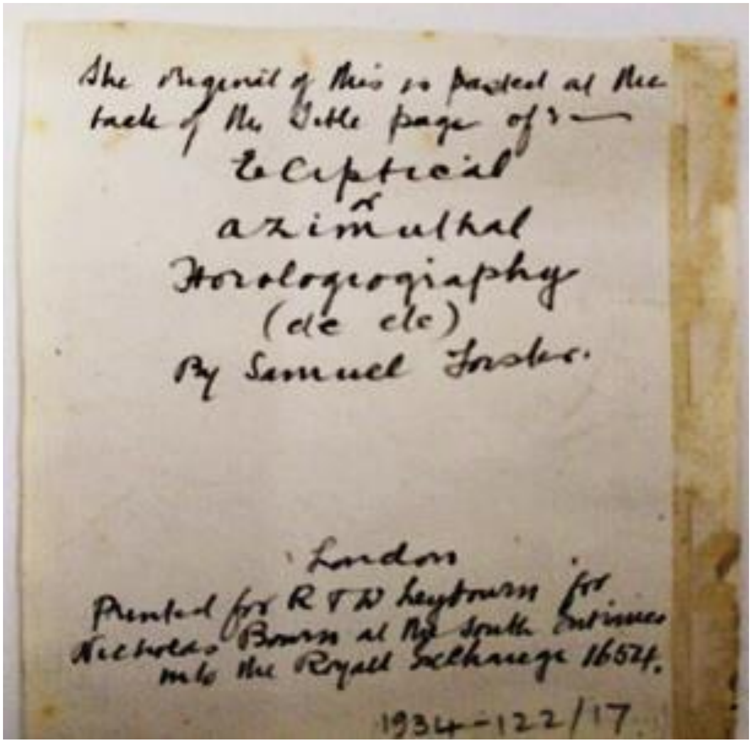

Illustration 37: Reverse image: Trade card: Walter Hayes: Moore Fields, Bethlem Gate, London, 1934-122/17, Science Museum Group Collection

[342] Calvert, 9.

The book that this print was cut from is noted in the inscription on the reverse, and is attributed to Samuel Foster, entitled *Elliptical Or Azimuthal Horologiography.* Foster is described on the title page to the book as the 'late Professor of Arithmetic at Gresham Colledge'.[343] The book instructed users on how to use elliptical dials, or sundials. The inscription on the Hayes print also indicates that the book was originally printed for a Nicholas Brown of London in 1654, who lived near the Royal Exchange. Hayes' advertisement was stuck inside. This was not an unusual practice.[344] When 'advertisements' began in the *Philosophical Transactions*, they were often positioned as desirable 'commodities'.[345]

The language is typical of very early forms of 'advertisement', where the reader was told to 'take notice'.[346] But what does this tell us about 'trade cards' and advertising? First, that modern definitions of 'trade cards' have been affected by the looser collecting habits of collectors. Second, it is clear that despite later definitions such as Hubbard's, there has been no major classification or restyling of the terminology in many collections. The print gives information on Hayes' business and location, but this was not distributed to individuals as an object, but rather was a part of a specialist book. It is not a portable print, nor did it function as a ticket or standalone object, but has actually been cut out of a larger book. Third, this is indicative of the fluid, uncodified practice of early modern advertising that was emerging at the time Hayes made and sold mathematical instruments.

[343] Samuel Foster, *Elliptical Or Azimuthal Horologiography* (London, 1654)
[344] Similar papers were often pasted onto objects such as furniture.
[345] Wigelsworth, *Selling Science in the Age of Newton*, 17-21.
[346] Ibid.

Advertisements could be printed on broadsheets, many of which were posted on public walls in and around the Royal Exchange. They invited readers to stand and look, whereas portable ephemera were handed to customers and clients as part of the transaction of exchange. These there were forms of advertising that were less directed at individuals: the emergence of printed text advertisements in newspapers and books was a more mass, speculative, form of advertising. This is what Hayes' print was. Its aims and function were different from the ephemeral prints handed out in greater number by instrument makers later. Furthermore, it is an example of the mingling of multiple businesses in the realms of experimental and mechanical philosophy; in this case, a book on dials contains an advertisement for a maker who could supply the prospective reader. A later example can be found in an anonymous 1680 work: *The Description of the horologicall ring-dyall which sheweth the hour of the day in any part of the World*. The piece details 'How to Find the Hour of the Day' and also the 'Latitude of the Place' , the work is chiefly mathematical and horological.[347] After forty lines of technical and mathematical instruction and explanation, the final sentence of the piece reads: 'Note that this Dyal, or any other Instrument for the Mathematicks, are made by Walter Hayes, at the Cross-daggers in Moor-Fields, next door to the Popes-head Tavern, London'.[348]

This description reveals Hayes had a distinguishable shop sign and although the language is shorter, it is similar to the tone and purpose of the cut-out advertisement in the Science Museum. Did Hayes write the anonymous tract? Possibly not. Even though the tract is unattributed, it seems plausible that as with the cut-out advertisement, the maker was on the receiving end of a recommendation from a client or partner. Clearly, Hayes used print to

[347] *The Description of the horological ring-dyall which sheweth the hour of the day in any part of the world.* (London: s.n., 1680)
[348] Ibid.

highlight that his instruments were for sale. But this was rather different from the role that portable prints played, which were engraved, printed and handed over. For Hayes, the chief advertising activity was to promote his business in books to readers whose interests he could rely on to arouse interest in his shops, but there may also have been mutually beneficial business relationships for booksellers and instrument makers.

John Marshall

Calvert describes a third category of 'trade card' as the 'second rate' photographic reproductions held in the Science Museum. The Museum's collection is unusual for some reasons, and the inclusion amongst its archives of photographic or facsimile copies from other institutions is one of these elements. They no doubt came from the collections accumulated by Henry Court and Thomas Gabb, but their existence in the collection today, where sit alongside actual seventeenth- and eighteenth-century examples is a dilemma. If we accept that printed pieces of ephemera were objects at the heart of transactions of exchange, handed from maker to client, it seems illogical to retain photographs of the prints in the same way, for the cultural and material meaning they hold as physical objects is not the same. In effect these copies act as replicas, which for museum visitors arguably does not cause an issue as it is the visitor who often ascribes their own meaning onto the object, as a collector would have done.[349] But the replication through a different medium (photography) and a different material (not paper) means that the replication of the materiality is lost.[350] A prime example of this is a photograph of the 'trade card' of maker John Marshall, who operated in London in the 1680s and 1690s. Photographing a printed piece is not the same as creating a

[349] Gwyneira Isaac, 'Whose Idea Was This? Museums, Replicas, and the Reproduction of Knowledge', *Current Anthropology* 52, no. 2 (2008): 450-468.
[350] Hilde S. Hein, *The Museum in Transition* (New York: Smithsonian Books, 2014).

modern, physical, working replica of a scientific object.[351] A true 'replica' would not be a modern style photograph, but a printed piece made with similar materials.

[351] For recent debates on the place of replicas and originals in museums collections see: Marzia Varutti, 'Authentic reproductions: museum collection practices as authentication', *Museum Management and Curatorship* 33 (2018): 42-56; and Brita Brenna, Hans Dam Christensen, Olav Hamran, ed., *Museums as Cultures of Copies : The Crafting of Artefacts and Authenticity* (London: Routledge, 2018).
The difficulties with understanding the 'unstable' value and meaning between 'originals' and 'copies', and within a museum setting, are also explored in a recent comparison between Native American and European approaches to historic artefacts in: Gwyneria Isaac, 'Whose Idea Was This?: Museums, Replicas, and the Reproduction of Knowledge', *Current Anthropology* 52, No. 2 (2011): 211-233.

Illustration 38: Trade Card: John Marshall, 1951-685/52, Science Museum Group Collection

Marshall uses three languages. The same message describing himself as 'Optical Instrument Maker to His Majesty' appears in English, French and Dutch. As if to highlight to his clients the international reach and cultural superiority of his business, the middle verse (in French) is not italicised, and the differences in language stand out. The columns hint at prestige and wealth and the telescopic lenses immediately above the English text, positioned prominently, helpfully draw attention to the two figures reading and sewing. These could portray Mary II and William III. Engravers often retained images of monarchs even after they were deceased, the use of Queen Anne on many prints in the 1700 continued for some decades after her death.[352] They are doing both activities (reading and sewing) with the use of optical objects – conveying how optics could be useful in daily tasks. The royal coat of arms is included at the top in a self-contained image of Archimedes, using a telescope to point to the heavens, with the legend 'The Oldest Shop' also adding to the sense of tradition, expertise and fame that Marshall's print projected to its consumer.

In the twentieth century, advertisers identified what is known as 'depth' psychology to promote their goods, which involved '[making use of so-called 'subliminal' techniques of persuasion by association'.[353] The use of language here, associating the goods with institutions such as the Royal Society and the monarch, is a similar, subliminal approach, appealing to consumers through the association that was made.

The 'card' is held in the British Museum. At the end of the piece, there are the words 'B. Lens delin' and then 'J. Sturt sculp'. 'Delin', or delineavit, indicates who the drawing was made by, similar to 'fecit' used to indicate who made instruments.[354] In this case it was Bernard Lens II, who worked as a painter and miniaturist. The 'sculptor' who engraved the

[352] Heal, *London Tradesmen's Cards*, 2-3.
[353] Peter Burke, *Eyewtinessing – The Use of Images as Historical Evidence* (London: Rekation, 2021), 95.
[354] Julie L. Mellby, 'Printmaker's abbreviations', *Princeton.edu*, Feb 6, 2009, accessed Dec 10, 2018, https://www.princeton.edu/~graphicarts/2009/02/printmakers_abbreviations.html

image was John Sturt (1658-1730), who is known to have worked with Lens II, not Bernard Lens III the miniaturist (1682-1740) who is cited by the Museum.[355] The entry in the British Museum records the date for this piece as after 1760, but Marshall died in 1723 and it was the elder Lens that Sturt worked with. One reason that the two figures at the top may be William and Mary is that mezzotint likenesses of the two made by Bernard Lens II (and from the 1690s) are held in the Royal Collections.[356]

The final line refers to the 'approbation of the Royal Society'. In 1693, John Marshall made a major breakthrough in lens grinding techniques that allowed him (and subsequently others who 'borrowed' his method) to create batches of 'identical, good quality lenses, of a specified focal length'.[357] This is evidence of the importance of improving precision in lens grinding. Marshall's lens grinding technique was a radical change to lens production; the first such change in their production since modern spectacles were invented in the thirteenth century. He applied to the Royal Society for a 'testimonial', and after assessments by noted Fellows Edmund Halley and Robert Hooke, the method received the approval of the Society on their recommendation. Unfortunately, perhaps sensing the likelihood of his revolutionary technique being pinched in the absence of patenting, Marshall did not publish or record copies of his methodology.[358] This may have been a wise attempt at restricting the likelihood of the information reaching his competitors. On the other hand, the fact that they were being sold by other makers so rapidly, leads to the conclusion that either his efforts were unsuccessful, or that he or a fellow at the Royal Society talked to many others in their

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[355] 'John Sturt', *The British Museum*, accessed Dec 19, 2020, https://www.britishmuseum.org/collection/term/BIOG47695

[356] 'King William', *Royal Collection Trust*, accessed Dec 19, 2020, https://www.rct.uk/collection/603126/king-william

[357] D.J. Bryden & D. L. Simms, 'John Marshall: the making of true spectacles', *British Medical Journal* 39, no 6970 (1994), 1713-14.

[358] Ibid.

network about the new method that had so impressed Hooke and Halley. His lack of patent also led Marshall to use advertisements to assert that whilst others claimed to have the design, the letter of recommendation had been made for his work alone, and no-one else's.[359]

Bryden and Simms believe that Marshall created and sold suitable tools for his technique to other gentlemen amateurs. From this it was easy, they say, for the journeymen and apprentices to pirate his method and indeed 'within months trained rivals advertised that they were using a method approved by the Royal Society'.[360] One of the noted copiers of the method was Marshall's rival optical instrument maker John Yarwell, who used a shop sign of Archimedes as well. Yarwell's claims led to a pamphlet war between Yarwell and Marshall and each claimed the right to practice the technique. Marshall's newspaper advertisements differed in tone, style and language, from the announcement contained in his portable print. An advertisement from 4 August 1693 announced his wares in a less grandiloquent and genteel manner, whilst curiously emphasising the low cost:

> 'Whereas Generally the *Spectacles* that are made and sold in England are *Irregular*: because the Tools that they are made with are so: Now there is found out a *New way* of making the best sort of *Spectacles* that are true *Sections of Spheres*, as cheap as the best *Irregular* ones used to be sold for. I have enquired of those who are extraordinarily skilled in *Opticks*, who confirm the same, and think they deserve to be encouraged. *They are to be sold by* John Marshall at the *Sign of the* Archimedes and Spectacles in Ludgate Street. London'.[361]

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359 Crawforth, 463-464.

360 D.J. Bryden & D. L. Simms, 'John Marshall: the making of true spectacles', *British Medical Journa*l 39, no 6970 (1994): 1713-14.

361 Classified Advertisements. Collection for Improvement of Husbandry and Trade (London, England), Friday August 4, 1693; Issue 53. 17th-18th Century Burney Collection Newspapers.

Compared to the styling of his portable print, Marshall's newspaper advertisement was composed differently. Money is not mentioned perhaps because it was a souvenir as part of the transaction of exchange that had already taken place. It may also perhaps in part be because advertisements appeared in newspaper pages surrounded by competitors. The bigger audience of newspaper readers, in coffee-houses, taverns, inns, could have been put off by cost. The language is also rather more personal, Marshall uses the first-person pronoun 'I' to describe himself, and the wider language is less effusive and more restrained. This points to different advertising and rhetorical techniques being used, a result of the different readers and contexts within which they were read.

Crawforth argues that the aesthetics of these prints (style of language, typeface and content) can be used 'to deduce dates and business practices'.[362] Within these, the 'status' of the maker was often on show, and Crawforth cites the use of patents, crests, and references to the Royal Society as good examples of this.[363] Marshall's language and his use of a crest makes it distinct from his newspaper advertisement, where there are no images.

Similarly, a 2004 article on luxury goods sold in eighteenth-century Paris by Natacha Coquery discusses the so-called 'Language of Success'. Her ideas are relevant to the language these 'cards' have. In terms of what they were presenting to their clients through the language they chose to use, both printed advertisements and 'trade cards' were geared towards enticing customers and projecting an image of success. Her choice of Paris as case study is deliberate. The city was, after all, '... one of the great European centres of the luxury

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[362] Crawforth, 453-54.
[363] Crawforth, 455.

industries - gold and silver-smithing, book-binding, clock-making and weaving were among those celebrated in guidebooks, almanacs and the [...] press'.[364] Coquery contrasts and compares trade cards with printed advertisements in newspapers and she argues that through the use of distinctive and imaginative pictures and text, they 'played an essential role in the creation of an image of individual shops , and of shopping in general'.[365] She also highlights the unique 'opportunity of a double seduction' that advertisements in newspaper did not achieve: primarily the use of image and texts together (it was not until a century later that images in newspaper advertisements became commoner).[366] In portable prints such as Marshall's, however, there are images accompanying the text.

Marshall's shop sign was printed on his 'card' – namely the image of Archimedes. Coupled with this, the use of language provides the 'seduction' Coquery describes as indicative of trade cards. It also meant that a consistent image between the physical sign of the shop and the trade cards that were handed out existed to promote the space.

John Yarwell

Marshall, his rival Yarwell (and Yarwell's own apprentices turned rivals George Willdey and Timothy Brandreth) used the image of the ancient scholar Archimedes as their sign and on their printed wares. Archimedes was said to have 'invented' the parabolic mirror, was often depicted with a cross-staff, and contemporaries in the seventeenth century were firm in their belief the ancients knew of optic glasses.[367]There were strong degrees of conformity when instrument makers presented themselves and their businesses outwardly to customers through

[364] Natacha Coquery, 'The Language of Success: Marketing and Distributing Semi-Luxury Goods in Eighteenth Century Paris', *Journal of Design History* Vol. 17, no 1 (2004): 71-89.
[365] Coquery, 75.
[366] Coquery, 76.
[367] See W. Molyneux, *Dioptrica Nova* (London, 1692), and R. Smith, *A Compleat System of Optics* 2 (1738).

the words and images they used. Unlike newspaper advertisements, the visual nature of ephemeral prints meant the shop sign was included as a reminder of the customer's shopping experience and this can perhaps best be seen as an early modern method of branding. Throughout Europe, shop signs routinely employed images that were either religious, of objects, geographic, symbols of prestige (coats of arms), literary allusions, skills, jokes or puns.[368]

David Garrioch states that shop signs were a marker of individual, family or group identity, as opposed to 'advertising'; he identifies this as only changing in the eighteenth century, when the relationship between shops and residents changed due to urbanisation and social integration.[369] Heal says that many were 'loathe' to give up a sign, despite changes in fashion, or regulation.[370] The portable replication of the elaborate shop sign in print was part of a wider trend, where makers fashioned their shops as locations for luxury, desirable items.[371]

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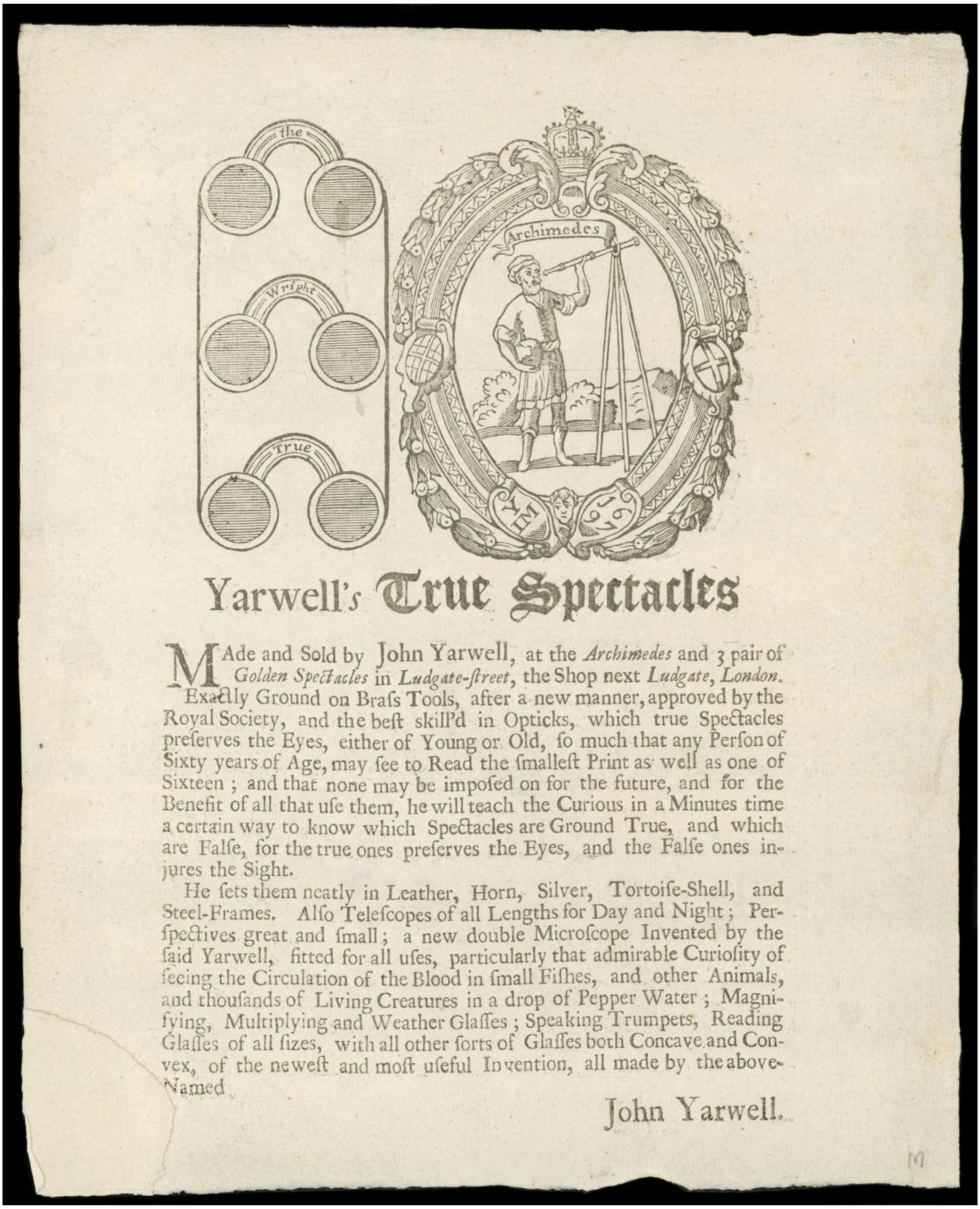
[368] Nevett, 6.
[369] David Garrioch, 'House names, shop signs and social organization in Western European cities, 1500–1900', *Urban History* 21, (1994): 20-48.
[370] Heal, *The Signboards of Old London Shops*, 3.
[371] Barbara M. Benedict, 'Encounters with the Object: advertising, time and literary discourse in the early eighteenth-century thing-poem', *Eighteenth Century Studies* 40, no. 2 (2007): 193-207.



