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RESEARCH ARTICLE

Between Apprenticeship and Skill: Acquiring Knowledge outside the Academy in Early Modern England

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Argument
Apprenticeship was probably the largest mode of organized learning in early modern European societies, and artisan practitioners commonly began as apprentices. Yet little is known about how youths actually gained skills. I develop a model of vocational pedagogy that accounts for the characteristics of apprenticeship and use a range of legal and autobiographical sources to examine the contribution of different forms of training in England. Apprenticeship emerges as a relatively narrow channel, in which the master's contribution to training was weakly defined and executed conservatively. The creation of complementary channels of formal instruction was constrained by cost and coordination problems. When we consider a range of British youths who obtained advanced skills as artisan practitioners (and engaged in invention or pursued natural philosophical interests), we see the importance of individual agency over institutional structures. For these youths, training could involve rejecting apprenticeship, engaging in periods of advanced study, including time in multiple workshops after the end of apprenticeship, and parallel campaigns to access scarce books and communities of scholarship.

Keywords: Apprenticeship; training; invention; industrial revolution; human capital

1. Introduction

Many of the artisans who (admittedly mostly silently) contributed to the development of natural philosophy, whether directly or through offering exemplars of empirical knowledge, had learned their craft by serving an apprenticeship. This extended stage of learning formed a key period in their lives and the development of their skills. Studies of artisan-practitioners regularly reference their apprenticeships in passing. If we consider the varied but significant contributions made by artisans to innovations in knowledge, whether in natural philosophy, science, or technology, then there is good reason to think that we need to take apprenticeship seriously as a foundational stage in their careers. But what kinds of skills did people acquire as apprentices? How did apprentices learn? And in what ways did apprenticeship adapt to shifts in the types of knowledge, other forms of training, or the spread of new technologies across the early modern period?

The connections drawn between artisans and science in recent studies vary. In the work of Pamela Smith, Pamela Long, and others on the significance of artisanal participation to the epistemological transformations that occurred in natural philosophy, artisanal approaches were appropriated into and transformed science itself through exchanges that brought artisans and the learned together (Smith 2004; Long 2011). In the various studies on how artisans produced new technologies through collective invention or sequential micro-inventions, skilled craftsmen working in autonomous craft communities directly generated new knowledge (Allen 1983; Hilaire-Pérez 2008). Another quite different connection is visible in the collaborative relationship between natural philosophers, inventors, and artisans identified in studies of laboratories, academies, firms, and factories. Joel Mokyr, for example, has recently put a great deal of emphasis on the

thin slice of the skilled labor force who were able to implement inventions, to debug them, to 'tweak' them into viability (Mokyr 2002; 2009). In Mokyr's analysis, the artisans' contribution was central to making innovation a reality, but was specifically based on their craft skills.

In all these accounts, however, artisans contributed substantially to the intensifying production of both practical and theoretical knowledge that characterized the early modern period. If the question of how apprenticeship shaped this contribution – and might have been reshaped in turn – has not been asked before, then perhaps one reason is that in general the innovative, creative artisan was a rare beast among a mundane herd; the active recombination of different aspects of knowledge or communication across disciplinary or occupational boundaries that Long and Smith emphasize was, as they note, unusual, even if the sites where such exchanges occur were becoming increasingly common. Another reason is that, in some of these analyses, the artisans' contribution was embedded within their craft – it was the contribution of their core skill, whether as a nimble-fingered machinist or master of distillation, that was valuable. If so, then at least one possible answer to the question of how artisans contributed to knowledge is rather obvious: artisans contributed by being themselves, so long as the place, incentives, or institutions aligned properly.