Yarwell's True Spectacles

MAde and Sold by John Yarwell, at the *Archimedes* and 3 pair of *Golden Spectacles* in *Ludgate-ſtreet*, the Shop next *Ludgate*, *London*. Exactly Ground on Braſs Tools, after a new manner, approved by the Royal Society, and the beſt skill'd in Opticks, which true Spectacles preſerves the Eyes, either of Young or Old, ſo much that any Perſon of Sixty years of Age, may ſee to Read the ſmalleſt Print as well as one of Sixteen ; and that none may be impoſed on for the future, and for the Benefit of all that uſe them, he will teach the Curious in a Minutes time a certain way to know which Spectacles are Ground True, and which are Falſe, for the true ones preſerves the Eyes, and the Falſe ones injures the Sight.

He ſets them neatly in Leather, Horn, Silver, Tortoiſe-Shell, and Steel-Frames. Alſo Teleſcopes of all Lengths for Day and Night ; Perſpectives great and ſmall ; a new double Microſcope Invented by the ſaid Yarwell, fitted for all uſes, particularly that admirable Curioſity of ſeeing the Circulation of the Blood in ſmall Fiſhes, and other Animals, and thouſands of Living Creatures in a drop of Pepper Water ; Magnifying, Multiplying and Weather Glaſſes ; Speaking Trumpets, Reading Glaſſes of all ſizes, with all other ſorts of Glaſſes both Concave and Convex, of the neweſt and moſt uſeful Invention, all made by the above-Named

John Yarwell.

Illustration 39: Trade Card: John Yarwell, 1951-685/88, Science Museum Group Collection

Why was Archimedes so prominent on Yarwell's prints? If we take David Garrioch's categories for shop signs, Yarwell's Archimedes applies to three: first, it contains objects.

Second, the image could be said to encompass a symbol of prestige, for Archimedes appears within what might be considered a crest: the crown is included too, with coats of arms either side. Third, this is a literary reference, Archimedes was an ancient author. As evidenced from the case studies of Walter Hayes, instrument making, and book selling were overlapping trades that provided mutual benefits to makers and sellers of both.

In art history, the iconographic method is used to analyse the symbols in a work and uncover their 'deeper' meaning.[372] The use of the spectacles, in iconographic terms, could also be to invite the viewer to take a closer look. Spectacles are used to improve sight, and their positioning and prominence and their visual meaning with regards to 'looking', prompts the viewer to look closer and take attention – of the images, the names and the text. Similarly, the image of Archimedes holds a telescope, again with the implicit meaning to 'look' or look more closely.

Yarwell's use of Archimedes gives this impression of prestige. He is placed in the centre of a floral crest, with a crown at the head, and the arms of St George's Cross on either side. In a sign that the reference may not have been fully understood by all customers, the figure holding the globe and telescope is named 'ARCHIMEDES'.

At face value, it is contradictory that an ancient Greek mathematician was selected to be the sign of not one, but multiple instrument making workshops in early modern London. The use of his image and name for shops in the 'new' trade of making telescopes and microscopes appears at odds with the new technology. By basing their signs around a classical image,

[372] Dana Arnold, *Art History - A Very Short Introduction (*Oxford: Oxford University Press, 2004), 106.

makers such as Yarwell were identifying with a group of fellow traders, something that Garrioch says was consistent with traders since the Middle Ages. However, these instrument making businesses operated at a time when the authority of Aristotle and the ancient learning that these figures symbolised was under threat from the newer philosophies of experimentalism and observation, as advocated by Boyle and Hooke.[373]

Archimedes had a strong connection to ancient astronomy and was thought to have created his own mechanical planetary models, which used rings, rather than the solid spheres of the early modern era.[374] Although Archimedes' own work on the subject, entitled 'On Sphere Making' is no longer extant, he was also credited by Cicero in *De Re Republic* as the inventor of such models and wrote: 'I had often heard tell of this globe thanks to the fame of Archimedes: yet I was not so impressed with it when I saw it. For the other one [...] which the same Marcellus had put in the temple of Valour, was more beautiful and more widely known'.[375]

How far the reference was understood by buyers and shoppers is difficult to measure. This aside, it is far less straightforward to understand the implications and nuances of each presentation of self that the makers offer within their trade cards, especially if, as in these cases, they appear to conform to a single image. In the examples of early optical instrument makers, they often conformed around Archimedes. It is necessary to identify (as Bryden does) the possible and probable original reasons for the selection of the image of Archimedes and its place in John Yarwell's trade cards. Conversely, it is much more difficult in the

[373] For further context, see C. W. Groetsch, 'Aristotle's Fall' *The American Mathematical Monthly* 105, no. 6 (1998): 544-547.
[374] Marco Ceccarelli, 'Contributions of Archimedes on mechanics and design of mechanisms', *Mechanism and Machine Theory* 72 (2014): 86-93.
[375] Marcus Tullius Cicero, *De re publica*, translated by Niall Rudd, Book One: 21-23 (Oxford: Oxford University Press, 2008), 12.

modern day to understand the connotations this had for buyers, or for the general public, including why it was chosen as Yarwell's shop symbol, what impression this gave and the effect it had on the success of his business.

Bryden and Simms note the speculation that these trade cards have attracted in this area from scholars: 'Quite why Yarwell, an optician [sic], chose Archimedes as the principal symbol of his business is unknown. Commentators have assumed that the reason was the belief that Archimedes used burning lenses to set the Roman fleet on fire at...Syracuse'.[376] On the face of it, for someone at the heart of the growing market for experimental instruments, the choice of Archimedes appears at odds with the changes that occurred at this time. Looked at another way, Archimedes is thought credited with the first calculus, which may have meant he was revered as important to the new movements in philosophy.[377] It may have been to give credence to the workshops supplying the relatively new technologies of microscopes and telescopes by linking to the past.

Bryden and Simms are adamant that '...[t]he use of Archimedes… as part of a business sign is an indisputable […] demonstration that he was fully established in the hierarchy of heroes of late-17th [sic] century London' and that works on his life at the time were 'plentiful'.[378] One explanation may be the use of Archimedes by Galileo. In his essay 'Archimedes among the Humanists', W.R. Laird notes that Galileo referred to Archimedes as a 'superhuman'.[379] The precise reach of this amongst the closed circle of instrument makers and buyers cannot

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[376] D.J. Bryden and D. L. Simms, 'Archimedes as an Advertising Symbol', *Technology and Culture* 34, no 2 (1993): 387-391.
[377] Alexander Hahn, 'Basic Calculus: From Archimedes to Newton to its role in Science', *University of Notre Dame*, accessed Dec 10, 2020, www3.nd.edu/~hahn/
[378] Ibid.
[379] W.R. Laird, 'Archimedes among the Humanists', *Isis* 82, no. 4 (1991): 628-638.

be ascertained. Laird cites the Italian writer Petrarch who, in the fourteenth century, described Archimedes as a 'mechanic', hinting that the use of the classical thinker was not, therefore, entirely inconsistent with the characteristics of the 'Scientific Revolution'.[380] Although when one considers that Petrarch's major source of intellectual knowledge was Livy, perhaps Laird's explanations break down. It seems logical to conclude that Archimedes was recognised and that by using his name and image, makers added prestige to their own names.

The trend even continued with other makers in the eighteenth century: John Smith, Edward Scarlett, Thomas Gay, Thomas McIntosh and Mary Sterrop are all listed by Bryden and Simms as examples of instrument makers after 1700, who resided and traded at premises with the name of Archimedes.[381] As the eighteenth century progressed, it was common for instrument makers to name and depict Isaac Newton as the dominant figure in their shop signs, as Archimedes fell away from favour.[382] The repeated use of shop names by different makers may have led to the recycling of engraved wooden (later copper) templates to replicate them, as believed by many including M.A. Crawforth and Elizabeth Eisenstein.[383]

This would most likely have been the case for the standardised borders or columns. However, the depiction of Archimedes and the instruments for sales, as well as the typeface, are clearly all very different when one compares the printed ephemera of Yarwell with those of Marshall. This leads to the conclusion that they must have been produced from new woodcuts, and would be a sign of the importance that the prints had in the relationship between maker and buyer. The changes in Yarwell's prints show a progression in branding,

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[380] Laird, 632.
[381] Laird, 632.
[382] Heal*, London Tradesmen's Card*s, 24.
[383] Crawforth, 453-54. See also: Elizabeth Eisenstein, *The Printing Press as an Agent of Change* (Cambridge: Cambridge University Press, 1980).

perhaps a sign too of success, when compared to the much earlier print of his. The later images use three spectacles (part of his shop sign) and rely more on the message, rather than the depiction of multiple different types of instruments as in the earlier piece. For a trade to centre around the image of a single figure of authority was common: the use of the sign of Galen's Head (second century Greek physician), to advertise apothecary goods and services in England even spread to North America, such was its recognition.[384]

It is noticeable that despite beginning the text with his surname, the print gives prominence and space to the name 'John Yarwell' at the bottom right of the piece. In proximity and location, this is reminiscent of a signature. Book sellers sometimes signed their names personally in their works, as a re-enforcement of trust and dispel fears over forgery.[385] The example is, like the prominent Marshall piece, a photograph of an ephemeral print held in the British Museum. As the piece was not stuck to a mount by the Science Museum, it is possible to read an inscription on the reverse that it was '…left with me by Mr Court on 4/2/38' although the initials of the curator are unclear. It is immediately apparent that the instruments depicted on this card are not to scale. The piece was intended as a visual guide, to the goods that Yarwell offered his clients. The print was made at a much earlier stage in his career: the year 1683 appears on the paper. Under the table of microscope parts, the text: 'Made and Sold by John Yarwell at ye Archimedes and Spectacles in St Paul's Church yard, LONDON 1683' is visible. The text at the bottom of the print is rather shorter than the grandiose declaration to those aged sixteen or sixty in his much later piece from 1697 mentioned at the start of this chapter.

[384] James Harvey Young, *The Toadstool Millionaire: a social history of patent medicine in America before federal regulation*, (Princeton: Princeton University Press, 1961), 4.
[385] Glaisyer, 685-7.

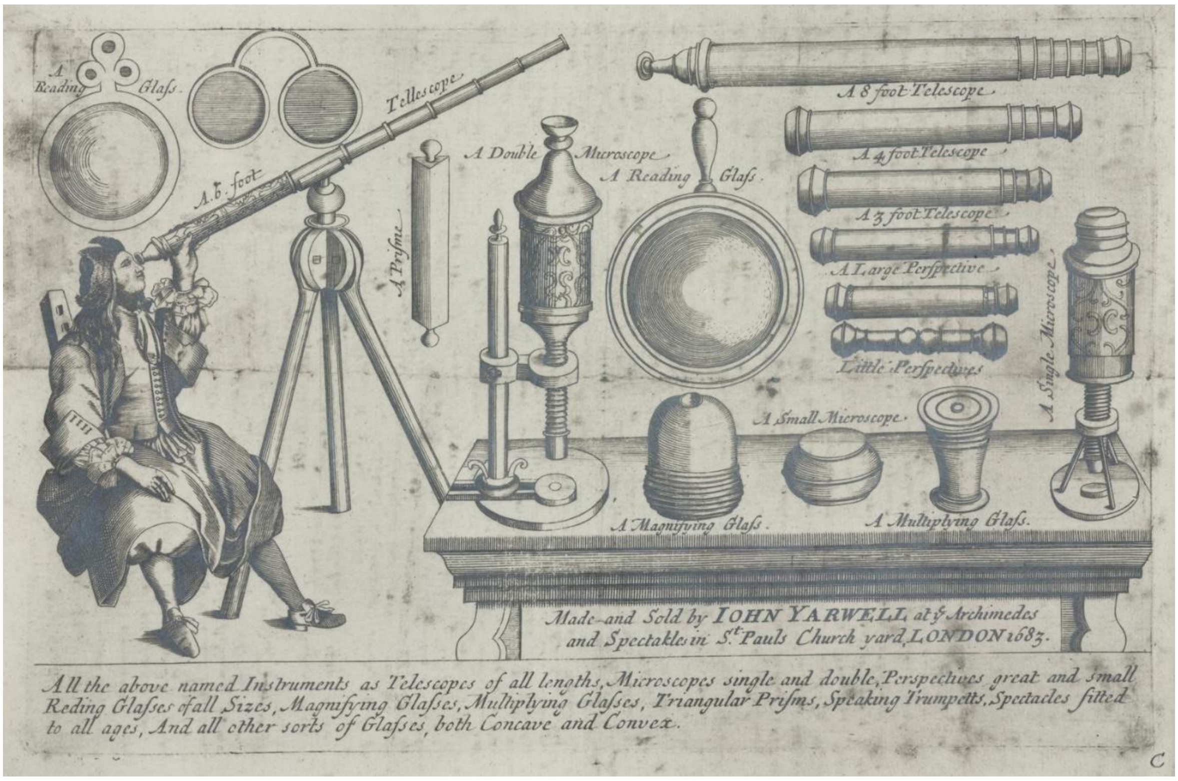

Illustration 40: Trade Card: John Yarwell, 1951-687/45, Science Museum Group Collection

The objects are depicted, with their names next to them: ‘A Reading Glass’, ‘A 8 foot Telescope’. This indicates an evolution in business practice. In the early 1680s, Yarwell felt it necessary to include images of the objects he made and sold to potential clients with visual references; as the result of growing demand and possibly the use of such prints to a selected clientele, by the late 1690s, it was possible to refer to them by name only to these discerning customers. A second evolution can be observed with the replication of the visual shop sign. Whilst the 1683 piece refers to Archimedes as part of the name of Yarwell’s shop, it is not entirely clear whether the seated figure is indeed the famed classical writer. Robert Whipple considered this possibility in 1951, when the original version was found amongst a collection of Isaac Newton’s papers and sold at auction.[386]

[386] Robert S. Whipple, ‘John Yarwell or the story of the trade card’, *Annals of Science* 7 (1951): 62-69.

Whipple concluded that it was very similar to an earlier engraving of Johannes Hevelius. Recent authorities including Bryden and Simms believe the image was a direct re-use from Yarwell's engraver of an image of Hevelius used for his 1673 work *Machina Colestis*, but the engraving was reversed and enlarged, and they describe it as an almost perfect 'mirrored' image.[387] They note too that the new image was clean shaven, with minor adjustments to the waistcoat as well.[388] Even though there is consensus that the image of Hevelius was a replication, the length of time between images and the fact the image has been slightly changed, reversed and enlarged, all make it seem that the original image was used but with a different purpose. It could be that Yarwell may have intended this to be himself, or a gentleman philosopher, or perhaps even Charles II.

The important change was that whilst in 1683 Yarwell needed to show customers the new and novel experimental instruments that he made and sold, a decade later he merely had to tell them, and this he did through the association of his shop sign. This points to changes in consumer knowledge and behaviour, as well as the growth in Yarwell's business.

Willdey and Brandreth

Alexi Baker's research looks at George Willdey and she too notes that he conformed with a shop sign and name that incorporated Archimedes. Much remains unknown about the

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[387] D. Bryden & D. Simms, 'Trade Ephemera, Archimedes and the Opticians of London', *Atti Della Fondazione Giorgio Ronchi Anno LXII* 6 (2007): 797-838
[388] Ibid.

instrument maker's early life. In a career spanning over forty-two years, Willdey is estimated by Baker to have made and sold over one thousand spectacles and optical instruments.[389] An apprentice to Yarwell, Willdey gained his freedom in 1702 and decided to set up his own workshop on Ludgate Street, with his associate (another freed apprentice) Timothy Brandreth; they operated 'under the sign of the Archimedes and Globe near the Dog Tavern in the middle of Ludgate Street', and used their newspaper advertisements and printed ephemera to publicise the arrival of their new business, which was quickly successful.[390] Baker's thesis and subsequent work includes estimates from the accounts of Willdey's shop and argues that barter and exchange between differing socio-economic ties was an important part of his trade.[391]

The print by Willdey and Brandreth is held in the Science Museum Collection, as are some printed and cut out advertisements labelled as trade cards. Their ephemeral piece, however, not only uses the same motif as Yarwell, that of Archimedes with using a telescope, but is set out in the same way, with a comparable positioning of image and text (although in Willdey and Brandreth's case there is considerably more text than Yarwell's) and appears remarkably similar. Baker notes that a 'trade card war' subsequently broke out between Yarwell, Willdey and Brandreth over the use of the image of Archimedes. It may not be the case that the choice

[389] Alexi Baker, 'This Ingenious Business: the socio-economics of the scientific instrument trade in London, 1700-1750' (doctoral thesis, University of Oxford, 2010), 254-55.
[390] Alexi Baker, 'Symbiosis and Style: the Production, Sale and Purchase of Instruments in the Luxury Markets of Eighteenth Century London', in *How Scientific Instruments Have Changed Hands*, ed. A.D. Morrison-Low, Sara J. Schechner & Paolo Brenni (Leiden: Brill, 2017), 1-20.
[391] Ibid.

was deliberately to rival Yarwell, but instead they conformed to a more accepted, wider-known association with the classical author and optical instruments.[392]

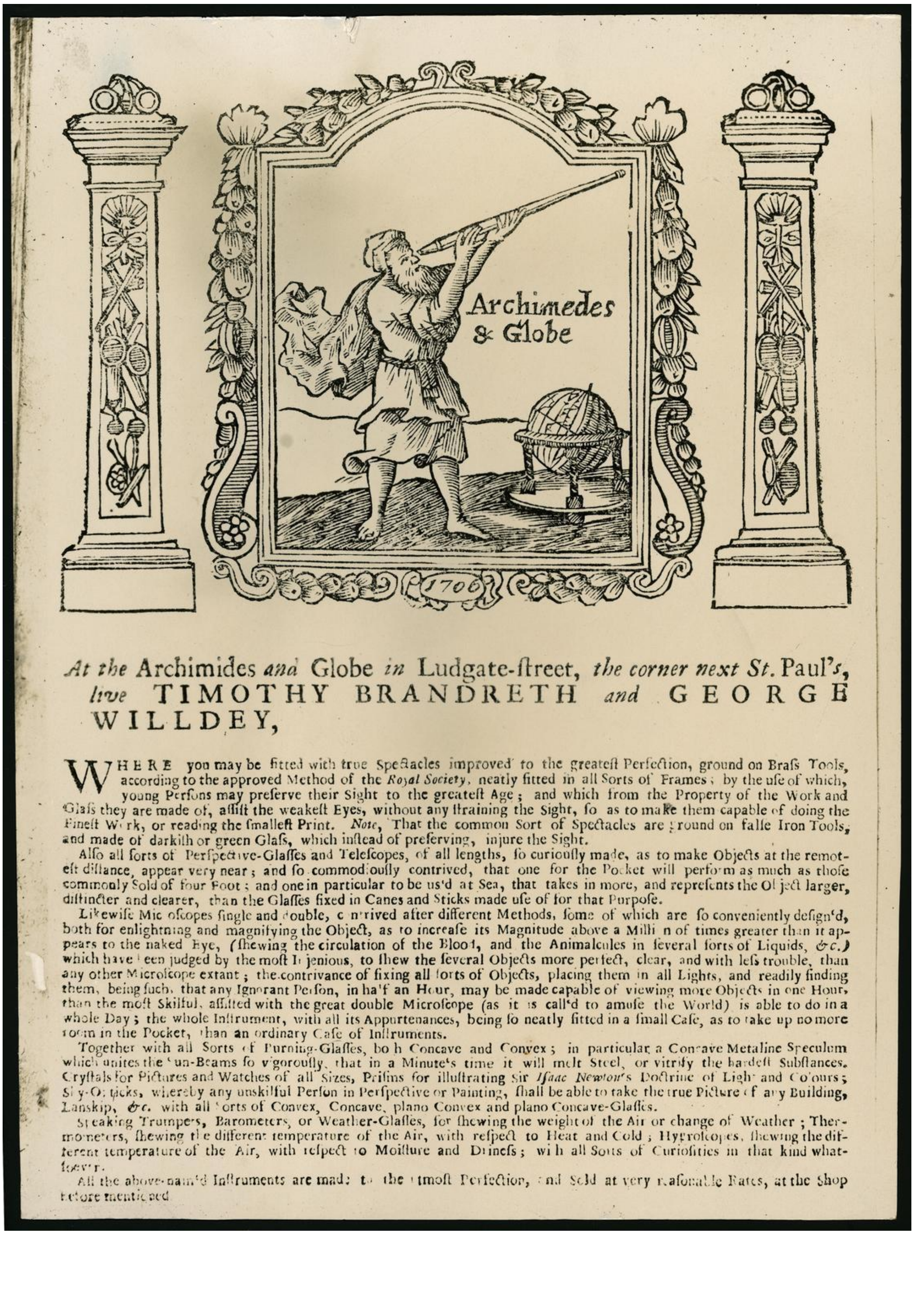

Illustration 40: Trade Card: George Willdey and Timothy Brandreth, 1951-687/41, Science Museum Group Collection

[392] Baker. 'Symbiosis and Style'.