The argument I present here is simple, but not quite that reductive. To summarize: apprenticeship was a distinctive type of training in that most masters paid little attention to teaching and much of what was learned depended on the effort made by the apprentice. What was learned in the context of apprenticeship was focused on the specifics of the trade involved: it was "knowledge how." The degree to which this required teaching rather than depending on the observation, practice, and initiative of the youth is often questionable: so far as we can tell, masters often gave limited amounts of direct instruction. Where skills beyond occupational know-how – such as the ability to employ textual and visual media – were identified as a specific item that young people needed to acquire, they tended to be either a precursor to apprenticeship, or delivered through complementary instruction. We can only identify a few, rare occasions where such skills were gained during apprenticeship, either through printed guides or complementary institutions. Moreover, as we will see, print and formal institutions played a modest role in apprenticeships: the market was too constrained, and the approach too distant from what youths needed. Finally, I suggest that if we consider how those artisans who demonstrably gained elements of learned theoretical knowledge – demonstrably because these individuals experienced apprenticeship and later contributed to technological or scientific advances – we need to highlight the importance of individual characteristics, particularly aptitude and enthusiasm, and the significance of unstructured and self-directed learning, in explaining how they acquired an advanced understanding of fields outside their own crafts. In short, artisans' theoretical knowledge of natural philosophy or science was supplementary to, and acquired independently from, apprenticeship, usually outside any formal pathway, while the expansion of print and the growth in prescriptive knowledge only lightly touched the content and form of training in apprenticeship.

To understand why this was the case, we need to understand the basic characteristics of artisanal learning. First, masters' approach to teaching and learning reflected a fundamental problem that communicating craft skills presents to instructors, then and now. It was not negligence. Apprenticeship was usually effective and successful, so far as we can tell. Apprenticeship can be, and often is, conceived of as a way to acquire tacit or embodied skills.[1] Acquiring tacit skills depends on a "vocational pedagogy" that is quite different to the pedagogies employed in teaching codified skills. Its features include: a high ratio of practice to instruction; long periods of working on the job at different skill levels; circulating between workshops or sites to acquire expertise through observation and immersion in different settings. As Jean Lave has emphasized, the master's key function is in allowing newcomers a legitimate way to access the sites of production where they can observe and practice techniques (Lave 2011, 81).

[1]The distinction is Polanyi's (Polanyi 1962), however I gloss this with Mokyr's somewhat different definition, as the argument parallels (Mokyr 2002).

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The tacit character of occupational skills meant that transferring knowledge was costly in early modern Europe. Print and its equivalents played a relatively unimportant part in the process. Replicating apprenticeship training in institutions was difficult and expensive, demanding that materials, tools and machinery be tied up in instruction rather than production. Transferring tacit skills was – and remains – hard precisely because they were literally embodied in the person of the artisan (Epstein 1998; Hilaire-Pérez and Verna 2006). Perhaps the most direct example of this was the importance of moving people to moving knowledge, as seen when the emigrant glassmakers from Murano established the glass industry elsewhere in Europe (Maitte 2014).[2]

In contrast, codified, academic or propositional knowledge could be more easily acquired using print media, which enabled its reproduction and dissemination between people and places with relatively low transaction costs; hence, the famously "revolutionary" impact of print in this period. Needless to say, written and printed texts can complement tacit or embodied skills. The substantial recent literature on recipes and secrets has highlighted precisely this balance between written words and manual skill (Leong and Pennell 2007; Leong and Rankin 2011). At the same time, this research has underlined the pragmatic exclusion or minimization of "how to" sections within these texts. Using a recipe book built upon a basis of manual ability that was acquired outside the text. Print and other forms of text, in short, were much less important for tacit, manual skills of the kind that were central to artisanal abilities than they were becoming for most other areas of knowledge. Securing the skills and literacies needed to use print or its equivalents was irrelevant to most apprentices and masters, at least in so far as they were concerned with occupational training. As this would imply, it was in those trades where Latin literacy or drawing were important, as for apothecaries and goldsmiths, that requirements for specific pre-apprenticeship training in languages or art, or supplementary institutions (such as the Antwerp Academy) came to matter most.

Additionally, the narrowness of the skill set that most apprentices obtained produced problems of scale that were not paralleled in, say, literacy. The number of people learning the intricacies of a specific occupation will always be far smaller than the number gaining more widely applicable skills. One result of the smaller scale of demand is that technologies of vocational education generally lag behind those for general, elementary education where demand was much larger. Evidence of this divergence can be found in the lack of a craft equivalent to the innovative development of primers and catechisms that assisted primary and religious education in this period. Similarly, institutional structures that could have supported training were harder to establish and maintain, given lower and more volatile levels of demand for specific craft skills. There may have been a great many apprentices in most early modern cities, but outside the very largest centers only a few youths would enter a particular trade or craft each year. This gives us a further explanation for print's minor role in transferring craft and trade skills in early modern Europe.

The paper is organized into three parts. First, I look at how apprentices and masters conceptualized learning, to substantiate the image of training as a space more than a process of instruction that my account of vocational pedagogy suggests. Second, I turn to some examples of the employment of formal institutions for vocational training, to examine cases when the general rule that apprenticeship was unchanged by intellectual shifts and new technologies of communication was breached. Finally, I draw on artisanal life-stories to examine the balance of channels of learning within specific individuals' lives.

2. Learning within Apprenticeship

Despite more than a century of research into apprenticeship, little is known about how early modern apprentices actually acquired skills.[3] To consider this issue, we have to look outside the formal

[2]Multiple other examples could be cited (e.g., Mathias 1977; Mokyr and Voth 2010; Bertucci 2013).

[3]The main recent contributions on training are De Munck 2010, 336-9; Earle 1989, 96-102; More 1980, 137-152; Wallis 2008.

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framework of apprenticeship. For apprenticeship had no curriculum, no set of examinations from which we might infer a course of learning, no manuals to support masters in teaching. To explore how people learned, we need to turn instead to how apprentices and masters described training.

Disputes between apprentices and masters at the Lord Mayor's Court of London in the seventeenth century have left a rare set of sources in which apprentices, masters, and others discussed the content of apprenticeship training.[4] For example, one witness to a dispute between an apprentice pewterer and his master reported that the master "never employed the said complainant in any servile or domestic work not relating or usual in the Trade of a Pewterer but always put him as forward in the learning of his trade and gave him all the encouragement as possible might be." The apprentice, he concluded: "has as much instruction and understood his trade as well as most Apprentices for the time he was with" his master (CLRO MC6/526A [1691]).[5] Similarly, in a dispute between an apprentice apothecary and his master, a witness testified that the master put his apprentice "forward in the learning of his trade & did usually read Doctor's bills to him." The apprentice was "well instructed . . . during the time he was with him & understood the same very well" (CLRO MC6/525B [1691]).

This combination of language about training – "putting forward," "encouragement," and "instruction" – appeared in other similar suits.[6] So too did the point about using the apprentice in his trade, not "in servile & domestic affairs," or the "drudgery work of the trade." Somewhat surprisingly, even jobs taken on by journeymen might fall below the apprentice's lot: the apothecary James Cooke was accused of making his apprentice beat the mortar, "which is many times performed by the journeymen & other sorts of servants" (CLRO MC6/547 [1672/3]; MC6/477B [1687]). Together, opportunity (whether positive or negative), encouragement, and instruction formed a trinity of concepts that contemporaries identified as central to apprentices' learning.

That instruction had a place in this conceptualization of learning is one thing. Understanding in any detail the method, content, or intensity implied by "instruction" is quite another. That intensity, at least, might have been increased is explicit in Martha Drury's defense of how her son, Walter, treated his apprentice. Walter had instructed his apprentice, James, well she argued, "he was able to make plasters, caudles & most medicines & do many things as well as the defendant himself, & the defendant having no other apprentice & [James] being the 1st he took, did use the greater Time & Labour with him that he might be sooner capable of doing business than usually apprentices are wont to be." As a result, James "did often say & declare that he understood his trade" and "was able to do things as well as those who had been three times longer at the trade than himself" (CLRO MC6/552A (1673]). The converse – that instruction might be consciously and deliberately delayed – was also true. A good example of this is found in the case in which Thomas Hiat, an apprentice distiller, chemist and surgeon, accused his master of keeping him out of the room when important distillations were occurring. His master, in reply, suggested that the final year of training was ample time to learn secrets, and teaching them earlier would only encourage his apprentice to abscond (Pelling 1995, 258–259).