The version of this print in the Science Museum is noted in Calvert's catalogue but is once again a photographic reproduction. Evidence from the photograph suggests this was a page in a book or periodical. On the right side adjacent to the main text and image, letters unconnected to the piece can be observed. Reminiscent of Yarwell's print, this cut out advertisement contains the word Archimedes, written next to the human figure, observing the heavens through a telescope and pointing in the same direction. He is accompanied by a globe and not, as with Yarwell's image, under his arm, but rather at his feet. Both of Archimedes' hands are depicted holding the telescope, no telescope stand or mount is required, indicating strength, dynamism and focus on the instrument itself.

These may have been the characteristics that the new makers themselves wished to present. There are fewer royal allusions than with Yarwell's image (coats of arms are absent) but the floral decoration around the image is consistent with earlier pieces, and so too are the Roman columns adorned on each side, this time, packed with other types of instruments.

Illustration 41: Detail of: Trade Card: George Willdey and Timothy Brandreth, 1951-687/41, Science Museum Group Collection

The inclusion of two spectacles atop each column is not just a sign that these men are optical instrument and spectacle makers by training, but a hint at the name of Yarwell's workshop. Heal says that it was '…quite common…for a young tradesman starting on his own account to add to his own sign that of the master he had served'; although how often permission was required for this practice is not known. The spectacles are positioned moderately differently from Yarwell's. It is presumably for these reasons of similarity that a 'trade card war' began between the two workshops. The opening wording on this cut out advertisement does not exactly seem peppered with originality, when compared with Yarwell's earlier phraseology:

> 'Where you may be fitted with true Spectacles improv'd to the greatest Perfection, ground on Brass Tools, according to the approv'd Method of the Royal Society,

> neatly fitted in all sorts of frames, by the use of which, young Persons may preserve their sight to the greatest Age'.[393]

This is similar to Yarwell. In a modified listing of objects for sale that differentiates the Willdey-Brandreth business from Yarwell, every paragraph in the long text focuses on a different type of object for sale, with the names of each standing out in upper case letters: telescopes, microscopes, burning glasses, crystals for pictures and watches, speaking trumpets, globes, maps, cases of mathematical instruments, load-stones, and finally 'all sorts of curiosities'. Indeed, in the advertisement, Willdey and Brandreth presented their shop more for the curious, rather as makers of astronomical and optical instruments used alone. The final words of the document confirm this:

> 'All the above-named Instruments and Things, are made to the utmost Perfection, and sold at very reasonable rates at the shop before-mentioned, *Note*, That no one shop in *London* hath the like of all sort of these Curiosities'.[394]

Hooke amongst others, is known to have become critical of the change in status of optical instruments from the 1690s, in particular the use of items without serious application by amateurs.[395] Hooke's 1690s *Discourse Concerning Telescopes and Microscopes* focused on this very gripe.[396] Typifying this trajectory of instruments that moved towards being used as novel or curious items, the Willdey-Brandreth advertisement includes an eclectic, in some

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[393] Trade card for George Willdey and Timothy Brandreth, London, England, 1707-1711. 1951-687/41. Science Museum Group Collection.
[394] Ibid.
[395] Catherine Wilson, 'Visual Surface and Visual Symbol: The Microscope and the Occult in Early Modern Science', *Journal of the History of Ideas,* 49, (1988), 85-108.
[396] Adam Max Cohen, *Technology and the Early Modern Self* (New York: Palgrave, 2009), 145.

ways unrelated, mixture of saleable items. Indeed, Baker's research shows that in 1712, Willdey described his occupation as 'toy maker' at the time he took out his Sun Insurance policy application.[397] This variety is proclaimed as the important part of the notice for the reader; their shop, Willdey and Brandreth wrote, is unlike any other in the capital. The claim was a bold one, although its place at the very end of a long piece of text, and the fact it is accompanied by a replication of the format and image of the Yarwell piece also makes it seem a rather timid claim. It is conceivable that the new makers were keen to harness business immediately and make a name for themselves by equating their work with the aforesaid Yarwell.

Another intriguing aspect that separates this example from the portable pieces of print is the reference to cost. Without detailing the exact pricing of their pieces, the phrase 'reasonable rates' is similar to the one used by John Marshall in the 1693 printed advertisement referenced earlier. A survey of newspapers shows that or advertisements in early modern science, affordability was a common theme.[398] It seems that whilst the 'cards' exchanged did not contain reference to precise costs, for they were given to an already selected and discerning clientele. Mass advertisements in printed texts such as newspapers made reference to 'reasonable rates' or low costs.

This was so as not to put off potential customers who may have previously not bought such objects. Whilst they can be seen as forms 'marketing apparatus' they also targeted the elite, according to Cox.[399] The claims that the small papers on instruments made were more

[397] Baker, 'Symbiosis and Style', 13.
[398] Jeffrey Wigelsworth, 'Bipartisan Politics and Practical Knowledge: advertising of public science in two London newspapers, 1695-1720', *British Journal for the History of Science* 41, no. 4 (2008): 517-540.
[399] Cox, 110.

descriptive of the actual objects, and how they were made, rather than the claims made in other advertisements such as the Anodyne Necklace, designed to seduce the 'gullible' with their claims.[400] In some cases it is apparent that the portable advertisements were exchanged as part of the transaction, with the instrument or upon commission. Nonetheless, this is all in contrast to printed advertisements to speculative customers via the still new medium of newspapers.

Makers at War – An Example of How Newspaper Advertisements Differed

It may have been the similarities in presentation that set off the subsequent 'pamphlet war' between the rival workshops. The known deviser of the Royal Society approved grinding method was John Marshall, rather than Yarwell. This did not preclude Yarwell from considering himself an 'owner' of the method, as well as to the skills and knowledge he passed down. In comparison with other so called 'pamphlet wars' in the fields of early modern medicine and quackery, the exchanges between Yarwell and Willdey and Brandreth were tame. The claims to success for instrument making rested on a consumer's interaction with a physical object and this may too have meant that testimonials needed not to be featured as frequently.

Compared with other episodes (such as the long pamphlet war between Christopher Merrett and his allies against apothecaries in the 1660s) these disputes were more personal, contained

[400] Francis Doherty, *A Study in Eighteenth Century Advertising Methods – the Anodyne Necklace* (Lampeter: Edwin Mellen Press, 1992), 3-4.

and the battles were over within a shorter timeframe.[401] Advertisements in printed newspapers were used for a markedly different task than the printed portable advertisements handed to customers in the same way as tickets. Based on research into the *Burney Collection* of eighteenth-century British newspapers for this thesis, multiple advertisements from the rival workshops have been found.[402] Hundreds of newspapers were examined, and the selections in this chapter give the most revealing insight into the identity and presentation of instrument makers. These advertisements were directed at fellow makers, and published across 1707 in the *Daily Courant*, *Post Man, Post Boy, English Post with News Foreign and Domestick*, and these were no doubt reproduced in other provincial or trade publications.[403] Whereas the *Post Boy* published some one hundred and ninety-six advertisements in 1696, by 1700 this had almost doubled to three hundred and sixty.[404]

The earliest advertisement found from Willdey and Brandreth, appeared in the *Daily Courant* on 22 February 1707. Comprising seventeen lines, the text begins with their names and location:

> 'George Willdey and Timothy Brandreth, now living at the Archimedes and Globe in Ludgate-Street the corner next St Paul's, who serv'd their Apprenticeships to Mr Yarwell and Mr Stirop, and since for Several Years have made for them and Mr Marshal, but now make for their own Sale, those Incomparable Spectacles and

[401] Patrick Wallis, 'Competition and Cooperation in the Early Modern Medical Economy' in *Medicine and the Market in England and Its Colonies, 1450-1850,* ed. P. Wallis & M. Jenner (Basingstoke: Palgrave, 2007), 62.
[402] The collection can now be searched in combination with the British Library's own database of British newspapers which focuses on the nineteenth century online: https://www.bl.uk/collection-guides/burney-collection/
[403] For statistical analysis on the cost and reach of advertisement and on newspapers sold and circulated during this time: R.B Walker, 'Advertising in London Newspapers 1650-1750', *Business History* 15, no. 2 (1973): 112-130; A. Aspinall, 'Statistical Accounts of the London Newspapers in the Eighteenth Century', *The English Historical Review* 63, (1948): 201–232.
[404] Jeremy Black, *The English Press 1621-1861* (London: History Press, 2001).

> Reading-Glasses that are ground on true Brass Tools, according to the approv'd method of the Royal Society.'[405]

The advertisement goes on to list the other instruments the two produced for sale and concludes with confirmation that they sold '…several other Instruments at Reasonable Rates'. Immediately, the noted difference of printed classified advertisements referring to expense compared to the portable prints is apparent. The advertisement announced George Willdey and Timothy Brandreth: their names appear in a typeface twice the size of the full text. The advertisement was in a sense an announcement that their workshop was open. They also sought to persuade the readers that they were no amateurs (and perhaps as good grace): they credit both Yarwell and Marshall, but tellingly praise neither with the famed Royal Society method that both had long claimed and fought for recognition for. The same advertisement was reissued in the following Wednesday's *Daily Courant*, but almost a month later a different, longer advertisement appeared.[406]

This advertisement is not a procedural announcement that they had moved workshops: the word 'now' is dropped from the opening line and the expanded text made bolder claims on their combined contribution to Yarwell and his assistant Sterrop's success, with the claim that during their apprenticeships, they:

> '…did bring to Perfection for them, by our own Industry, the New Method of Grinding on Brass Tools, which hath been approv'd of by the Royal Society; and we

[405] Classified Advertisements. *Daily Courant* (London, England), Saturday, 22 February 1707; Issue 1515. 17th-18th Century Burney Collection Newspapers.
[406] Classified Advertisements. *Daily Courant* (London, England), Wednesday 26 February 1707; Issue 1518. 17th-18th Century Burney Collection Newspapers.

> were wholly imploy'd in making the Best sort of Spectacles, Reading-Glasses, Telescopes, Microscopes, and Perspective-Glasses; by which they gain'd a great Reputation…'[407]

Perhaps their first advertisements had not worked as well as they had hoped, but whatever the motive of the two makers, this advertisement makes clear that they were the technicians that worked on the instruments sold by Yarwell and it was their skills and knowledge that was employed. Building on this theme of technical competence and ingenuity, Brandreth and Willdey then go on to say that

> '…since we have kept Shop for ourselves, we have contriv'd, and now brought to Perfection a new Microscope, that is both Double and Single, adapted for all Objects, and 'tis computed that it magnifies them more than Two Millions of Times' [408]

This is very different to their 'trade card' in the Science Museum. Whilst it is imperative to take early modern claims on lens magnification very carefully, the fact that both were keen to demonstrate their own skills and knowledge with an entirely novel object provided them with a measure of differentiation from their former masters. Furthermore, when coupled with the earlier words on their 'own industry' they appear to be putting forward a claim to where the real skill and ingenuity lived with: themselves. In a sign that this attempt at owning the credit for the success of Yarwell's business was prompted by others, perhaps even Yarwell himself, the advertisement continues that 'Also we do protest we pretend to no Impossibilities, and

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[407] Classified Advertisements. *Daily Courant* (London, England), Monday, 24 March 1707; Issue 1594. 17th-18th Century Burney Collection Newspapers
[408] Ibid.

that we Scorn to impose on any Gentleman or others, but what we Make and Sell shall be really Good'.[409]

They end with news of their development of a telescope whose viewer could see up to six miles away. They also say that they were '…modestly Speaking… now writing a Small Treatise, with the Advice and Assistance of the Learned' on how the telescope and other optical instruments worked, '…which will speedily be finished, and given (Gratis) to our customers'. Such prints with claims to superior knowledge by experts were routine in the early modern period, and much like the vastly circulated justifications and explanations for the Anodyne Necklace, or Anderson's Pills, they were often filled with claims from known works of fiction and non-fiction. In comparison with the gentle language of the portable print, these advertisements were written in a brasher tone, indeed the latter example from 24 March 1707 reads as a form of defence, but to whom or what is not clear.[410] A surviving advertisement or print from Yarwell attacking his two former apprentices before this date has not been found. However, it may well be this advertisement, which was also reprinted in an edition of the *English Post*, that led Yarwell to respond.

On 16 April 1707, John Yarwell responded to the two challengers in his own classified advertisement in the *Daily Courant*. It was both a defence and an attack.

> 'By John Yarwell and Ralph Sterrop, Right Spectacles, Reading and other Optick Glasses, correctly ground on fine Brass Tools, in the newest Manner, and with the Universal Approbation of the Royal Society, were first brought to Perfection by our

[409] Ibid.
[410] Classified Advertisements. *English Post with News Foreign and Domestick* (London, England), Monday, 31 March 1707; Issue 1014. 17th-18th Century Burney Collection Newspapers

> own proper Art, and needed not the boasted Industry of our Two Apprentices to recommend 'em to the World; who by fraudalently appropriating to themselves what they never did, and obstinately Pretending to what they can never Perform, can have no other end in view, than to astonish the Ignorant, impose on the Credulous, and to amuse the Publick.. For which Reasen, and at the Request of Several already impos'd on, as also to prevent such further Abuses as may arise from the repeated Advertisements of these Two wonderful Performers, we John Yarwell and Ralph Sterrop do give Publick notice […]'.[411]

At which point, the two list the objects their workshop was capable of supplying. Attacking a rival in such a personal way was nothing new amongst those involved in the new sciences; Samuel Morland certainly lacked diplomacy in his attacks on others, including Isaac Newton, in the introduction to his 1679 *Doctrine of Interest*.[412] Newton was criticised for his 1667 book on the same subject which Morland complains was 'full of mistake and errors', in a list that identified other offenders.[413] Yarwell and Sterrop show a similar lack of tact later in their text when they admonish the 'extravagant Vanity' of Willdey and Brandreth before ending with the notice that all the instruments and curiosities produced by Yarwell and Sterrop are '…at Reasonable Rates, fairly and honestly'.[414]

The contrast that Yarwell draws between himself and his new rivals highlights honour, trust and probity. Again, in keeping with the style of advertisements generally in highlighting 'reasonable rates', it differs from Yarwell's portable prints. The prints, with their classical

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411 Classified Advertisements. *Daily Courant* (London, England), Wednesday 16 April 1707; Issue 1613. 17th-18th Century Burney Collection Newspapers
412 Glaisyer, 694.
413 Samuel Morland, *The doctrine of interest, both simple & compound* (London, 1679)
414 Ibid.

imagery and projection of grandeur, was in clear contrast to this more direct, unsubtle and in part scathing personal attack on Willdey and Brandreth. For seventeenth-century optical instrument makers, it seems, business was sometimes personal, but played out publicly in newspapers.

Like the trade 'cards', Yarwell's printed advertisement drew the reader's attention to who had worked upon the lens grinding technique 'first'. In this case, he was correct to say that it was himself that perfected the method ahead of Willdey and Brandreth, whilst casually ignoring the fact that his own, earlier, rival John Marshall was the rightful 'owner' of the letter of approval from Hooke and Huygens at the Royal Society. The advertisement appeared again on 18 April 1707 and 22 April 1707 in the *Daily Courant*.

It did not take long for Willdey and Brandreth to respond. On 25 April 1707, they decried being 'notoriously abus'd' by Yarwell, Sterrop and by John Marshall.[415] A printed attack by Marshall has not been uncovered and these may have circulated elsewhere, perhaps as posters in coffee houses, or flyers. In a sign of damage limitation, or awareness of the potential negative effect that a vitriolic response may have had, the two makers rebutted the slurs and insults levelled at them by Yarwell and Sterrop, by claiming that:

> '…now they being envious at our Prosperity have publish'd Several False, Deceitful and Malicious Advertisements, wherein they assert that we cheat all that buy any of our Goods, and that we pretend to many Impossibilities and impose on the Publick'.[416]

[415] Classified Advertisements. *Daily Courant* (London, England), Friday 25 April 1707; Issue 1621. 17th-18th Century Burney Collection Newspapers
[416] Ibid.

It is a sturdy, polite and measured response to the previous attack before leading to a long list of instruments being made, worked on and supplied. The defence is that whilst they may appear 'astonishing' creations, the two makers were not liars. In a direct challenge to a perception that Yarwell may have been protecting his supposed duopoly with Marshall on the sale of telescopic lenses at this time, they end the advertisement with the standout phrase: 'Let Ingenuity Thrive'; indicating that Yarwell's attack was a hindrance not only to their workshop and business, but also to the overall progression being made with optical and other experimental instrument makers. There is an implication too that they were for a wide benefit. The allusion to the 'ingenuity' typified by Robert Hooke is noticeable too for its succinctness and its resemblance to a form of slogan, or branding.