What masters and apprentices thought of the content and methods of instruction that were appropriate within apprenticeship is – and will remain – elusive. One thing is clear though: any answer would need to be broadly defined. For example, many of the elements of instruction that an apprentice merchant received were contextual, environmental, or experiential (Grassby 1995; Gauci 2001; Zahedieh 2010). Exposure to the business was crucial. Defending the merchant

[4]The evidence discussed here is from the records of the Lord Mayor's Court of London, Equity Side, formerly in the Corporation of London Record Office (hereafter CLRO), now in the London Metropolitan Archive. The references are to the CLRO cataloging. The Court's actions are discussed by Wallis and Pelling (Wallis 2012; Pelling 1994). De Munck has discussed similar evidence for Antwerp (De Munck 2007, 53-8).

[5]CLRO stands for City of London Record Office, the holdings of which are now available at the London Metropolitan Archives. The MC6 series are Mayor's Court records. Note that contractions in the manuscript are silently expanded and spellings modernized in this and subsequent quotations.

[6]For example, CLRO MC6/521B (1691); MC6/529A-B (1691); MC6/506B (1689).

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William Barron's ability to instruct his apprentice, his partner highlighted the scale of their business: they had "a considerable trade in way of merchandizing sufficient to instruct an Apprentice therein" (CLRO MC6/508A [1689]; MC6/500A [1689]). Sir Peter Rich argued "that unless a Merchant's Apprentice be sent abroad as a factor he cannot be fully instructed in the way of Merchandize" (CLRO MC6/503A [1689]). In defense of another merchant, Elias Lambert, one of his former journeymen emphasized that "he sent [his apprentice] Lewis to fairs into the Country which is esteemed the most beneficial [experience] for an Apprentice both in respect of his gaining acquaintance & understanding his trade" (CLRO MC6/553 [1673]). Similarly, the only regularly specified detail of training in Southampton merchant apprentices' indentures was that they should be dispatched aboard during the latter part of their term of service, mostly to Spain or France, for a period to learn a language and gain experience as a factor (Merson 1968, xxii–xxiii).

In other trades and crafts, too, the ways in which masters justified their training also emphasized exposure, through access to sites or experiences that enhanced skills. The merchant's notion of instruction as immersion had its counterpart within the shop, although the journeys through business papers that apprentices were offered were somewhat less exotic. In defense of John Brownrigg, a silk wholesaler, one witness emphasized that he "let [the apprentice] have use & custody of all his books both of buying and selling" (CLRO MC6/551A [1673]; see also, MC6/503A [1689]). Similarly, the druggist John Coningsby let his apprentice have "as much freedom to resort to the Books & other matters relating to instruction therein as any Apprentice is wont to have" (CLRO MC6/506B [1689]). The books in question were the business's account books, not printed books of instruction. Unusually, Coningsby's books survive from a few years prior to the date of this dispute; at that time, he was in partnership with Francis Estwicke (who died in 1682) and kept a complex set of records to manage a business that was turning over more than two thousand pounds a year in a mix of retail and wholesale sales (Wallis 2002, 200–202). More than eighteen separate account books existed in parallel, each devoted to recording different elements of the firm's activities. The freedom to roam through these accounts was no trivial opportunity.

The content of instruction, as far as it can be discerned from these records, encompassed exposure, opportunity, witnessing, travelling. Learning equated to being and doing in the trade. These masters visualized high-quality instruction – for they all, of course, claimed to be exemplary masters – as navigating the apprentices' voyage through a space of opportunities to learn. Whether the apprentice raised up their eyes from the distractions of youth to learn from the practices that surrounded them was not the master's responsibility. In this Cook's Tour of a trade, some soaked up the sights, others frittered their time away in taverns or idle conversation with maids.

Who supplied instruction was also open for dispute. That it might *not* be the master was implicit in various statements. One witness on behalf of Thomas Wallon, a wine cooper, asserted that "If [the apprentice] wanted any instruction it was his own fault, for the Defendant kept several Journeymen, & had an Apprentice almost out of his time very well skilled in his trade, and that one or other of them were always at home" (CLRO MC6/488A [1688]). The importance of journeymen was also reflected in another case, where one witness argued that the apothecary James Cooke's apprentice was not as well instructed as he could have been because his master "kept divers outlandish men as Journeymen in his shop ... whereby the complainant could not attain to any sufficient knowledge & experience in his trade" (CLRO MC6/477B [1687]).

To the extent that we can see anything of the content of training here, it is closely tied to the practice of craft or trade. It is important to emphasize that there is no evidence in these cases that skills such as literacy were expected to be part of the usual package of instruction supplied by the master. Literacy and accounting do feature occasionally. For example, faced by a new apprentice who "could not write or cast accounts well," Isaac Barnard, a haberdasher of small wares, "gave him leave near upon a year to go to school to learn the same." Barnard paid for this schooling, but he did not teach. The writing master involved, one Richard Allen, testified that he received £2 for the 12 months in which he "taught & instructed [the apprentice] in writing and accounts here in

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London" (CLRO MC6/505A [1689]). Barnard, it should be noted, had received a premium of £100 with the youth. In a similar vein, the apprentice Jasper Gifford "did learn to write off & on [for] about a quarter of a year of a master [Humphrey Kessell, a schoolmaster] that had a part of [his master's] ... house & for the most part the Complainant did write in the shop & sometimes he would go up to the school"; George Hanbury, another witness in this case, also reported that Gifford's master "did allow him time to learn to write & cast accounts, but the complainant neglected the same" (CLRO MC6/479A [1687]). Such arrangements were rare. In Southampton, in a register of 650 indentures, only one master of a regular apprentice in the seventeenth century contracted to teach his apprentice "to write and cipher," although a blacksmith taking a 10 year old pauper apprentice also agreed to keep him at school for the first three years of his term (Merson 1968, xxii). Apprentices might thus gain these general skills during their indentures, but they did so through specialists, and they only did so rarely.

For the most part apprentices would have been expected to have learned their letters and numbers – if they were to learn them at all – before they began training. In his 1747 guide to parents considering an apprenticeship for their children, Campbell identifies those trades that *require* literacy or ability in drawing, rather than those that will *teach* it. Literacy was a part of earlier education, not a sub-set of the skills apprentices learned. Numeracy, even accounting, were in the same category. For this reason, they were the focus of small mathematical and accounting schools in cities such as London by the sixteenth century (Charlton 1965, 264–5, 268; Schulz 1943). As Campbell notes, those parts of education that "are universally useful," such as reading, writing, arithmetic, and drawing, should be learned "before [the apprentice] enters." If they are not, Campbell goes on to warn, then "it is seldom that he can find Time to acquire it till he is out of his Time; when he is far from being capable of making any Proficiency" (Campbell 1747, 19–20).

Prior literacy was not commonly a formal requirement in a system of guild apprenticeship – although in London, three guilds (the Apothecaries, Barber Surgeons, and the Goldsmiths) did expect literacy, and the apothecaries mastered a Latin pharmaceutical lexicon (Wallis and Wright 2014).[7] Instead, it was a practical effect of the form and timing of different kinds of education. The basic chronology of learning in early modern Britain began with schooling in reading and arithmetic between six and fourteen years of age, whereas apprenticeships rarely started before sixteen, giving youths ample time to acquire such skills in advance (Wallis, Webb, & Minns 2010). Thus, the pauper apprentice in Southampton mentioned above was being educated in part because he was the right age. Certainly, some people would learn these skills later, as we have seen. But this was more common among labourers than artisans: in David Galenson's study of how literacy grew with age in early modern England, he found that the 'skilled' workers in his sample (those who probably served apprenticeships) had a higher probability of being able to sign when young and a low rate of increase in literacy thereafter (Galenson 1981, 823).

In summary, learning relied heavily on the agency of the apprentice not the master. Apprenticeships in this period gave a youth the chance to observe, practice, and repeat; they provided youths with access to tools and materials; they exposed them to norms, exemplars, and models. Precisely this kind of repetitive practice and extended embedding in a field of practice features prominently in modern analyses of how humans gain embodied skills and acquire exper tise (Ericsson 2006). This trope of youths gaining skills by watching, copying, and repeating is found across a wide range of anthropological and historical studies of apprenticeship (Wallis 2008, 849–50; Lave 2011).