Willdey and Brandreth's 1 May 1707 advertisement went further still, and opened with the hyperbolic, and one might have thought desperate, line: 'The naked Truth Still defended by G. Willdey and T. Brandreth…', whereby they then complain that in a prior advertisement, Yarwell equated his former colleagues to 'Mountebanks', a term frequently used in lieu of 'charlatan' which held historical connotations to public sellers of patent medicines in England.[417] They further claimed that in the quest to find the perfect lens grinding technique, it was Willdey and Brandreth's own 'Patience and Industry' that provided the breakthrough: a contestable claim given Marshall's work. They moreover state:

> '…it is to be observ'd that when Mr. Yarwell left off he would have turn'd over his Apprentice to Mr Stirop his tenant, but the Lad had a great desire to learn the new

[417] Classified Advertisements. *Daily Couran*t (London, England), Thursday 1 May 1707; Issue 1626. 17th-18th Century Burney Collection Newspapers

> Method, and to that end-would be turn’d over to us, and lives with us at present: All of which is sufficient to convince that it was never perfected by their Art, and show that all they have said against us is Envy and Malice’.[418]

In tone and language this was the most critical and personal of Willdey and Brandreth’s advertisements from this episode. They directly challenged Yarwell’s behaviour and conduct. Upping the stakes, literally, they even offered their competitors a wager, on the to-and-fro boasts, on who made superior telescopic lenses:

> ‘We G. Willdey and T. Brandreth will lay 20 Guineas to their 10 that neither they nor Mr. Marshall can make a better Telescope than we can, and we do protest that those things they call impossibilities are very easy to be done. Let Ingenuity thrive.’[419]

Two days later on 3 May 1707, Yarwell responded once more: ‘Mr Wildey and Brandith [sic] have the folly to believe that abundance of Words is Sufficient to gain Applause and therefore throw ‘em out with regard to Truth or Reason’.[420] Towards the end of the advertisement, or diatribe, they write: ‘The Secrets they brag of is all a falsehood, and the Microscope the same that any one may have from Culpeper who is the maker’.[421] It is hard not to read this as an insult to Culpeper as well as Willdey and Brandreth, but perhaps Yarwell was defending the trade of optical instruments as a whole from what he saw as the pretenders, or liars. There may have been perceived to be a resultant threat to the prestigious

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418 Classified Advertisements. *Daily Courant* (London, England), Thursday 1 May 1707; Issue 1626. 17th-18th Century Burney Collection Newspapers

419 Ibid.

420 Classified Advertisements. *Daily Courant* (London, England), Saturday 3 May 1707; Issue 1628. 17th-18th Century Burney Collection Newspapers

421 Ibid.

name he and other instrument makers had accumulated over the preceding three decades in central London. The worst insult is hidden mid-way through the piece and refers not to the previous themes of truth, training, skill or honesty, but class, a possible last resort:

> ‘And therefore the Lye is all on his Side, and the impossibility in his pretensions is as strong as ever, and what we have said is just Truth, and his foul Language no better than Billingsgate Railing’.[422]

For Yarwell, the two men were not instrument makers, but no different to the lower class of market traders. In a cunning piece of editing, when the Willdey-Brandreth ‘wager’ advertisement of 1 May 1707, and Yarwell’s ‘Billingsgate Railing’ advertisement of 3 May 1707, were scheduled for reprint on Tuesday 3 May, they appeared not only on the same page of the classified advertisements in the *Daily Courant*, but with Yarwell’s preceding Willdey’s. Records of advertisements by Willdey from a later period (1717-1720) survive in greater number and, long after Yarwell’s heyday, contain few personalised insults.[423] Whilst entertaining to a twenty-first century reader, these exchanges demonstrate the enormous difference in tone, style, purpose and outward presentation that existed in newspaper advertisements and portable prints. It re-enforces the idea, stated at the outset, that it is not desirable to classify printed ephemera as ‘advertisements’ without moderating the definition. Advertisements printed in newspapers had a different function, and resultant different presentation of self and business, to the personal, portable prints handed directly to clients. But this, and the photographic reproductions are not the only anomalies to the category of ‘trade cards’ within collections.

[422] Ibid.
[423] Wigelsworth, ‘Bipartisan Politics’, 537.

Edmund Culpeper

Edmund Culpeper is thought to have been born in 1670, and he became active as an optical instrument maker in the 1690s, after he first trained as a mathematical instrument maker. He then worked on creating instruments until his death in 1737. As well as surviving optical instruments, the Science Museum collections holds pieces of ephemeral print that can be attributed to Culpeper. Part of the evolution of these portable prints from marks of exchange or tokens and tickets towards use as memos, souvenirs or bills can be observed with the example of a 'trade card' of mathematical and optical instrument maker Edmund Culpeper. Culpeper's shop sign was well-known in the vicinity as that of the Cross Daggers and this is the image which takes centre piece in his square print.

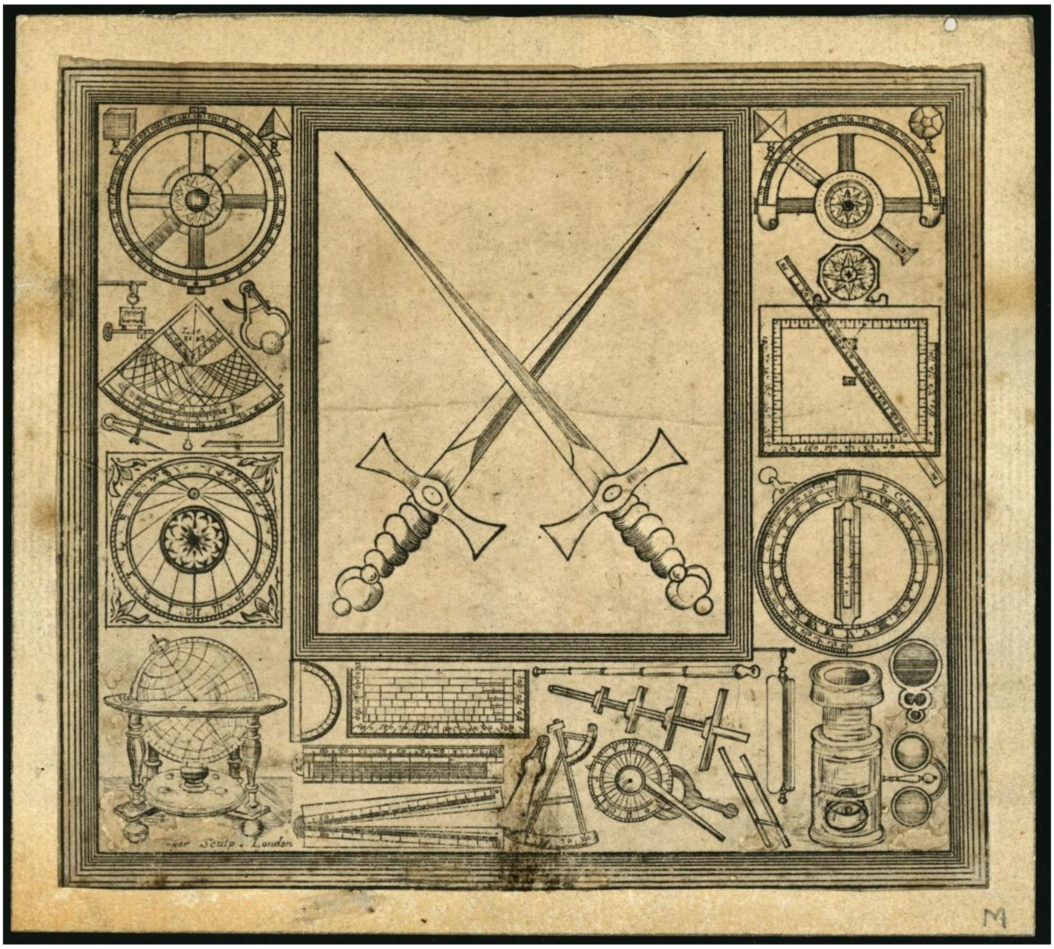


Illustration 42: Detail of: Trade Card: Edmund Culpeper, 1934-121/31, Science Museum Group Collection

Most of the instruments included on this piece are mathematical and trigonometrical. As with other makers of surveying devices, Culpeper also appeared to have sold globes, evidenced from the inclusion of one in the bottom left corner of the paper. He may have made these himself, although his background in instruments means it is possible he sourced these elsewhere and sold them on to accompany his terrestrial telescopes, and maybe surveying objects. Underneath this, the partially obscured inscription '[...]eper, Sculp. LONDON' is visible. Clifton's Directory lists that the Cross Daggers sign, and name was used by Culpeper from 1700, until the 1730s (he died in 1737).[424] As the piece includes only mathematical objects, not the optical instruments that Culpeper and his similarly named successors would also work on, it seems that this piece of print may have been used from the earlier years of Culpeper's business, and he is known to have used this to paste on the back of instrument cases. Instead of the usual method of a central figure, Archimedes, or, as would become common later in the eighteenth century, Isaac Newton, Culpeper's piece only contains objects.

If we consider the composition of the image in the Culpeper 'card' (one of the multiple elements of formalism in art history), then the positioning and size of the crossed daggers is the main feature that draws the attention of the viewer.[425] Without context, the daggers would mean little, so it is fair to assume that this was given out at or near Culpeper's shop. The images, in formalistic terms, promote the shop by its sign, with the instruments surrounding it. Identifiable items include horary quadrants and a globe, visible in the bottom left corner,

[424] Gloria Clifton, *Directory of British scientific instrument makers, 1550-1851, Volumes 1550-1851* (London: Wilson edition, 2001).
[425] Bohdan Dziemidok, 'Artistic Formalism: its achievements and weaknesses', *The Journal of Aesthetics and Art Criticism* 51, No. 2, (1993): 185-193.

with some optical devices (although not telescopes) apparent in the opposite corner in the form of spectacles and magnifying glasses. There is no text on the piece, but unlike later ‘cards’ that have been attributed as bills or receipts, there is no blank space for Culpeper or a worker to write details of bill, payment or credit on.

The possibility that such pieces were used to write on the back cannot be fully discounted, although this example is blank. Instead, it is important to consider this print as a part of the evolution of the ephemeral prints in their function and use. Whereas earlier pieces by Yarwell, Marshall and others can be thought of as portable advertisements, but simultaneously marks of transaction and exchange, these are a bridge to the later use of the prints as bills and receipts. They have evolved, in Culpeper’s case, from being portable advertisements, to pocket reminders or souvenirs of the shopping experience.

They could also act as mini catalogues. Around the same time as Culpeper’s print, the instrument maker Thomas Tuttell produced similarly visual guides to his goods on a similarly sized print. Tuttell was born in 1674 and died in 1702. He operated close to Culpeper’s workshop, first at the ‘King's Arms and Globe at Charing Cross’ (between 1695 and 1702) but also near the Royal Exchange in Cornhill during the same years.[426] Tuttell’s short life means he has sometimes been omitted from studies into seventeenth-century instrument makers, but he was clearly something of an expert on the mathematical objects he created. In 1698, Tuttell published a book, entitled *The Description and Uses of a New Contriv'd Eliptical Double Dial*, ‘…in which he described a new form of analemmatic sundial which he had recently devised… the book also contains a description of the universal equinoctial ring

[426] ‘Thomas Tuttell’, Science Museum, accessed Feb 20, 2018, http://collection.sciencemuseum.org.uk/people/cp80213/thomas-tuttell/

dial.'[427] Tuttell was also a supplier to the royal court of novel items including magnetic playing cards.[428]

Perhaps because the mathematical and surveying instruments that Tuttell sold had longer histories than the newer optical instruments and were better known by sight by those who bought them, Tuttell's trade card is a visual catalogue of the items he could make for his customers. It may also be that given the specialised, practical nature of the mathematical and surveying instruments, that these were sold to a more discerning clientele than the sellers of curious items or 'playthings'. The objects are not to scale, as some of the globes in the top left demonstrate, and the trade card is often compared to a form of catalogue because the items are clearly numbered.

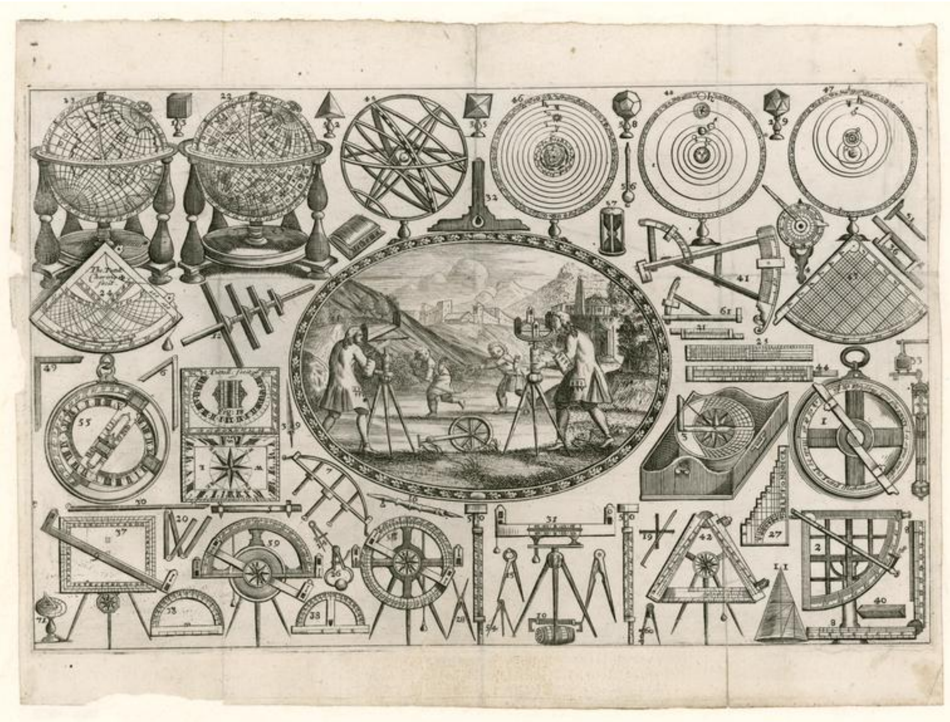


Illustration 43: Trade Card: Thomas Tuttell, 1934-123, Science Museum Group Collection. Image reproduced by permission of the Science Museum

[427] H.K. Higton, 'Thomas Tuttell', *Oxford National Dictionary of Biography*, published September 2004; accessed April 09. 2018, https://doi.org/10.1093/ref:odnb/49523

[428] Patricia Fara, *Sympathetic Attractions - Magnetic Practices, Beliefs, and Symbolism in Eighteenth-Century England* (Princeton, Princeton University Press, 1996), 31-34.

The paper is dominated by the circular scene engraved in the centre of the print, showing two men using surveying equipment, with a mountainous scene in the background with a sky above, hinting not only at the potential use for such instruments in practical terms (to the trained users at least) but also at the symbolic potential heights that surveying with the use of precision instruments made by Tuttell could achieve. The image also presents an image of the genteel nature of surveying: the two surveyors are gentlemen, wearing periwigs. The engraving of a building on the right with classical architecture is both a nod to the importance of learning and knowledge, but perhaps too of the emerging Enlightenment ideals. The mathematical instruments that Tuttell sold included drawing instruments, rules, surveying instruments, navigational instruments, timekeepers and models such as globes and armillary spheres. Altogether, Tuttell's projected image is different from that of Culpeper's, and from the historically inaccurate, but fun, image of Archimedes using a telescope favoured by Yarwell, Marshall and others, as noted previously.

In the eighteenth century the models used for demonstration came to be referred to as 'philosophical' instruments, with the term 'mathematical' used exclusively to mean instruments used in trade by surveyors and navigators. The instruments on Tuttell's 'trade card' are part of this wider category, and although like Culpeper he was a 'mathematical' instrument maker, it appears he focused on a closer, more specialised line of products than Culpeper (and others) did. The printed item on the next page is comparable to Culpeper's, but the inclusion of numbers, indicates this was a guide, and therefore had a different purpose. Culpeper's may too have acted as a visual catalogue, but it would appear unlikely that customers would visit his workshop and point at objects on a piece of paper without any label indicating their name, or number. In size and format there are similarities, but the differences lead to the conclusion that its purpose as an object must have been that it was exchanged. In Tuttell's case this would have likely been before the purchase, or could have been when a client visited one of his workshops, or a lecture or demonstration elsewhere.

However, one of the other items labelled as a 'trade card' in the collection, and attributed to Edmund Culpeper, is very different to any other in the Science Museum's archives. Leading authorities on trade cards do not mention a trade card similar to this and it does not fit into any of Calvert's four categories. At first approach this trade card seems to be like many others, especially of Culpeper's. The parts of optical instruments he made are depicted and labelled, with letters as a guide. However, this 'trade card' is not a card, nor can it even be regarded as a 'ticket', or portable advertisement. It is not a single, portable advertisement, but rather a sort of mini guide to saleable instruments, and this is contained within a small book, measuring no more than 7cm by 3cm, held together by the binding of a single string. The first page of this booklet is a title page and declares that it is for 'The Description and Use of a Set of Portable Microscopes Made and Sold by Ed. Culpeper at the Old Mathematical Shop, The Cross-Daggers in Moore-Fields'.[429]

[429] Trade card for Edmund Culpeper, London, England, 1700-1737c., 1951-685/19 Science Museum Group Collection.

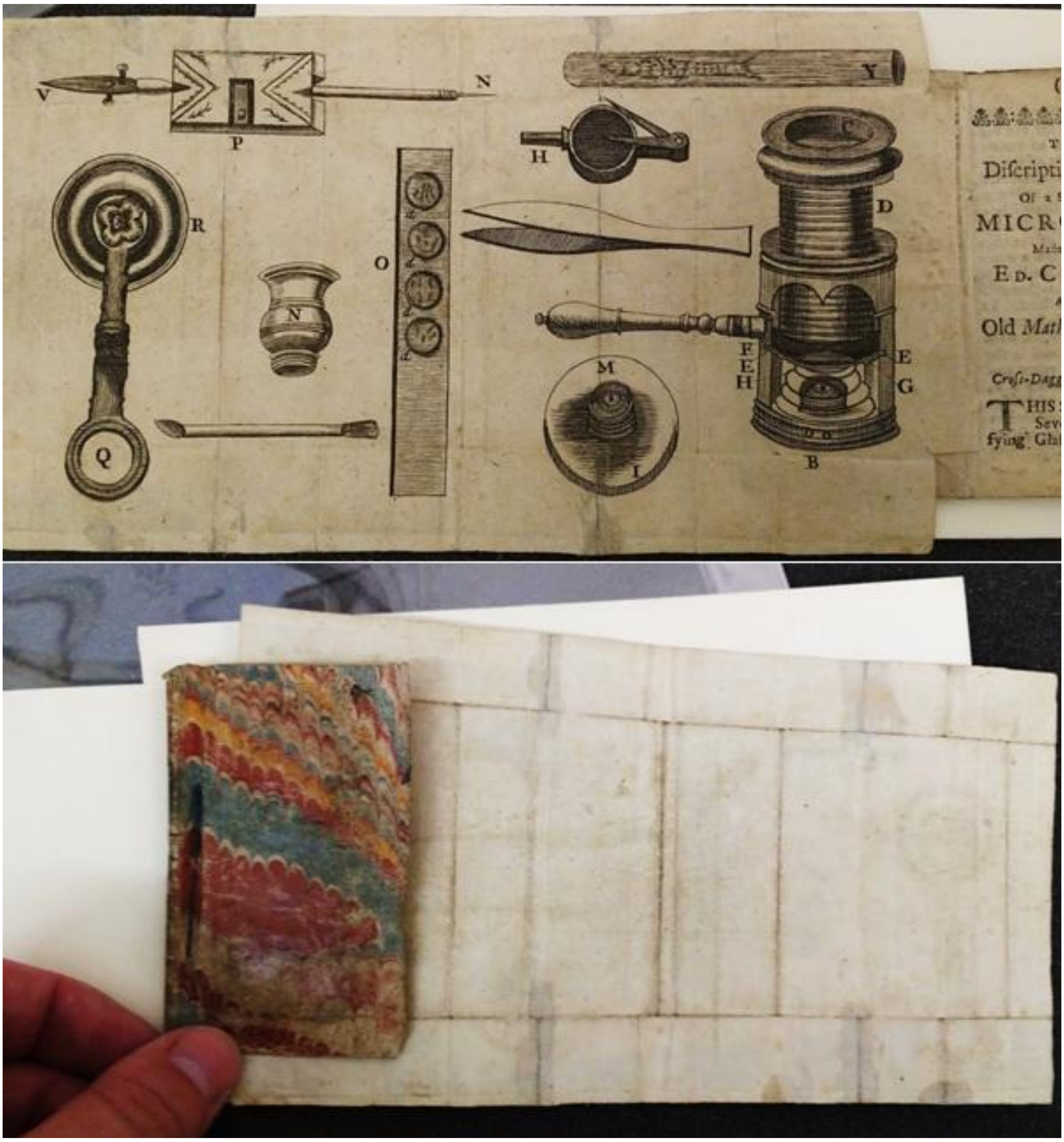
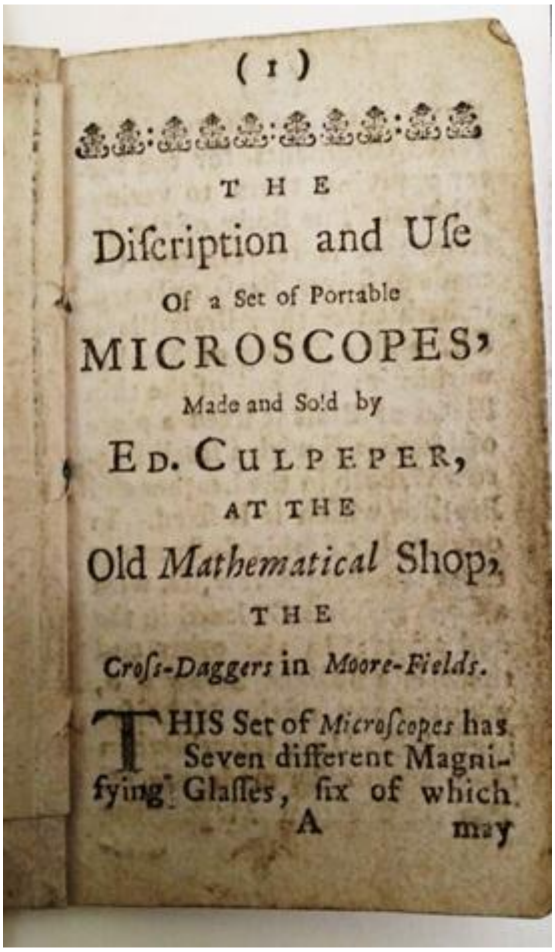


Illustration 44: Composite Image: Detail of: Trade Card: Edmund Culpeper, 1955-695/19, Science Museum Group Collection


(1)

THE

Diſcription and Uſe

Of a Set of Portable

MICROSCOPES,

Made and Sold by

ED. CULPEPER,

AT THE

Old *Mathematical* Shop,

THE

Croſs-Daggers in *Moore-Fields.*

THIS Set of *Microſcopes* has Seven different Magnifying Glaſſes, ſix of which

A may

Illustration 45: Detail of: Trade Card: Edmund Culpeper, 1955-65/19, Science Museum Group Collection

The page with the engraved instruments is a single sheet, similar in size to some other trade cards, such as Yarwell’s, although the fact it is contained within a book is strikingly different. It is a curious inversion of the Hayes approach to pasting pieces inside books (pages 17 to 19), this was attached to a small booklet. The booklet contains what we may consider ‘instructions’ for a set of microscopes. Some of the instructions are quite vague, which suggests that there may have been more than one instrument that this booklet accompanied. For example, on pages fifteen and sixteen, the owner is instructed to keep the microscope ‘…at its proper distance’, although how one would calculate or set this up is not explained. The booklet includes the drawing of a flea on page eight, no doubt in emulation of Robert Hooke’s *Micrographia* (1665). Some of the booklet’s instructions are not explicit, and this is a sign that for the makers and buyers of these instruments there was a shared, closed circle of knowledge and skill.

The booklet must have been given away (the assumption is without extra charge) to the purchaser of a set of microscopes, although the possibility that this was given to fellow tradespeople and makers of component parts cannot fully be discounted. It would be strange, when one realises the amount of paper, engraving and printing that this booklet comprises, if this had been given away for free to a *potential* buyer; it is a fair assumption to conclude it accompanied the sale of objects.

The printed booklet of directions for the user is not included in Calvert's categories, or indeed an artefact he mentions in his 1971 guide. How this came to be classed as a 'trade card' is unknown, but it is logical to assume it was partly due to the original collector, who was interested in the folio sheet attached to the booklet, with multiple component microscope parts engraved. It is known that prints were exchanged with instruments, and many experimental objects contained such guides to their use. Their inclusion in a collection of portable prints is misleading, however. Culpeper's booklet had a practical, different use, to the other portable prints that this chapter has contended with. It is further evidence of the immense difficulty that collectors, archivists and historians have faced when classifying ephemeral collections.

Collecting 'Trade Cards' – Objects or art?

The case studies analysed in this chapter reflect how the overall category of 'trade cards' is unstable. Museum and collection classifications could be altered, to better reflect the function of the individual pieces as physical objects. Calvert's 1971 guide drew out four classifications for his list on trade cards, but as noted in earlier sections, his intervention into curating and archiving the 'cards' was not taken up, Indeed Calvert himself does not assign the individual pieces into any of his four categories in his book. As objects, their classification could better reflect the eclectic mixture of pieces that the original collectors accumulated, and which have since been added to. One object from the nineteenth century, a copper engraved plate used for the printing of trade cards, is a rather different artefact than the actual cards, and this too is held within the ring binders.[430] This may have come from the collector. Subsequently, there is a difficulty in classifying a misnomer like this.

At the Science Museum, the 'trade cards' are classified under the term 'Art'. This chapter argues that the 'cards' constitute items rather than visual pieces only. This chapter makes the case that what are partly considered 'trade cards' are in fact a form of 'ticket' in both the sense of being an object and fulfilling part of the function of transaction. As objects, like the instruments, at the heart of exchange between maker and buyer, these prints can be considered artistic from a stylistic and engraving point of view. The fact that William Hogarth in the mid to late eighteenth century engraved a considerable number of such pieces and signed them himself at the bottom of the pieces has perhaps led curators and art historians to analyse them from an artistic and aesthetic point of view.[431]

This could be remedied by emphasising the role these pieces of paper had as objects and how this evolved. In small measure, it may be appropriate for the Science Museum to consider moderating their antiquated description of 'Art' to 'Print'; whereas art can be found in the

[430] 'Trade card: copper plate', 1987-242/1, Science Museum Group Collection.
[431] Jenny Uglow, *William Hogarth: A Life and a World* (London: Faber & Faber, 2001), 109.

realms of pastime and pleasure, the ‘trade were dedicated marks of transaction, interaction, as well as souvenirs. The Science Museum’s category could be altered to reflect the place of ‘trade cards’ in its wider collection and in the role of the manufacture, sale and use of early modern instruments.

The examples that were selected for this chapter were chosen because they are the most illuminating and appropriate pieces to highlight the changes in instrument making selling and advertising practices. The chronological evolution from early makers such as Hayes, through to later makers such as Timothy Brandreth and George Willdey can be observed the changing ways in which their businesses and items are presented to their customers. They also exemplify some of the issues with classification, archiving and storage that have been indicated in this museum collection and others. The changes between those texts and the printed objects in this study are marked and the case is made for a clearer division to exist between the act of advertising, and the function of these portable prints as objects of exchange.

It is likely too premature to declare that there was no such thing as a trade card. For collectors, curators and historians for much of the twentieth century, these collections have been broad, encompassing and eclectic mixtures of different types of print, for varied purposes and spanning vast date ranges. Instead, this chapter has evaluated the surprising ways that instrument makers presented themselves to their clients via portable prints compared to newspaper advertisements, and the relations this bore to their shop signs and business practices. What most ‘trade cards’ constituted, was a form of portable, printed advertisement. These were handed from maker to client and were visual representations of the business that acted as markers of transaction, souvenirs and their exchange was similar to the tickets emerging in multiple other areas. Calvert acknowledges their broad nature, but still sought to fit them into just four categories.

Conclusions

This chapter has taken a case study approach to examine various 'trade cards' of late seventeenth-century instrument makers to make five arguments. First, it is argued that these portable prints reveal much about the identity of instrument makers, and these identities displayed surprising degrees of conformity. This is evidenced by the use of similar shop signs and imagery, in particular the use of the name of the ancient scholar Archimedes to sell optical instruments. The reasons for this most likely stemmed from earlier classical allusions to the mathematician's supposed models of 'globes', but the trade came quickly to be synonymous with his name and image, as it was used by many makers.

Second, that historians' own understanding of 'trade cards' as a mere form of 'advertising' hinders our understanding of their function as objects of communication and transaction. This has been evidenced by direct comparison between newspaper advertisements and 'trade cards' from the early 1700s. The two have messages and tones that differ markedly, and they also differ in terms of length, reference to cost, and their brasher attacking of rivals. Unlike advertisements printed in newspapers, and periodicals, the portable prints undoubtedly were individual physical objects.

Third, that this difference in the items, away from the usual role accorded of prints and pieces of 'art' can be moderated, by emphasising the agency that makers and buyers had. Building on the earlier research of Lloyd on ticketing, this author believes that the 'trade cards' can be considered an early form of 'ticket'. However, the possibility of changing the overall names and categories is complicated by the long-standing name ‘trade card’ and by the eclectic collecting patterns of collectors. In agreement with the detailed, recent research by Baker, Scott and Hubbard, this chapter makes the case that individual purposes for different ‘cards’ can be analysed and recreated and that their purposes changed as the eighteenth century progressed.

Fourth, the Science Museum’s method of archiving, categorisation, cataloguing, display and use of trade cards should be modified to reflect some of the historiographical changes that affect the categorisation of the prints. Much of this work is due to take place with the ‘One Collection’ programme before 2023, which will see the modernisation and sophistication of the storing of all museum artefacts moving to the new National Collections Centre at Wroughton. This also gives us the opportunity for a modified classification for the individual items that have been accorded the name ‘trade cards’. There could also be a separation from the unhelpful category of ‘art’, and the reassessment of their function as objects.

Fifth, that the characteristics and content that the prints bore are emblematic of the changing ‘business of science’ and the growth of scientific instrument making in London. Whereas earlier prints were explanatory, labelled and visual, later pieces came to focus more on the name of the maker and the shop sign. Types of instruments that were new in the city, and in Europe, in the 1660s and 1670s, at a time when Pepys referred to ‘perspectives’ and ‘glasses’, a term also used by Yarwell in his earlier prints, by the 1690s, recognition and understanding of the terms ‘telescopes’ and ‘microscopes’ were adequately and routinely used to describe instruments, often without direct visual representation.

This is part of a wider pattern of the growth in their sale, the knowledge of buyers and the demand for such instruments. The increasing commercial nature of the prints, with early modern forms of slogan (such as ‘the Wright True’) and images (the Cross Daggers, or ancient figures) was itself part of the context of a growth in consumption of luxury, unusual and expensive items. We can assume why buyers saved some prints, and not others; likely a memorable shopping experience, purchased object or time. The cultural meanings contained within these exchanged pieces of paper contain a rich amount of information, some obvious, much that requires reconstruction, and that more research may yet uncover, of the early modern London trade in scientific instruments.

5

Conclusions

Through a range of objects made in London during the mid to later seventeenth century, this thesis has built the case that the material cultural approach can yield information about instrument making that cannot be obtained from the scarcer documentary evidence that is available. The wider social and cultural value and meaning of instruments can be uncovered through a focus on their materiality. As new technologies emerged in the early seventeenth-century, the meaning of ‘instrument’ changed. As a consequence of this, the meaning of being a ‘maker’ also changed. Instead of being produced and consumed for niche, practical and professional purposes, instruments crossed socio-economic boundaries. They began to occupy new places where they were marketed as desirable collectables, rather than as tools of calculation and application by those working in trades. By the end of the century, the widened consumer base, who were interested in instruments such as telescopes and microscopes for fun, curious, novel purposes, meant that London was the dominant market for instrument production. In the eighteenth century, this dominance would decline, although London remained a major market.

The varied material qualities that many of the surviving instruments in the Science Museum and other collections have reflects the contemporary changes to demand and taste. Each of these changes meant that what it meant to be a maker changed, as the makers themselves crossed social boundaries. In the second chapter, the thesis argued that a breakdown in the consensus of what constituted ‘mathematics’ and who could practice it, led to changes to instrument consumption and consequently who could make them. Debates about whether it was necessary to understand mathematical theory to make and use instruments led to the traditional division of forms of knowledge breaking down. In the wake of this, an emergent form of 'hybrid' maker can be observed. These makers positioned themselves increasingly as not only artisanal craftsmen with material knowledge and training, but also marketed themselves as authorities on mathematics or mechanics. Whether they had this knowledge is sometimes unclear. Uncertainties with who could be credited as the 'maker' are reflected in the objects. The physical producer or the designer (as in the case of Morland) the claims to credit lend support to this view of a fluid, changing landscape, where instruments and instrument making expanded beyond its traditional bases.

The implications on the working practices and the relationship between maker and mathematician therefore changed as the former division between forms of knowledge crossed over, so that by the end of the century instrument makers acted as 'hybrid' agents, who performed both roles of mathematical understanding and craft skill. Their knowledge and skill crossed into both forms. This had later implications on makers of instruments that were not 'mathematical' but optical. The practitioners of mathematics comprised a variety of agents, who consumed and used instruments for reasons linked to their occupations, education, institutions and for practical purposes such as in surveying. But the dissemination of mathematics to new groups of people, and the rejection by some that that training in mathematical theory was necessary for using instruments, both led to these demonstrable changes.

Makers from the mid-century such as Sutton, Hayes, Morland and then later makers, crossed the socio-economic boundaries that governed working practices between the traditional 'savant' and 'fabricant' where knowledge had traditionally been divided. The practice of publishing, selling and writing mathematical instrument pamphlets or books was just one sign of this crossover and that the assumed model of divided roles had begun to break down. These emergent ‘hybrid’ makers, who were highly skilled, were renowned for the objects they produced, but also publicised themselves as authorities on using instruments, or mathematics itself. In turn, this change in the concept of mathematics, instruments and who could make and use mathematical instruments expanded to other forms of instrumentation.

In the third chapter, the thesis argued that the growth in the later century of telescopes and microscopes meant they went from being instruments with applications that were practical, such as surveying and in warfare, as well as observational (astronomical), towards being marketed and consumed as ‘curious playthings’. From their origins in the very early part of the seventeenth century, telescopes first resulted in a ‘wave of discoveries’ in the words of Willach, but their application after the middle of the century changed. Made from the cheaper pasteboard, rather than the more expensive wood, these instruments were made for a widening client base, with different aims and ambitions.

The materiality of many of these surviving instruments, comprising a variety of materials, gives historians and curators today an unique insight into the context of seventeenth-century instrument making. The chapter presented new findings on the origins of a microscope’s pasteboard; the book from which it was made, and the edition, and commented on the possible connection between the maker and the bookseller. It was reflective of the ‘make do and mend culture’ of seventeenth-century England, where materials were often reused, repurposed or used for different purposes than they were initially intended. This included when books or newspapers were reused for their paper and turned into a pasteboard: such as for an optical instrument tube.

Aesthetic qualities such as the use of exotic and new materials, including shagreen, demonstrate the importance of these items being visually impressive and hint at their role as commodities for collection. Shagreen, as with the Isaac Carver instrument made from ivory that was referenced in the second chapter, reveal that the instruments' component parts often had hidden lives and histories that only a material approach can uncover. In the case of shagreen, made by the ancient practice of skinning and preserving ray or shark hides, and their transaction was only possible after the maritime and trade connections that the encroachment of Europeans made, into what they termed 'the New World', took hold.

The chapter also looked at the skills required for separate parts, the role of marking signatures or initials, the possible links to authority and authenticity that these suggested, albeit in an unregulated trade, and the purchase and use of these instruments by institutions such as the Royal Society. A number of different telescopes and microscopes of different size, and therefore portability, were analysed. They show that the use of optical instruments in the mid-seventeenth century was not only for practical application or for natural philosophy, but for domestic use and in the collections of cabinets of curiosity.

The fourth chapter examined a number of paper objects traditionally known by their label 'trade cards'. The chapter rejected this term as non-contemporary, and instead considered them as objects in their own right. As portable pieces of ephemeral print, they were in many ways akin to tickets, small pieces of paper that were exchanged at the time of purchase, as publicity or as a form of receipt. The visual and textual information recorded on many of these forms of print was an early form of advertising and highly revealing about the identity of makers, what objects they created and how they positioned themselves and their businesses to their consumers. By comparison with longer advertisements in newspapers, the chapter demonstrated how makers were keen to stress the multiplicity of instruments they were capable of creating, their royal connections, testimonials and how they often centred around accepted social ideals about instrument making (such as the use of classical figures as shop signs and on these prints). They show how, as the year 1700 approached, instrument making became increasingly likely to be promoted through the sale of telescopes and microscopes, rather than mathematical or mechanical devices. It is also clear from these prints that whereas someone such as Hooke could complain about instrumentation being reduced to 'playthings' (mentioned in the third chapter), makers actually used this as part of their positioning, with early eighteenth-century makers including Willdey and Brandreth promoting themselves as making toys, as well as instruments. This was to broaden their appeal.

In short, this thesis argued that across the seventeenth century, what constituted an instrument, and by consequence an 'instrument maker' changed over the course of the period. The trade in instruments became popularised to appeal to a new, larger and broader consumer base, who consumed instruments for reasons other than the traditional ones associated with mathematical theory and its application. As different forms of knowledge (craft, mechanical, mathematical, optical) crossed over, a change in the role of the maker was initiated. Objects were marketed and created with multiple purposes for this more popularised clientele, and the aesthetics and material qualities of many of the surviving instruments are evidence of this. They are also products of a wider consumer culture in a city that had new access to global markets, used recycled or unusual materials, and where instrument making encountered other trades such as printing, bookmaking and toymaking.

This thesis has advocated a new interpretation of instrument making and offered original new discoveries about different instruments, and how they were made. Future research may focus more on individual aspects such as investigating more telescope and microscope tubes and seeking to find which books they were made from. The importation of shagreen into England is not well-documented, but an analysis of more objects could yield further light into which parts of Asia these came from, as with ivory and Africa. However, the fundamental finding of this thesis has been the result of a material cultural approach: the objects that survive had individual lives (not necessarily agency) and that researching their materials and histories can uncover much about their original contexts, and explain how instruments were made, why and for whom. In summary, the culture of instrument making from the mid-point of the century, as evidenced by the instruments themselves, was opened up. In the words of Willdey and Brandreth, 'let ingenuity thrive' may summarise the attitude of new makers and the culture of instrument making that existed in London by 1700: it was open to anyone.

6.

Coda – Watchmaking and Future Research

'1. The World, according to our Author, is like a Clock; it is a Machine, says he, that moves of it self. God is the Author and Workman of this Machine, as the Clock-maker is of a Clock.

2. The Matter of the Machine of the World, as is that of a Clock, is Extent, or something extended, to which the Workman has given the Shape in which we see it; that is to say, the five Modes or Manners of being extended, as well in what relates to the entire Machine, as to each of the Parts that compose it.

3. The Machine of the World, as that of a Clock, has always the same Parts that the Workman compos'd it of.'[432]

'the Sieur C.P. Doctor of Physick', 1704

These words are attributed to a 1704 paper that linked watchmaking with the order of the natural world. The equation of the natural world order with a regulated 'machine' was not an original idea. Descartes compared biological organisms with artificial machines, and his ideas, as well as those of his contemporaries on this subject, are now the source of a considerable body of scholarship in the field of intellectual history.[433] It is striking that the author above explained that the mechanism of a clock was consistent and comparable with the order of nature, but in such a regimental way. This was done with a detailed understanding of the principles of spring-driven clocks, (a newer aspect of the technological side to timekeepers). It is not clear whether the purpose of the essay was to explain that for

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[432] "Histoire De La Machine Du Monde, Ou Physique Mechanique, i. e. an History of the Machine of the World, Or Physical Mechanicks." *The History of the Works of the Learned, Or, an Impartial Account of Books Lately Printed in all Parts of Europe* 6, no. 12 (12, 1704): 707-714. https://www.proquest.com/historical-periodicals/histoire-de-la-machine-du-monde-ou-physique/docview/5923179/se-2?accountid=15181.

[433] D. Des Chene, *Spirits and Clocks: Machine and organism in Descartes* (New York: Cornell University Press, 2001)

people to understand clocks they must first understand that they were similar in purpose and function to the natural world. Was it the reverse? What this sums up is that with watchmaking, a connection to motion and physics meant that they were linked to a branch of scholarship in the same way that mathematical or microscopic ones were to their fields. But the analogies made between how the objects worked and the natural world did was a difference. Historians tend to 'denigrate' the accuracy of clocks made before the seventeenth century, but it is the case that significant advances in design were made in the century.[434] These changes were the topic of much discussion at institutions such as the Royal Society, where work to understand advance physics was carried out. There were also advances taking place in watchmaking.