Apprenticeship was more of a chance to learn, rather than to be taught. In part, the reason is economic. Apprenticeship was an unstable, fluid relationship in much of Europe: many youths would leave their contract early; only a tiny number would work for their master after finishing their indentures (Wallis 2008; Minns & Wallis 2012; Schalk 2017; Schalk, Wallis, Crowston, and

[7]Based on a sample of 27 surviving Guild's Ordinances (see Wallis et al. 2017).

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Lemercier 2017). A master who could not force his apprentice to stick with him had little incentive to invest much effort in training. What they did invest, they needed to recover quickly; so productive and profitable work – even if it was unskilled – featured prominently in the apprentice's daily existence. Even in modern contexts with high completion rates and the potential for long-term hiring, companies tend to under-invest in training. Early modern production was organized on a microscopic scale, with only a tiny share of workers engaged in long-term relationships with a firm or institution that might have justified their employer investing in their abilities. Another part of the reason was pedagogical, however. As we discussed, the process of acquiring embodied skills in craft or trade largely depended on immersion, exposure, and practice. Listening to a master articulating how a particular process needed to be executed could only ever have been a small part of the overall package of training. This remains one of the reasons for why technical education today is still an expensive proposition, because the amount of capital (tools, materials) involved in unproductive repetition is large.

3. Complementary Institutions for Training

If the core of early-modern apprenticeship training can only be defined vaguely, but seems to have been rooted in the inculcation of embodied practical knowledge, could other kinds of knowledge have been acquired in parallel? Might the skills transmitted within workshops have been complemented by instruction in theoretical principles or academic knowledge through other channels? Could such additional education have been a consequence of the shifts in the structures of knowledge that occurred in this period?

This possibility has been highlighted by Bert De Munck, who has discussed the establishment of a new pair of formal teaching institutions in Antwerp in the seventeenth century, the Art Academy and Medical College. These institutions provided a new arena for detailed instruction in specific skills. And they used quite different pedagogical techniques – lectures, classes, and so on – to those seen in apprenticeship. De Munck identifies this with a shift in how skills are perceived, and particularly the increasing importance of "an individualistic culture of humanistic elites" (De Munck 2010, 356). Books and other media might offer a further alternative to such organizations, possibly one with a greater reach.

The process of institutional innovation that De Munck discusses has parallels across Europe, where a number of cities created similar centers to teach surgery, pharmacy, art, and drawing (De Munck 2010, 334 n. 8; Pevsner 1940; Tkaczyk 2017). Yet these teaching institutions never became common. If we look at how they operated as complements or substitutes for apprenticeship, we can gain some insight into the differences between the frameworks for learning that were at play, and from that derive an explanation for their limited scale.

Here, I focus in detail on one example of institutionalized teaching in London. In this case, it is instruction in a corpus of learned knowledge, specifically the general principles of the human body, its operation and structure, as understood by ancient and modern anatomists and physicians, that was complementary to the skills surgeons gained in their apprenticeships. In London's Company (guild) of Barber Surgeons, series of lectures on anatomy and surgery were given regularly by the end of the sixteenth century. These lectures were mostly given by physicians, but funded and hosted by the Company as a collective good: they paid the lecturer the substantial gratuity of around £10 a year in the early seventeenth century. To support this, the guild had a collective right to a corpse. The lectures were sufficiently reputable that one of the physicians who delivered them, Helkiah Crooke, addressed his anatomical compilation to the Company (O'Malley 1968, 7). It is important to note that the lectures on surgery were intended for the freemen of the guild, the masters or journeymen, not the apprentices of the craft. This was advanced instruction that occurred after an apprenticeship. Freemen (journeymen and masters) had to attend or pay a fine; conversely, individuals who the guild found to be bad surgeons were ejected

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from the "lecture bill." Admission to the lecture was a mark of growing expertise, not a way to gain basic skills. However, the anatomy lectures were still meant to be a site for learning.

We can get a flavor of how the lectures worked from the guild's records. It is clear that these were *read* lectures that accompanied a dissection. Lectures were taken from identifiable texts and were, at least in principle, reproducible by any skilled and literate surgeon: in 1616, the Company asked Dr Gwynne to proceed with reading the lectures "out of Guoydoes Surgery" – presumably Guy de Chauliac's work (Guildhall Library [hereafter GL] MS 5257/5, f. 294). In 1627, when Dr Gwynne's death left them without a lecturer, the guild decided that rather than choosing another physician, every surgeon would take a turn reading them according to his antiquity (seniority); possibly misleadingly, this was described as the "ancient custom." They also specified that:

> during the time of reading of such lecture, none of the audience shall interrupt and question the reader till the hour be run out and the lecture ended, at which point it shall be lawful for the master, wardens and examiners then present (if any error have been committed by such lecturer) to question such reader & to make manifest wherein he hath erred. (GL, MS 5257/5, f. 70)

This was, however, an experiment that failed quickly. Instead, they returned to hiring a doctor to read the lectures, and by 1628 it was Dr. Andrews, probably Richard Andrews, the son of a leading member of the London butcher's guild, who was reading (GL, MS 5257/5, f. 135; Birken 1977, 199–203).

This brief sketch points to some important features of the challenges that the surgeons faced when they attempted to convey more highly codified fields of knowledge to their members. Surgeons in the London guild had been trained via apprenticeship primarily (Pelling 1995). Yet the perceived need to acquire a knowledge set associated with learned medicine and universities – particularly the centers of anatomy, the universities of Northern Italy – led them to adopt and reproduce academic modes of instruction. Moreover, when they tried to adopt a form of communal learning, by taking on the lecturing themselves, they were unsuccessful, and quickly reverted to using an expert in this mode of delivery and material (a university-educated physician). Their skill at surgery, the quality that made them viable masters to apprentices, did not translate into skill at lecturing on the codified anatomical knowledge conveyed in these lectures. For that, they needed a specialist in academic not practical medicine.

One might see these lectures as an attempt to reconstruct the craft around learned principles, to raise its status by association perhaps. This is one of the motives for the creation of such institutions that De Munck identifies. Surely there is evidence for this in the mannerisms that the Company at times adopted – for example, appointing "Anatomists to the Students in Surgery" in 1635 who have the privilege of calling upon "any of the rest of the Students to make repetition or to move a question to them in the form of argument concerning the present or precedent Lectures" (GL, MS 5257/5, f. 209).

At the same time, the form that these lectures took and their restriction to freemen – members of the guild, not apprentices – also highlights the resources that are embedded in institutionalized learning. Teaching institutions, whether lectures or academies, offer economies of scale. They can maximize the utilization of scarce resources, whether corpses, books, or live models; as the surgeons knew, one corpse can serve one student or forty as easily, although they may not all have the best view. They rely upon teaching by experts whose knowledge goes beyond that of the everyday practitioner. Moreover, they provide (or temporarily construct) spaces where practice can be oriented towards the student's needs, rather than the employer's profit. Yet, they also bring direct costs in their train that require a revenue stream to overcome. Lecturers need paying. Bodies need to be acquired. Rooms need to be rented. If the "how" of learning becomes much more visible with institutionalization, so does the problem of financing it. No surprise that the guild was willing to

fund lectures for its members, whose dues paid for them, and offered nothing for apprentices who mostly never became freemen.

As this example makes clear, anatomy lectures and the like are separated by a substantial gulf from on-the-job training. Formal institutionalized instruction may productively co-exist with apprenticeship, but it depends on quite different pedagogical strategies – and these strategies may not be more effective. Educational institutions offer economies, but only at scale, and only when the type of instruction is suited to delivery *en masse*. When adopted within technical schools, the vocational pedagogy needed to gain artisanal skills proves to be tremendously capital intensive and costly. Institutions providing vocational or technical skills equivalent to those gained in apprenticeship were rare in part as a result of the costs involved. A few schools for design, drawing, cookery, and similar skills appeared in England in the later seventeenth and eighteenth century, but they can only ever have served a small share of those undertaking these occupations (Craske 1999, 206).