Therefore, in closing, this thesis considers an area for future research: the role of clock and watch making in London in connection to the production of other instruments. Some of the makers that featured less prominently in this thesis, such as Thomas Tompion and George Graham, worked as watch and clockmakers, as well as made instruments. There are two reasons that watches and clocks as objects were deliberately not included in this thesis. First, most of the instrument makers that featured predominantly in the project did not make timekeeping devices. Second, the lives, work and objects made by makers such as Tompion and Graham are, in the words of one museum colleague to me, 'already well-trodden ground'. However, in closing, it seems appropriate to consider how future research may integrate watchmaking and clockmaking with that of other instruments. Although the makers feature in directories such as Gloria Clifton's, watches and clocks (and their makers) seem to occupy an academic territory separate and individual to that of instrument making. It seems

[434] Paul Glennie & Nigel Thrift, *Shaping the Day: A History of Timekeeping in England and Wales: 1300-1800* (Oxford: Oxford University Press, 2011), 250

that watchmakers can be considered instrument makers by historians, but the status of watches and clocks as instruments is unsettled, and the status of 'watchmaker' stands out as somehow able to be considered both a branch of instrument maker, and simultaneously not.

This could partly be due to the financial value that is attached to horological items on the open market today. One only need look to Tompion to find the objects he created causing modern commercial interest. Robert Hooke's relationship with watchmaker Thomas Tompion has received much scholarly attention. This may be because for Tompion, unlike with fellow instrument makers from the seventeenth century, comparatively more is known by modern historians about his career and day-to-day relationship with Hooke, the Royal Society's Curator of Experiments. This is because of the references Hooke made in his Diary about this work with Tompion. It is also a likely consequence of the importance that antique collectors have attached to Tompion's name and work particularly since the early twentieth century. The sought after nature of Tompion timekeepers means that when Tompion items come up for sale, it usually generates headlines: one Tompion grandfather clock sold for a record £901,600 at auction in 2003.[435] For a watchmaker such as Tompion, historians have no corresponding manuscript evidence of his life and work in the same way that accompanying documents can be found for the instrument makers in this thesis; as Evans says: 'As far as manuscript evidence is concerned it is sad to report that not a single page of Tompion's handwriting has been found'.[436] This is surprising, given Tompion's importance to horology.

[435] Simon de Burton, 'The Market: Antique Clocks', *Financial Times*, Sept 3, 2011, https://www.ft.com/content/fb164fe4-d502-11e0-a521-00144feab49a accessed Dec 3, 2020.
[436] Jeremy Lancelotte Evans, *Thomas Tompion at the Dial and Three Crowns* (London: AHS, 2006), 40.

In museums and galleries, watches are sometimes kept apart from ‘instruments’ – at the Science Museum, the long-standing watchmakers gallery was not a part of the galleries for objects used for mathematics and observation. As well as the separate spheres that watchmaking and instrument making appear to today constitute in historiography, there is some evidence that this distinction was also a contemporary one. It is not necessary at this point to repeat well-known facts about trades and their companies. Instead, it is the way that makers identified and named themselves in other ways that may be a more illuminating insight. In 1700, a petition was ‘[h]umbly Represented to the Honourable House of Commons’ with regards to the supposed case of the nation being ‘defrauded, by the Exportation of Boxes, Cafes, and Dial-Plates for Clocks and Watches…’.[437] Submitted to defend English watchmaking interests from the practice of cases being shipped abroad to France and then being falsely inscribed with the names of London-based traders, the petition is noteworthy for its use of the terms ‘watchmaker’ and ‘clockmaker’ at the end of the petition, but no reference to ‘instrument’, ‘instrument making’ or ‘making’. Did they see themselves as distinct from ‘instrument makers’ or not?

Instead, the petitioners argued that it was important to regain their ‘*reputation* abroad, relating to [the] Ingenious Art and Manufacture […]’.[438] The phrase ‘ingenious’ appeared earlier in this thesis, when discussing the work of Willdey and Brandreth. But the use of the two other terms ‘art’ and ‘manufacture’ may hint at a differing identity based along trades, or even along social lines. This was not within the scope of this thesis, to consider the identity of watchmakers, but it could be an important question for future research. In short, did watchmakers see themselves as ‘instrument’ makers? Historians sometimes, but not always,

[437] *England defrauded, by the exportation of boxes, cases, and dial-plates for clocks and watches, without their movements.: Humbly represented to the Honourable House of Commons* (London: 1700).
[438] Ibid.

classify them together. This thesis focused on mathematical and optical instruments as the makers of both often crossed over. A future piece of significant research building on this thesis could look more closely at how the trades of watchmaking and instrument making, and the identities and statuses that their makers had, either overlapped or differed.

Similarly, it may be that the greater recognition that watches or clocks had as items, compared to the discussion of instruments and Blount's definitions in the third chapter, can be seen in other sources. Research into the historic proceedings of the Old Bailey carried out for this thesis looked at accounts from the 1674 (when the database starts) until 1730. An AHRC collaborative project, the database is the largest searchable record of its kind and contains a total of 197,745 records.[439] Evidence of the wealth of information to be found in the database comes from searches of terms such as 'clock', which returned over 1,800 matches for records up until 1730 (although the database continues until 1913). Most documents with the term 'clock' used the word in the context of referring to times when events occurred, in either criminal proceedings, witness statements, or accounts of punishment and execution. Searches such as these, therefore, were refined to alternative terms such as 'watchmaker' or 'clockmaker'. The term 'timekeeper' returned zero matches, as did comparable searches to 'optical instruments', 'perspective glasses', 'perspectives', 'lens', 'telescopes' and 'microscopes'. It is not being suggested that no crimes at all were committed that involved these objects. However, a considerable number of documents were found referring to watches, clocks and their makers, which were analysed as part of this research. It was deemed out of the scope of the thesis to directly link them to instrument making, but they do provide a useful insight into where further research could be carried out.

[439] *Old Bailey Proceedings Online*, accessed Dec 19, 2019, https://www.oldbaileyonline.org/

Early accounts in the Old Bailey proceedings that reference watchmakers are mostly records of theft or fraud. For example, there is a 14 January 1676 account of an 'Irishman tryed for a Cheat' who ran away with a gold watch and a silver watch and was then challenged by the watchmaker, 'who persued him, and afterwards brought him to a Justice of the Peace, and he committed him to Prison, and upon his Tryal was found guilty'.[440] The convict was subject to the punishment of being pilloried, a common punishment where the criminals were locked into a wooden structure in public and faced abuse from passers-by for their misdemeanours. References to the theft of timekeepers during this period do not refer to cost or value of the items, although this was also the case for theft and fraud in connection with other types of goods during the 1670s and 1680s. A decade later it was usual for the court record to note the value. This is one reason why estimating the value that goods had at the time, such as watches, and instruments, has been difficult. The precise value of other instruments is challenging, although one standout is the estimates for costs of goods and bartering from Willdey and Brandreth calculated by Alexi Baker.[441]

Similarly to the above case, in April 1686, two Londoners, Charles Condrel and Thomas Arnold were accused by watchmaker Henry Godfrey of theft. The two defendants were '...indicted for breaking up the house of Henry Godfry, the 1st. day of March last, and stealing from him, one Gold Watch, value 15 1. and 3. Silver Watches, value 18. l.'[442] The recorded value of the pocket watches is noteworthy. Godfrey was a member of the

[440] 'Deception, 14 January 1676, t16760114-14', *Old Bailey Proceedings Online, a*ccessed Dec 01, 2020. www.oldbaileyonline.org
[441] Alexi Baker, 'Symbiosis and Style: the Production, Sale and Purchase of Instruments in the Luxury Markets of Eighteenth Century London', in *How Scientific Instruments Have Changed Hands*, ed. A.D. Morrison-Low, Sara J. Schechner & Paolo Brenni (Leiden: Brill, 2017), 1-20.
[442] 'Theft, 14th April 1686, T16860414-23', *Old Bailey Proceedings Online, accessed Dec 01, 2020, www.oldbaileyonline.org*

Clockmakers' Company from 1685 until 1707.[443] He had left his workshop to go abroad and on finding items missing from his workshop on his return, made enquiries and found that a local man called Condrel had been seen selling watches. The court record shows that Godfrey had good reason to suspect Condrel, '...the Prisoner Condrel appearing to be an old Offender and branded in his hand'. Despite 'no Evidence appearing', Condrel was found guilty, although his companion was acquitted.

There are two points of conjecture here that may form the basis of new research. First, that watches or clocks were more recognised objects amongst the public than others such as mathematical instruments. Second, that the perceived value of these objects as a result of their recognition meant they were more desirable and therefore more likely to be the subject of crimes such as theft or fraud. They could more easily be sold on. There were other court cases found that were similar to the two cases described above. No firm conclusions are being drawn. It is appropriate, however, to document an area of research that was undertaken as part of this thesis, that if advanced could lead to an even greater understanding of the status and identities of makers across different devices, as well as how their objects were valued. It is also important to consider in the future whether there was a clearer separation between watchmaking and other types of instrument-making. There are hints in the evidence presented in this final section to suggest that there are significant areas where our understanding of how the historical trade of watchmaking fitted in to the newer and emerging trades of mathematical and optical instruments could be improved. Future research on the precise nature of watchmaking and its status as compared to other forms of instrument making, and

[443] 'Henry Godfrey', *Sothebys*, accessed Dec 09, 2020, http://www.sothebys.com/en/auctions/ecatalogue/2015/david-ramsay-and-the-first-clockmakers-l15056/lot.31.html

whether they are right to be considered ‘instruments’ in the same way, could be revealing – and possibly very surprising.

References

PRIMARY

Archived Materials

Classified Papers, various dates (AB/1/1/1) Royal Society, London.

Classified Papers, various dates (AB/1/1/2) Royal Society, London.

Classified Papers, undated (RS.12572) Royal Society, London.

Books

(Books with named authors followed by unnamed books)

Blount, Thomas. *Glossographia or, A dictionary interpreting all such hard words of whatsoever language now used in our refined English tongue*. London, 1661.

Browne, John. *The Description and Use of a Joynt-Rule*. London, 1661.

Campbell, Richard. *The London Tradesman*. Oxford, 1747.

Defoe, Daniel. *The English Tradesman*. London, 1727.

Everard, Thomas. *Stereometry*. London, 1696.

Foster, Samuel. *Elliptical Or Azimuthal Horologiography*. London, 1654.

Hearne, Thomas. *The Works of Thomas Hearne – Peter Langtoft's Chronicle*. London: 1810.

Malpighi, Marcello. *De Pulmonbus Observationes Anatomicae*. Rome, 1661.

Molyneux, W. *Dioptrica Nova*. London, 1692.

Morland, Samuel. *The description and use of two arithmetic instruments*. London, 1673.

Morland, Samuel. *The doctrine of interest, both simple & compound*. London, 1679.

'N.H'. *The Compleat Tradesman*. London, 1684.

Oughtred, William. *The Circles of Proportion and the Horizontall Instrument*. London: 1639.

Ptolemy. *Theory of Visual Perception: An English Translation of the Optics*, translated by A. Mark Smith. Philadelphia: American Philosophical Society, 1996.

Sprat, Thomas. *The History of the Royal Society of London*, Printed by T.R. for J. Martyn. London, 1667.

A True and perfect description of the strange and wonderful elephant sent from the East-Indies: and brought to London on Tuesday the third of August, 1675: with a discourse of the nature and qualities of elephants in general. London, 1675.

England defrauded, by the exportation of boxes, cases, and dial-plates for clocks and watches, without their movements.: Humbly represented to the Honourable House of Commons. London: 1700.

Plutarch's Lives. Translated from the Greek by several Hands: Printed for Jacob Tonson. London, 1693.

The Description of the horological ring-dyall which sheweth the hour of the day in any part of the world. London, 1680.

The Penny Cylcopaedia of the Society for the Diffusion of Useful Knowledge, published by Charles Knight. London, 1840.

Diaries

Evelyn, John. *The Diary of John Evelyn*. Edited by E.S. de Beer. Oxford: Oxford University Press, 1959.

Hooke, Robert. *The Diary of Robert Hooke*. Edited by Henry Robinson and Walter Adams. London: Wykeham, 1968 edition.

Pepys, Samuel. *The Diary of Samuel Pepys*. Edited by Robert Latham and William Matthews. Berkely: University of California Press, 1971.

Journals

Knight, Gowin. 'A Description of a Mariner's Compass Contrived by Gowin Knight, M. B. F.R.S.', *Philosophical Transactions*, Volume 46 (1749-50), 508.

Newspapers

Classified Advertisements. *Collection for Improvement of Husbandry and Trade*. London, England. August 4, 1693. Issue 53. Burney Collection Newspapers.

Classified Advertisements. *Daily Courant*. London, England. February 22, 1707. Burney Collection Newspapers.

Classified Advertisements. *Daily Courant.* London, England. February 26, 1707. Burney Collection Newspapers.

Classified Advertisements. *Daily Courant*. London, England. March 24, 1707. Burney Collection Newspapers.

Classified Advertisements. *Daily Courant*. London, England. April 16, 1707. Burney Collection Newspapers.

Classified Advertisements. *Daily Courant*. London, England. April 25, 1707. Burney Collection Newspapers.

Classified Advertisements. *Daily Courant*. London, England. May 1, 1707. Burney Collection Newspapers.

Classified Advertisements. *English Post with News Foreign and Domestick*. London, England. March 31, 1707. Burney Collection Newspapers.

Other

'Deception. 14 January 1676. t16760114-14'. *Old Bailey Proceedings Online*. Accessed Dec 01, 2020. www.oldbaileyonline.org

'Theft. 14th April 1686. T16860414-23'. *Old Bailey Proceedings Online*. Accessed Dec 01, 2020. www.oldbaileyonline.org

SECONDARY

Books and Journal Articles

Aghion, Philippe and Steven M. Durlauf, ed. *Handbook of Economic Growth*, Amsterdam: Elsevier, 2005.

Ahearn, Laura. 'Language and Agency'. *Annual Review of Anthropology* 30 (2001): 109-137.

Alberti, Samuel J.M.M. 'Objects and the Museum'. *Isis* 96, no. 4 (2005): 559-571.

Alexander, Edward P. 'Early American Msueums: from collection of curiosities to popular education'. *The International Journal of Museum Management and Curatorship* 6, no. 4 (1987): 337-351.

Andrewes, William. 'A Chronicle of Timekeeping'. *Scientific American (special issue: a matter of time)* 287, no. 3 (2002): 76-85.

Appadurai, Arjun, ed. *The Social Life of Things – commodities in cultural perspective*. Cambridge: Cambridge University Press, 1986.

Appleby. John. 'A new perspective on John Rowley, Virtusos Master of mechanics and hydraulic engineer'. *Annals of Science* 53 (1996): 1-27.

Ariotti, Piero. 'Galileo on the Isochrony of the Pendulum'. *Isis* 59, no. 4 (1968): 414-426.

Ark, Bart Van and Simon Kupers, Gerard Kuper, ed. *Productivity, Technology and Economic Growth during the Indsutrial Revolution*. Boston: Springer, 2000.

Arnold, Dana. *Art History - A Very Short Introduction.* Oxford: Oxford University Press, 2004.

Aspinell, A. 'Statistical Accounts of the London Newspapers in the Eighteenth Century'. *The English Historical Review* 63 (1948): 201-232.

Auslander, Leora, Amy Bentley, Leor Halevi, H. Otto Sibum and Christopher Whitmore. 'AHR Conversation: Historians and the Study of Material Culture'. *The American Historical Review* 114, no. 5 (2009): 1354-1404.

Aveni, Anthony. 'Time's Empire', *The Wilson Quarterly (1976 version)* 22, no. 3 (1998): 45-57.

Baker, Alexi. 'Symbiosis and Style: the Production, Sale and Purchase of Instruments of Instruments in the Luxury Markets of Eighteenth Century London'. In *How Scientific Instruments Have Changed Hands*, edited by A.D. Morrison-Low, Sara J. Schechner and Paolo Brenni, 1-20. Leiden: Brill, 2017.

Ball, Clara Sue. 'The Early History of the Compound Microscope'. *Bios* 37, no. 2 (1966): 51-60.

Bardell, David. ‘Eyeglasses and the Discovery of the Microscope’. *The American Biology Teacher* 43, no. 3 (1981): 157-159.

Bardell, David. ‘The First Record of Microscopic Observations’. *BioScience* 33, no. 3 (1983): 36-38.

Barker, Hannah. ‘Medical Advertising and Trust in late Georgian England’. *Urban History* 36, no. 3 (2009): 379-398.

Bedini, Silvio. ‘Lens Making for Scientific Instrumentation in the Seventeenth Century’. *Applied Optics* 5, no. 6 (1966): 687-694.

Belfanti, Carlo Marco. ‘Branding before the brand: Marks, imitations and counterfeits in pre-modern Europe’. *Business History* 60, no. 8 (2018): 1127-1146.

Benedict, Barbara. ‘Encounters with the Object: advertising, time an literary discourse in the early eighteenth century thing-poem’. *Eighteenth Century Studies* 40, no. 2 (2007): 193-207.

Bending, Silvio A. and Arthur G. Bennett, ‘“A Treatise on Optics” by Giovanni Christoforo Bolantio’. *Annals of Science* 52 (1995): 103-126.

Bennett, Jim. ‘Early Modern Mathematical Instruments’, *Isis* 102, no. 4 (2011): 697-205.

Bennett, Jim. ‘Knowing and doing in the sixteenth century: what were instruments for?’. *British Journal for the History of Science* 36, no. 2 (2003): 129-150.

Bennett, Jim. ‘Practical Geometry and Operative Knowledge’. *Configurations* 6 (1998): 195-222.

Bennett, Jim. ‘The Museum of the History of Science: Oxford’. *Arbor* CLXIV (1999): 435-444.

Bennett, Jim, Michael Cooper, Michael Hunter and Lisa Jardine. *London’s Leonardo: The Life and Work of Robert Hooke*. Oxford: Oxford University Press, 2003.

Berg, Maxine and Kristine Bruland, ed. *Technological Revolutions in Europe: historical perspectives*. Cheltenham: MA, 1998.

Berg, Maxine and Helen Clifford. ‘Selling Consumption in the Eighteenth Century’. *Social and Cultural History* 4, no. 2 (2007): 145-170.

Biagioli, M. *Galileo’s instruments of credit: Telescopes, images and secrecy*. Chicago: Chicago University Press, 2007.

Black, Jeremy. *The English Press 1621-1861*. London: History Press, 2001.

Bluhm, R.K. ‘A Guide to the Archives of the Royal Society and to Other Manuscripts in its Possession’. *Notes and Records of the Royal Society* 12, no. 1 (1956): 21-39.

Bourdieu, Pierre. *Distinction, A Social Critique of the Judgement of Taste* (1984)

Bragg, William. ‘History in the Archives of the Royal Society’. *Science* 89, no. 2316 (1939): 445-453.

Brenna, Brita, Hans Dam Christensen and Olav Hamran, ed. *Museums as Cultures of Copies: The Crafting of Artefacts and Authenticity*. London: Routledge, 2018.

Brewer, John, ‘Microhistory and the Histories of Everyday Life’, *CAS LMU E-Series*, no. 5 (2010): 1-17.

Brook, Timothy. *Vermeer’s Hat: The Seventeenth Century and the Dawn of the Global World*. London: Profile, 2007.

Brown, Joyce. ‘Guild organisation and the instrument-making trade, 1550-1830: the Grocers’ and Clockmakers’ Companies’. *Annals of Science* 36 (1979): 1-34.

Bryden, D.J. and D.L. Simms. ‘Archimedes as an Advertising Symbol’. *Technology and Culture* 34, no. 2 (1993): 387-391.

Bryden, D.J. and D.L. Simms. ‘John Marshall: the making of true spectacles’. *British Medical Journal* 309, no. 6970 (1994): 1713-1714.

Bryden, D.J. and D.L. Simms. ‘Trade Ephemera, Archimedes and the Opticians of London’. *Atti Della Fondazione Giorgio Ronchi Anno LXII* 6 (2007): 797-838.

Bryden, D.J. and D.L. Simms. ‘Trade Ephemera, Archimedes and the Opticians of London’. *Atti Della Fondazione Giorgio Ronchi Anno LXII* 6 (2007): 797-838.

Butters, Humfrey. ‘Europe in 1800’ in *The European World 1500-1800 - an introduction to early modern history*, edited by Beat Kumin. Oxford: Routledge, 2014.

Cajori, Florian. *On the History of the Gunter’s Scale and the Slide Rule during the Seventeenth Century*. Frankfurt: Verlag, 2018.

Calvert, H.R. *Scientific Trade Cards in the Science Museum Collection*. London: HM Stationery Office, 1971.

Carranco, Lynwood. ‘Let’s Stop Worshipping the Dictionary’. *The Clearing House* 29, no. 2 (1954): 72-76.

Ceccarelli, Marco. ‘Contributions of Archimedes on mechanics and design of mechanisms’, *Mechanism and Machine Theory* 72 (2014): 86-93.

Chaiklin, Martha. ‘Ivory in World History: Early Modern Trade in Context’, *History Compass* 8, no. 6 (June 2010): 530-542.

Chapman, Allan. ‘A study of the accuracy of scale graduations on a group of European astrolabes’. *Annals of Science* 40. no. 5 (1983): 473-488.

Chene, Des D. *Spirits and Clocks: Machine and Organism in Descartes*. New York: Cornell University Press, 2001.

Cicero. *De re publica*. Translated by Niall Rudd. Oxford: Oxford University Press, 2008.

Cipolla, Carlo M. *Clocks and Culture 1300-1700*. London: Norton and Company, 1978.

Clifton, Gloria and Gerard L'E Turner. Directory of British Scientific Instrument Makers 1550-1851. London: Zwemmer, 1995.

Cohen, Adam Max. *Technology and the Early Modern Sel*f. New York: Palgrave, 2009.

Coquery, Natacha. 'The Language of Success: Marketing and Distributing Semi-Luxury Goods in Eighteenth Century Paris'. *Journal of Design History* 17, no. 1 (2004): 71-89.

Cormack, Lesley, S. Walton and John Schuster, ed. *Mathematical Practitioners and the Transformation of Natural Knowledge in Early Modern Europe*. Bern: Springer, 2017.

Cox, Nancy. *The Complete Tradesman – a study of retailing 1500-1820*. Farnham: Ashgate, 2000.

Crawforth, M.A. 'Evidence from Trade Cards for the Scientific Instrument Industry'. *Annals of Science* 24, no. 5 (1984): 453-544.

Cuss, Terrence Camerer. *The English Watch 1585-1790, a unique alliance of art, design and inventive genius*. Woodbridge: ACC, 2006.

Dacome, Lucia. 'Waxworks and the performance of anatomy in mid-18th century Italy'. *Endeavour* 30 (2006): 29-35.

Daston, Lorraine. *Biographies of Scientific Objects*. Chicago: Chicago University Press, 2000.

Daumas, Maurice. *Scientific Instruments of the 17th and 18th Centuries and their Makers*. London: Batsford, 1972.

de Carle, Donald. *Clocks and their Value*. London: NAG Press, 1967.

Dear, Peter. 'Historiography of Not-So-Recent-Science'. *History of Science* 50, no. 167 (2012): 197-212.

Dickinson, H.W. 'A Brief History of Draughtsmens' Instruments'. *Transactions of the Newcomen Society* (1949): 73-84.

Dickinson, H.W. *Sir Samuel Morland – Diplomat and Inventor*. Cambridge: Heffer, 1970.

Dijksterhuis, Fokko Jan. *Lenses and Waves: Christian Huygens and the Mathematical Science of Optics in the Seventeenth Century*. Leiden: Luwer, 2005.

Doherty, Francis. *A Study in Eighteenth Century Advertising Methods – the Anodyne Necklace*. Lampeter: Edwin Mellen Press, 1992.

Douglas, Mary and Baron Isherwood. *The World of Goods – towards an anthropology of Consumption* (1996).

Drake, Stillman, ed. *Discoveries and Opinions of Galileo*. London: Domesday Books, 1957.

Dudley, Sandra, ed. *Museum Materialities: Objects, Engagements, Interpretations*. Oxford Routledge, 2010.

Dupre, Sven. 'The value of glass and the translation of artisanal knowledge in early modern Antwerp'. *The Netherlands Yearbook of the History of Art* 64 (2014): 138-161.

Eagleton, Catherine and Boris Jardine. 'Collections and projections: Henry Sutton's paper instruments'. *Journal of the History of Collections* 17 (2005): 1-13.

Eisenstein, Elizabeth. *The Printing Press as an Agent of Change*. Cambridge: Cambridge University Press, 1980.

Ekirch, Roger A. 'Review – Shaping the Day'. *Journal of British Studies* 49, no. 2 (2010): 426-427.

Enos, Richard Leo and Tony M. Lentz. 'A Bibliographical Guide to English Linguistics: 1500-1800'. *Rhetoric Society Quarterly 6*, no. 4 (1976): 68-79.

Evans, Jeremy Lancelotte. *Thomas Tompion at the Dial and Three Crowns*. London: AHS, 2006.

Evans, Jeremy Lancellote, Ben Wright and Jonathan Carter. *Thomas Tompion 300 Years: a celebration of the life and work of Thomas Tompion*. Gloucester: Water Lane Publishing, 2013.

Evans, Robert and Alexander Marr, *Curiosity and Wonder from the Renaissance to the Enlightenment*. London: Ashgate, 2006.

Fara, Patricia. *Science – a Four Thousand Year History*. New York: Routledge, 2009.

Fara. Patricia. *Sympathetic Attractions - Magnetic Practices, Beliefs, and Symbolism in Eighteenth-Century England*. Princeton, Princeton University Press, 1996.

Feinburg, Harvey and Marion Johnson. 'The West African Ivory Trade during the Eighteenth Century: The "…and Ivory" Complex. *The International Journal of African Historical Studies* 15, no. 3 (1982): 435-453.

Ferguson, Eugene S. 'The Mind's Eye: nonverbal thought in technology'. *Science – new series* 197, no. 4306 (1977): 827-836.

Fleming, Juliet. *Graffiti and the Writing Arts of Early Modern England*. London: Reaktion Books, 2001.

Fowler, Chris. ‘From identity and material culture to personhood and materiality’. In *The Oxford Handbook of Material Culture Studies*, edited by Dan Hicks and Mary C. Beaudry, 352-385. Oxford: Oxford University Press, 2010.

Fournier, Marian. *The Fabric of Life: Microscopy in the Seventeenth Century*. Baltimore: John Hopkins University Press, 1996.

Gane, Mike. ‘Durkheim: the sacred language’. *Economy and Society* 12 (2006): 1-47.

Gardiner, Tony. ‘Rigorous Thinking and the Use of Instruments’. *The Mathematical Gazette* 476 (1992): 179-181.

Garrioch, David. ‘House names, shop signs and social organizations in Western European cities, 1500-1900’. *Urban History* 21 (1994): 20-48.

Geduld, Harry. *Prince of Publishers*. London: University of Indiana Press, 1967.

Gell, Alfred. *Art and Agency – an anthropological theory*. Oxford: Oxford University Press, 1998.

Gerritsen, Anne and Anthony MacFarlane. ‘Expanding Horizons’ in *The European World 1500-1800 - an introduction to early modern history*, edited by Beat Kumin. Oxford: Routledge, 2014.

Gerritsen, Anne and Giorgio Riello. *The Global Lives of Things, The Material Culture of Connections in the Early Modern World*. London: Routledge, 2015.

Gillespie, Stuart. ‘The Early Years of the Dryden-Tonson Partnership: The Background to their Composite Translations and Miscellanies of the 1680s’. *Restoration: Studies in English Literary Culture*, 1660-1700 12, no. 1 (1988): 10-19.

Ginzburg, Carlo. John Tedeschi and Anne Tedeschi, ‘Microhistory: Two or Three Things I Know About It’. *Critical Inquiry* 20 (1993): 10-35.

Glaisyer, Natasha. ‘Print Culture, Trust and Economic Figures: early eighteenth-century England’. *The Economic History Review* 60, no. 4 (2007): 685-711.

Glaisyer, Natasha and Sara Pennell. *Didactic Literature in England 1500-1800: expertise constructed*. London: Routledge, 2003.

Glennie, Paul and Nigel Thrift. *Shaping the Day: A History of Timekeeping in England and Wales 1300-1800*. Oxford: Oxford University Press, 2011.

Gosden, Chris and Yvonne Marshall. ‘The Cultural Biography of Objects’. *World Archaeology* 31, no. 2 (1999): 169-178.

Graemor, Rudi and Marion Kite. ‘The tanning, dressing and conservation of exotic, aquatic and feathered skins’ in *Conservation of Leather and Related Materials*, edited by Marion Kite and Roy Thomson, 170-183. London: Routledge, 2006.

Groetsch, C.W. ‘Aristotle’s Fall’. *The American Mathematical Monthly* 105, no. 6 (1998): 544-547.

Harkness, Deborah. *The Jewel House – Elizabethan London and the Scientific Revolution*. Yale: Yale University Press, 2007.

Hart, Susannah and John Murphy. *Brands: The New Wealth Creators*. London: Palgrave-Macmillan, 1993.

Heal, Ambrose. *London’s Tradesmen’s Card of the XVIII Century – an account of their origins and use*. New York: Dover Publications, 1968.

Heal, Amrbose. *The Signboards of Old London Shops*. New York: Blom, 1972.

Hein, Hilde. *The Museum in Transition*. New York: Smithsonian Books, 2014.

Hicks, Dan and Mary C. Beaudry, ed. *The Oxford Handbook of Material Culture*. Oxford: Oxford University Press, 2010.

Higton, Hester. ‘Does using an instrument make you mathematical? Mathematical practitioners of the 17th century’. *Endeavour* 25 (2001): 18-22.

Hill, Katherine. ‘ “Juglers or Schollers?” Negotiating the Role of a Mathematical Practitioner’. *British Journal for the History of Science* 31, no. 3 (1998): 253-274.

Hollenback, Kacy, and Michael Brian Schiffer. In *The Oxford Handbook of Material Cultural Studies*, edited by Dan Hicks and Mary C. Beaudry, 313-332. Oxford: Oxford University Press, 2010.

Hubbard, Philippa. ‘Trade Cards in 18th Century Consumer Culture: Movement, Circulation and Exchange in Commercial and Collecting Spaces’. *Material Culture Review* 74-75 (2012): 30-46.

Hughes-Warrington, Marine. *Fifty Key Thinkers on History*. London: Routledge, 2000.

Hunter, Michael. *The Image of Restoration Science, The Frontispiece to Thomas Sprat’s History of the Royal Society 1667*. London: Routledge, 2016.

Hunter, Michael and Michael Cooper. *Robert Hooke – tercentennial studies*. London: Ashgate, 2006.

Iliffe, Rob. ‘Guest Editorial: Technicians’. *Notes and Records of the Royal Society* 62, no. 1 (2008): 3-16.

Isaac, Gwyneria. ‘Whose Ideas Was This?: Museums, replicas, and the reproduction of knowledge’. *Current Anthropology* 52, no. 2 (2011): 211-233.

Jacob, Margaret. *Scientific Culture and the Making of the Industrial West*. Oxford: Oxford University Press, 1997.

Jacob, Margaret. ‘Mechanical Science on the Factory Floor: The Early Industrial Revolution in Leeds’. *History of Science* 45, no. 2 (2007): 197-232.

Jacob, Margaret. *The First Knowledge Economy – human capital and the European economy 1750-1850*. Cambridge: Cambridge University Press, 2014.

Jacob, Margaret and Larry Stewart. *Practical Matter: Newton’s Science in the Service of Industry and Empire 1687-1851*. Cambridge: Cambridge University Press, 2014.

Jardine, Boris. ‘Henry Sutton’s Collaboration with John Reynolds’. *Bulletin of the Scientific Instrument Society*, no. 130 (2006): 4-7.

Jones, Matthew. *Reckoning with Matter: Calculating Machines, Innovation and Thinking about Thinking from Pascal to Babbage*. Chicago: Chicago University Press, 2016.

Jones, Robert Alun and Douglas A. Kibbee. ‘Durkheim, Language, and History: A Pragmatist Perspective’. *Sociological Theory* 11, no. 2 (1993): 152-170.

King, Henry. *The History of the Telescope*. Dover: Griffin, 1955.

Kinsley, James and Helen Kinsley. *John Dryden: The Critical Heritage*. London: TJ Press, 1971.

Klein, Ursula. ‘Artisanal-scientific Experts in Eighteenth Century France and Germany - introduction’, *Annals of Science* 69, no. 3 (2012): 303-306.

Knights, Mark. ‘Samuel Pepys and Corruption’. *Parliamentary History* 33 (2014): 19-35.

Kriss, Timothy C. and Vesna Martich Kriss. ‘History of the Operating Microscope: From Magnifying Glass to Microneurosurgery’. *Neurosurgery* 42, no. 4 (1998): 899-907.

Kusukawa, Sachiko. ‘William Courten’s lists of ‘Things Bought’ from the late seventeenth century’. *Journal of the History of Collections* 29, no. 1 (2017): 1-17.

La Berge, Ann. ‘The History of Science and the History of Microscopy’. *Perspectives on Science* 7 (1999): 111-142

Laird, W.R. ‘Archimedes among the Humanists’. *Isis* 82, no. 4 (1991): 628-638.

Landes, David. ‘Watchmaking: A Case Study in Enterprise and Change’. *The Business History Review* 53, (1979): 1-39.

Latham, Kiersten and Elizabeth Wood. ‘Object Knowledge: Researching Objects in the Museum Experience’. *Reconstruction: studies in contemporary culture* 9, no. 1 (2009).

Latour, Bruno. *Give Me a Laboratory and I Will Raise the World*. Paris: Ecole des Moines, 2014.

Le Goff, Jacques. *Time, Work and Culture in the Middle Ages*. Chicago: University of Chicago Press, 1982.

Leopold, J.H. ‘Clockmaking in Britain and the Netherlands’. *Notes and Records of the Royal Society of London* 43, no. 2 ‘Science and Civilization under William and Mary’, (1989): 155-165.

Levenson, Thomas. *Newton and the Counterfeiter*. London: Faber and Faber, 2010.

Lindberg, David and Robert S. Westman, ed. *Reappraisals of the Scientific Revolution*. Cambridge: Cambridge University Press, 1990.

Lloyd, Alan H. *Old Clocks*. London: Ernest Benn, 1972.

Lloyd, Sarah. ‘Ticketing the British Eighteenth Century: A thing...never heard of before’. *Journal of Social History* 46, no. 4 (2013): 843-871.

Lucas, Gavin. ‘The Changing Face of Time: English Domestic Clocks from the Seventeenth to the Nineteenth Century’. *Journal of Design History* 8 (1995): 1-9.

Luthy, C.H. ‘Atomism, Lynceus, and the Fate of Seventeenth Century Microscopy’. *Early Science and Medicine* 1 (1996): 1-27.

Lux, David and Harold Cook. ‘Closed Circles or Open Networks?: Communicating at a distance during the Scientific Revoltuion’. *History of Science* 35 (1998): 179-211.

Lynch, Kathleen. *Jacob Tonson – Kit Kat Publisher*. Knoxville: University of Tennessee Press, 1972.

Malet, Antony. ‘Early Conceptualisations of the Telescope as an Optical Instrument’. *Early Science and Medicine* 10, no. 2 (2005): 237-262.

McKendrick, Neil, and John Brewer and J.H. Plumb. *The Birth of a Consumer Society. London*: Harper Collins, 1982.

Merton, Robert. ‘Science, Technology and Society in Seventeenth Century England’. *Osiris* IV (1938): 360-632.

Milburn, John. ‘Benjamin Martin and the Development of the Orrery’. *The British Journal for the History of Science* 6, no. 4 (1973): 378-399.

Miller, Adam. *Speculative Grace: Bruno Latour and Object-Orientated Theology*. New York: Fordham University Press, 2013.

Miller, Daniel. *Material Culture and Mass Consumption*. Oxford: Blackwell, 1987.

Mitchell, David, ed. *Goldsmiths, Silversmith and Bankers: Innovation and the Transfer of Skill 1550-1750*. Gloucester: Alan Sutton Publications, 1995.

Mitman, Carl W. ‘The Story of Timekeeping’. *The Scientific Monthly* 22, no. 5 (1926): 424-427.

Mokyr, Joel. *The Gifts of Athena: Historical Origins of the Knowledge Economy*. Princeton: Princeton University Press, 2001.

Morrison-Low, A.D. and Sara J. Schechner, Paolo Brenni. *How Scientific Instruments Have Changed Hands*. Leiden: Brill, 2017.

Munck, Bert de. ‘The agency of branding and the location of value. Hallmarks and monograms in early modern tableware industries’. *Business History* 54, no. 7 (2012): 1055-1076.

Naismith, Rory. *Money and Coinage in the Middle Ages*. Amsterdam: Brill, 2018.

Nevett, Terry. *Advertising in Britain*. London: Heinemann, 1982.

Nuttall, R. H. ‘That Curious Curiosity: The Scotoscope’. *Notes and Records of the Royal Society* 42, no. 2 (1988): 133-138.

Oakley, Peter. ‘Containing Precious Metals: Hallmarking, Minting and the Materiality of Gold and Silver in Medieval and Modern England’, in Hahn Hans Peter and Weiss Hadas, ed. *Mobility and Meaning and Transformations of Things: Shifting Contexts of Material Culture Through Time and Space*. Oxford: Oxbow, 2013.

Ochs, Kathleen. ‘The Royal Society of London’s History of Trades Programme: An Early Episode in Applied Science’. *Notes and Records of the Royal Society* 39, no. 2 (1985): 129-158.

Ogilvie, Sheilagh. ‘The Economics of Guilds’. *Journal of Economic Perspectives* 28, no. 4 (2014): 169-192.

Packer, Emma. ‘The interaction between English and Huguenot goldsmiths in the late seventeenth and early eighteenth centuries’. In *Goldsmiths, Silversmiths and Bankers*, edited by David Mitchell, 84-95. London: Alan Sutton Publishing, 1995.

Pagani, Catherine. *Eastern Magnificence & European Ingenuity: Clocks of Late Imperial China*. Ann Arbor: University of Michigan Press, 2001.

Papali, G.F. *Jacob Tonson, publisher*. Auckland: Tonson, 1968.

Paperno, Irina. ‘What Can be Done with Diairies?’. *The Russian Review* 63, no. 4 (2004): 561-573.

Peck, Linda Levy. *Consuming Splendor: Society and Culture in Seventeenth Century England*. Cambridge: Cambridge University Press, 2005.

Penchev, Pencho. D. ‘Book Review: The First Knowledge Economy’. *Economic Alternatives* 2 (2017): 323-326.

Pickering, James. ‘Material Culture and the Dance of Agency’. In *The Oxford Handbook of Material Cultural Studies*, edited by Dan Hicks and Mary C. Beaudry, 191-208. Oxford: Oxford University Press, 2010.

Pincus, Steve. ‘ “Coffee Politicians Does Create”: Coffeehouses and Restoration Political Culture’. *The Journal of Modern History* 67, no. 4 (1995): 807-834.

Poss, Richard. ‘The Social and Economic Causes of the Revolution in the Mathematical Sciences in Mid-Seventeenth Century England’, *Journal of British Studies* 15 (1975): 46-66.

Pumfrey, Stephen. ‘The Scientific Revolution’ in *A Companion to Historiography*, edited by Michael Bentley, 293-303. Routledge: London, 1997).

Pumfrey, Stephen. ‘Who Did the Work? Experimental philosophers and public demonstrators in Augustan England’. *The British Journal for the History of Science* 28, no. 2 (1995): 131-156.

Purrington, Robert. *The First Professional Scientist: Robert Hooke and the Royal Society of London*. Berlin: Birkhauser, 2009.

Quickenden, Kenneth, Sally Baggott and Malcolm Dick, ed. *Matthew Boulton – Enterprising Industrialist of the Enlightenment*. Oxford: Routledge, 2013.

Racine, Rene. ‘The Historical Growth of the Telescope Aperture’. Publications of the Astronomical Society of the Pacific 116, no. 815 (2004): 77-83.

Ratcliff, J.R. ‘Samuel Morland and His Calculating Machines c. 1666: The Early Career of a Courtier Inventor in Restoration London’. *British Journal for the History of Science* 40, no. 2 (2007): 159-179.

Raymond, Joad. ‘The Newspaper, Public Opinion and the Public Sphere in the seventeenth century’. *Prose Studies* 21 (1998): 109-136.

Rees, Mark. ‘Two Early Slide Rules’. *Journal of the Oughtred Society* 7, no. 2 (1998): 9-13.

Reyden, D. van der and D.C. Williams. ‘The Technology and Conservation Treatment of a 19th Century ‘Papier-mâché’ Chair’. *Preprints of the American Institute for Conservation, 14th AGM in Chicago* (1986): 125-142.

Reynolds, Anna. ‘Such dispersive scatterdness: Early Modern EncFounters with Binding Waste’. *Journal of the Northern Renaissance* 8 (2017): 1-43.

Riello, Giorgio. ‘Strategies and Boundaries: Subcontracting and the London Trades in the Long Eighteenth Century’. *Enterprise and Society* 9, no. 2 (2008): 243-280.

Rijkelikhuizen, Marloes. ‘Whales, Walruses and Elephants: Artisans in Ivory, Baleen and Other Skeletal Materials in Seventeenth and Eighteenth Century Amsterdam’. International Journal of Historical Archaeology 13, no. 4 (2009): 409.

Roche, Daniel. *A History of Everyday Things: The Birth of Consumption in France 1600-1800*. Cambridge: Cambridge University Press, 2001.

Roos, A.M. 'Review – The Image of Restoration Science: The Frontispiece to Thomas Sprat's History of the Royal Society 1667 by Michael Hunter'. *The English Historical Review* 133, no. 563 (2018): 952-953.

Ruestow, Edward G. *The Microscope in the Dutch Republic: the shaping of discovery*. Cambridge: Cambridge University Press, 1996.

Ryan, W.F. 'Scientific Instruments in Russia from the middle ages to Peter the Great'. *Annals of Science* 48, no. 4 (1991): 367-384.

Schiffer, Michael Brian. *Behavioural Archaeology*. New York: Eliot Warner, 1976.

Schmidgen, Henning. *Bruno Latour in Pieces: an intellectual biography. New York: Fordham University Press*, 2015.

Schoppa, Keith. 'Diaries as a Historical Source: Goldmines and/or Slippery Slopes'. *The Chinese Historical Review* 17 (2010): 31-36.

Scott, Katie. 'Archives and Collections. The Waddesdon Manor Trade Cards: more than one history'. *Journal of Design History* 17 (2004): 91-104.

Scott-Warren, Jason. 'Reading Graffiti in the Early Modern Book'. *Huntington Library Quarterly* 73, no. 3 (2010): 363-181.

Shapin, Steven. *Never Pure - Historical Studies of Science as if It Was Produced by People with Bodies, Situated in Time, Space, Culture, and Society, and Struggling for Credibility and Authority.* Baltimore: Johns Hopkins University Press, 2010.

Shapin, Steven. *The Scientific Revolution*. Chicago: Chicago University Press, 1996.

Shickman, Allan. 'The "Perspective Glass" in Shakespeare's Richard II'. *Studies in English Literature, 1500-1900* 18, no. 2 (1978): 217-228.

Silverman, Cathy. 'Shagreen. The history and conservation of decorative ray skin in furniture'. *Thirteenth International Symposium on Wood and Furniture Conservation* (2006): 63-73.

Simon, David Carroll. *Light Without Heat: The Observational Mood from Bacon to Milton.* New York: Cornell University Press, 2018.

Sorrensen, Richard. 'The state's demand for accurate astronomical and navigation instruments in eighteenth century Britain'. In *The Consumption of Culture 1600-1800: Image, Object, Text,* edited by J. Brewer and A. Berningham, 263-271. London: Routledge, 1997.

Sorrensen, Richard. 'George Graham: Visible Technician'. *The British Journal for the History of Science* 32, no. 2 (1999): 203-221.

Smith, Courtney Weiss, ‘A “Foundation in Nature”: New Economic Criticism and the Problem of Money in 1690s England’. *The Eighteenth Century* 53, no. 2 (2012): 209-228.

Snodin, Michael. ‘Trade Cards and the English Rococo’. In *The Rococo in England – a symposium,* edited by Charles Hind, 82-107. London: Victoria and Albert Museum, 1986.

Stewart, Larry. ‘A Meaning for Machines: Modernity, Utility and the Eighteenth Century British Public’. *The Journal of Modern History* 70 (1998): 259-294.

Stewart, Larry. ‘Other centres of calculation, or where the Royal Society didn’t count: commerce, coffee-houses and natural philosophy in early modern London’. *British Journal for the History of Science* 32 (1999): 133-153.

Stewart, Larry. ‘Public Lectures and Private Patronage in Newtonian England’. *Isis* 77, no. 1 (1986): 47-58.

Stocking, George, ed. *Objects and Others*. Madison: University of Wisconsin Press, 1985.

Styles, John. ‘Product Innovation in Early Modern London’. *Past and Present* 168 (2002): 124-169.

Taub, Liba. ‘Introduction: Re-engaging with Instruments’. *Isis* 102, no. 4 (2011): 689-696.

Taylor, E.G.R. *Mathematical Practitioners of Tudor and Stuart England*. Cambridge: Cambridge University Press, 1955.

Taylor, E.G.R. *Mathematical Practitioners of Hanoverian England*. Cambridge: Cambridge University Press, 1966.

Tilley, Christopher, Webb Keane, Susanne Kuchler, Michael Rowlands and Patricia Spyer, ed. *The Handbook of Material Culture*. London: Sage, 2006.

Tripati, Sila and Ian Godfrey, ‘Studies on elephant tusks and hippopotamus teeth collected from the early 17th century Portuguese shipwreck off Goa, west coast of India: Evidence of maritime trade between Goa, Portugal and African countries’, *Current Science* 92, no 3 (2007): 332-339.

Troughton, Walter. ‘The History of Trades: its relation to seventeenth century thought, as seen in Bacon, Petty, Evelyn and Boyle’. *Journal of the History of Ideas* 2 (1941): 33-60.

Turner, A.J. ‘William Oughtred, Richard Delamain and the Horizontal Instrument in Seventeenth Century England’, *Annali dell’Instituto e Museo di storia della scienza di Firenze* 6, no. 2 (1981): 99-125.

Turner, AJ. ‘The Observatory and the Quadrant in Eighteenth Century Europe’. *Journal for the History of Astronomy* 33, no. 4 (2002): 373-385.

Turner, Anthony. ‘Review – Shaping the Day’. *The English Historical Review* 49, no. 2 (2010): 426-427.

Turner. Anthony. ‘The Eclipse of the Sun: Sun-dials, Clocks and Natural Time in the Late Seventeenth Century’. *Early Science and Medicine* 20, no. 2 (2015): 169-186.

Turner, Gerard L’E. ‘Decorative Tooling on 18th Century Microscopes and Telescopes’. *Physis. Rivista internazionale di storia della scienza* 8 (1966): 99-128.

Turner, Gerard L’E. *Scientific Instruments 1500-1900 – an introduction*. Cambridge: Cambridge University Press, 1998.

Turner, Gerard L’E. ‘The Annual Invitation Lecture: scientific instruments – why?’. *Bulletin of the Scientific Instrument Society* 76 (2003): 2-4.

Turner, Gerard L’E. ‘The London trade in scientific instrument-making in the 18th century’. *Vistas in Astronomy* 20 (1976): 173-176.

Walker, Keith. ‘Publishing: Jacob Tonson – bookseller’ *The American Scholar* 61, no. 3 (1992): 424-430.

Turner, Gerard L’E. ‘The Impact of Hooke’s Micrographia and its Influence on Microscopy’. In *Robert Hooke and the English Renaissance*, edited by Paul Welberg Kent and Allan Chapman, 124-145. London: Gracewing, 2005.

Turner, Gerard, L’E. ‘The Three Astrolabes of Gerard Mercator’. *Annals of Science* 51, no. 4: 329-353.

Turner, Helen. ‘A newly discovered Elizabethan pocket sundial’ *Apollo* 109, no. 159 (2004): 35-37.

Uglow, Jenny. *William Hogarth: A Life and a World*. London: Faber and Faber, 2001.

Uglow, Jenny. *A Gambling Man: Charles II and the Restoration*. London: Faber and Faber, 2009.

Vainonen, Pilvi. ‘Making Museum Collections: Missionary Hilja Heiskanen’s Himalayan artefacts’. *Studia Orientalia* 109 (2011): 163-182.

Valleriani, Matteo, ed. *The Structures of Practical Knowledge*. Cham: Springer, 2017.

van der Reyden, D. and D.C. Williams. ‘The Technology and Conservation Treatment of a 19th Century ‘Papier-mache’ Chair’. *Preprints of the American Institute for Conservation, 14th AGM, Chicago* (1986): 125-142.

Van Helden, Albert. ‘The Telescope in the Seventeenth Century’. *Isis* 65, (1974): 38-58.

van Seters, W.H. ‘Shagreen on old microscopes’. *Journal of the Royal Microscopical Society* 71 (1951): 433-439.

Varutti, Marzia. ‘Authentic reproductions: museum collection practices as authentication’. *Museum Management and Curatorship* 33 (2018): 42-56.

Viljoen, Madeleine. ‘Aes Incidinus: Early modern engraving as sculpture’. *In Sculpture and Print: 1480-1600*, edited by Anne Bloemacker, Mandy Richter and Marzia Faietti, 41-69. Leiden: Brill, 2021.

Waddell, Mark A. *Jesuit Science and the End of Nature’s Secrets*. London: Routledge, 2016.

Walker. Keith. ‘Publishing: Jacob Tonson – bookseller’. *The American Scholar* 61, no. 3 (1992): 424-430.

Walker, R.B. ‘Advertising in London Newspapers 1650-1750’. *Business History* 15, no. 2 (1973): 112-130.

Wallis, Patrick. ‘Competition and Co-operation in the Early Modern Medical Economy’. In *Medicine and the Market and its Colonies, c.1450-c.1850*, edited by Patrick Wallis and Mark Jenner, 47-68. Basingstoke: Palgrave, 2007.

Wallis, Patrick. ‘Apprenticeship and Training in Premodern England’. *The Journal of Economic History* 68, no. 3 (2008): 832-861.

Warner, Deborah Jane. ‘What is a Scientific Instrument, When Did it Become One and Why?’. *British Journal for the History of Science* 23 (1990): 83-93.

Welberg-Kent, Paul and Allan Chapman. *Robert Hooke and the English Renaissance*. London: Gracewing, 2005.

Wennerlind, Carl. ‘The Death Penalty as Monetary Policy: the practice and punishment of monetary crime 1690-1830’. *History of Political Economy* 36 (2004): 131-161.

Werrett, Simon. ‘Recycling in early modern science’. *British Journal for the History of Science* 46, no. 4 (2013): 627-646.

Whipple, Robert. ‘John Yarwell or the story of the trade card’. *Annals of Science* 7 (1951): 62-69.

Wigelsworth, Jeffrey. *Selling Science in the Age of Newton – advertising and the commodification of knowledge*. Farnham: Ashgate, 2010.

Wigelsworth, Jeffrey. ‘Bipartisan Politics and Practical Knowledge: advertising of public science in two London newspapers, 1695-1720’. *British Journal for the History of Science* 41, no. 4 (2008): 517-540.

Willach, Rolf. ‘The Development of Telescopic Optics in the Middle of the Seventeenth Century’. *Annals of Science* 58, no. 4 (2001): 381-398.

Willemsen, Mathieu. ‘Shagreen in Western Europe: its use and manufacture in the seventeenth and eighteenth centuries’. *Apollo* 145, no. 463. (1997): 35-38.

Wilson, Catherine. ‘Visual Surface and Visual Symbol: the Microscope and the Occult in Early Modern Science’. *Journal of the History of Ideas* 49 (1988): 85-108.

Witt, Ulrich. *Escaping Satiation: The Demand Side of Economic Growth*. Berlin: Springer-Verlag, 2001.

Woolfson, Jonathan, ed. *Palgrave Advances in Renaissance Historiography*. London: Palgrave, 2004.

Young, James Harvey. *The Toadstool Millionaire: a social history of patent medicine in America before federal regulation*. Princeton: Princeton University Press, 1961.

Zuidervaart, Huib. 'The True Inventor of the Telescope. A survey of 400 years of debate'. *Origins of the Telescope – Royal Netherlands Academy of Arts and Science* (2010): 9-44.

Dictionaries

Oxford Dictionary of National Biography. Oxford: Oxford University Press, 2004.

Dissertations

Baker, Alexi. 'This Ingenious Business: the socio-economics of the scientific instrument trade in London 1700-1750'. Doctoral Thesis. University of Oxford, 2010.

Basford, Jenny. 'A Commodity of Good Names: the branding of products c. 1650-1900. Doctoral thesis. University of York, 2012.

Hubbard, Philippa. 'The Art of Advertising: Trade Cards in Eighteenth-Century Consumer Cultures'. Doctoral Thesis. University of Warwick, 2009.

Keller, Vera. 'Cornelius Drebbel (1572 - 1637): Fame and the Making of Modernity'. Doctoral thesis. University of Princeton, 2008.

McConnell, Anita. 'A survey of the network bringing a knowledge of optical glass-working to the London trade: 1500-1800'. Monograph. Whipple Museum of the History of Science, 2016.

Reynolds, Anna. 'Privy Tokens: Wastepaper in Early Modern England, 1536-1680. Doctoral Thesis. University of York, 2017.

Newspapers

de Burton, Simon. 'The Market: Antique Clocks'. *Financial Times*. Sept 3, 2011. Accessed Jan 20, 2019. https://www.ft.com/content/fb164fe4-d502-11eo-a521-00144feab49a/

Radio

Jardine, Lisa. 'Age of Ingenuity'. *Seven Ages of Science,* aired Aug 7, 2013. London: BBC Radio 4, 2013. Radio broadcast.

Websites

(Named website articles, followed by unnamed webpages)

Ashley, Steven. 'The Vulgar Mechanic and His Magical Oven'. *Nautilus*, no. 12 (2004). Accessed Jan 10, 2019. http://nautil.us/issue/12/feedback/the-vulgar-mechanic-and-his-magical-oven.

Cooke, Oliver and Andrew Shore. 'How Clocks work (in 5 easy steps)'. *British Museum* (blog) Feb 27, 2018. Accessed Jan 20, 2019. https://blog.britishmuuseum.org/how-clocks-work-in-5-easy-steps/

Dunn, Richard and Sheryl Twigg. 'The History'. *The Longitude Prize*, July 11, 2014. Accessed April 8, 2019. https://longitudeprize.org/about-us/history/

Hahn, Alexander. 'Basic Calculus: From Archimedes to Newton to its role in Science', *University of Notre Dame*. Accessed Dec 10, 2020. www3.nd.edu/~hahn/

Higgitt, Rebekah. 'Who's that man? Introducing our avatar'. *Metropolitan Science* (blog) July 17, 2017. Accessed May 2018. https://metsci.wordpress.com/blog/

Vincent, Clare. 'European Clocks in the Seventeenth and Eighteenth Centuries'. *The Met Museum*, Oct 2003. Accessed Jan 5, 2017. https://www.metmuseum.org/toah/hd/clck/hdclck.htm/

Wellby, Julie. 'Printmaker's abbreviations', *Princeton.edu*. Accessed Dec 10, 2018. https://www.princeton.edu/~graphicarts/2009/02/printmakers_abbreviations.html

British Museum. 'John Sturt', *The British Museum*. Accessed Dec 19, 2020, https://www.britishmuseum.org/collection/term/BIOG47695

College of Arms. 'Granting of Arms'. *College of Arms*. Accessed Dec 10, 2018. https://www.college-of-arms.gov.uk/services/granting-arms/

College of Optometrists. 'A Bit on the Side: the development of spectacle sides'. *College of Optometrists*. Accessed May 7, 2019. https://www.college-optometrists.org/the-college/museum/online-exhibitions/virtual-spectacles-gallery/a-bit-on-the-side.html.

Phys. 'Research discovers new 'type specimen' for the Asian elephant', *Phys.Org*, Nov 04, 2013, accessed Dec 01, 2020, https://phys.org/news/2013-11-specimen-asian-elephant.html

Royal Collection Trust. 'King William'. *Royal Collection Trust*. Accessed Dec 19, 2020, https://www.rct.uk/collection/603126/king-william

Sothebys. 'Henry Godfrey'. *Sothebys*. Accessed Dec 09, 2020, http://www.sothebys.com/en/auctions/ecatalogue/2015/david-ramsay-and-the-first-clockmakers-l15056/lot.31.html

The Turners Company. ‘Company History’. *The Turners Company*. Accessed Dec 10, 2018. https://turnersco.com/company/company-history/

Appendix

Email dated 31 January 2019 from Dr John Davis (British Sundial Society). Analysis of X-ray fluorescent readings of telescopes and microscopes at the Science Museum – January 2019.

I have attached all the results I obtained (including the two Mensing fakes), mainly in a spreadsheet derived from the analyser output. I've also included a few sample spectra, identified by their Reading #. I hope they are more-or-less self-explanatory but here are a few notes:

* Details of the analyser are as per my previous reports.

* All the results were taken with the full 8 mm diameter spot (not the 'small spot' option).

* All results are normalised to 100% and are measures of wt.% of each of the selected elements (independent of what molecular configuration they are in).

* The order of the elements, L to R, is my standard choice of importance to Cu-alloy studies. Empty cells means either not looked for or below the Limit of Quantification for the analyser.

* The spreadsheet numbers are as reported by the algorithm with typically three places of decimals. These should not be used in any report – the accuracy/repeatability means that only one place should be used for figures over 1% and two significant figures for values less than that.

* XRF can only measure elements from Sulphur upwards in the Periodic Table. Specimens which are basically organic, comprising C, O, N, H etc will not return these components but will normalise everything else to 100%.

* Most of the results were using my ‘Electronics Metals’ range which uses the analyser’s inbuilt algorithm to interpret the spectra, calibrated for use on specimens which are copper-alloys. As this makes uses of the CHARM set of certified reference materials, the results can be trusted when looking at brasses etc.

* The ‘General Metals’ option on the analyser uses a slightly different set of target elements and is optimised for a general alloy. It also has the option of running with a set of filters in the primary X-ray beam to concentrate on light elements and very near-surface components, ie with low secondary X-ray energies.

* For the Culpeper microscope, the metal components are a fairly typical lightly-leaded brass of the period. The amount of lead in the alloys, together with significant traces of tin, lead me to suggest that the items are castings finished off in a lathe (lead makes the liquid more fluid). The exception is the specimen mount (flat side) where the Zn level is higher and there is no Sn which suggests that it is made from a sheet alloy, possibly contemporary but perhaps a later replacement – it is not modern, though. The other side of this mount (where the analysed area covered several separate pieces) shows a composition the same as the struts etc.

* For the second microscope, the alloy components are substantially the same as on the Culpeper one, though with slight variations. For example, the arsenic concentration is relatively high.

* The analysis for the wooden base produces some very odd looking results and I don't know how to interpret them.

* The analyses for the gilded patterns on the composite tubes of the two microscopes are surprisingly different. Both show the expected Au, though of quite different levels. This could be due to different areas of the pattern in the beam, different thicknesses of gold, or different contributions of the unseen organic components. On the Culpeper instrument, there is no Hg which is what you would expect of a pressure-transfer process (not fire-gilded). This instrument also shows Cu and Zn suggesting that it has a brass core. The 'other' microscope shows a huge amount of mercury which I can't explain – the value is probably so high because there is not much else that the analyser can see. It would need some research to see what processes other than fire-gilding were in use at the time. Both microscope tubes (particularly the Culpeper) show the presence of niobium (Nb) which is very unusual in anything I've looked at previously.

END.