A similar conclusion can be drawn from the various attempts to strengthen the technical skills of young workers engaged in on-the-job training that occurred in Britain in the nineteenth century (see Dearle 1914; Knox 1980, 228–279; More 1980, 198–225). From at least the 1820s, artisans, employers, and politicians were worrying about workers' capacity to understand the scientific principles involved in their work. The response to this led to the creation of a number of important institutions, including the Mechanics Institute (1823). After the depression of the 1870s, efforts to increase training intensified. In 1879, the Livery Companies of London came together to create the City and Guilds Institute to supply technical training and qualifications aimed at "educating young artisans and others in the scientific and artistic branches of their trades" (Floud 1982, 159). Finally, in 1889, Parliament passed the Technical Instruction Act, allowing local authorities to levy a modest tax (one penny on local rates) to fund technical education "in the principles of science and art applicable to industries"; the Act specifically *excluded* "the practice of any trade" (ibid., 160, 162–3). This amounted to a major campaign to transfer high-level general skills to the workforce – to create a generation of workers who were able to advance production through the application of scientific knowledge.

What stands out here is not just the ambition, but the mechanisms involved in this campaign. First, this was largely a movement that occurred outside the firm. As standard human capital theory would predict, few employers offered to fund or supply this kind of instruction in general skills directly. As a result, instruction was supplementary to work. It took place through evening classes or weekend schools, outside of working hours. This suggests another point: it was left to youths to seize the chance to train – which they did: perhaps a third of boys in the building trade, engineering, printing, and wood and furniture trades in London were taking classes at the end of the nineteenth century, although only one percent of workers took any technical examinations each year (Knox 1980, 255; More 1980, 207). Finally, the subsidies that made technical education financially feasible were drawn from charitable donations or general taxation. Youths on their own could not muster the funds to sustain a large-scale system of technical education, even though there was clearly substantial demand for this provision once it existed, while most firms lacked the interest or will to pay for training.

The creation of educational institutions focused on transmitting advanced vocational skills – art academies, colleges, lectures, and so on – was an important shift in the sources of skill in European history. But these institutions were relatively peripheral to the world of the craft or trade apprentice, outside of a few, select occupations, until the twentieth century. Medicine was one exception, but even there the majority of training continued to be delivered via apprenticeship (Pelling 2019). Drawing appears to be another (De Munck 2010). As Klein observes, many of the institutions to train experts in areas such as mining and engineering that emerged in the eighteenth century focused on occupations that lacked guilds or apprenticeship (Klein 2017). Schools, colleges and academies offered a counterpoint and complement to apprenticeship as a mode of teaching. They offered efficiencies in learning, but at the price of crystallizing the costs

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of teaching and abandoning the traditional means that had allowed youths to pay for their training; students at colleges could not fund their learning through their labor. No wonder then that the inauguration of these institutions often depended on wealthy, sometimes royal, sponsors.

Did print offer an alternative to formal institutions? Might artisans and traders have enlarged their abilities by wandering through the pages of books instead of sitting in lecture halls? This possibility does not seem to have been realized in most occupations. The exception in some ways proves the rule. Merchant's manuals were published in very large numbers, forming a literary genre in their own right (Glaisyer and Pennell 2003, 2006; Rabuzzi 1995; Finkelstein 2000). As a hodgepodge of legal information, accounting techniques, guides to commodities, outdated market prices, and so on, they illustrate the potential of print to provide a short-cut to knowledge, at the same time as they reveal how little of the practice of commerce could be condensed and communicated in print. Where their authors tried to talk of trade itself, they were usually quickly reduced to general moral injunctions, to the sensibilities and qualities of merchants, not their skills (Rabuzzi 1995). One of the earliest manuals printed in England, Browne's *Marchants Avizo*, incorporated a section on "certain godly sentences necessary for youth to meditate upon," for example (Browne 1589, 55ff).

Merchant's manuals have few equivalents in artisanal trades. Medicine, navigation, and accountancy are the only other sectors where print gained a major role. A growing body of guides to drawing and design appeared in the eighteenth century, but these set out general skills, ideally acquired before entering a trade (Craske 1999, 190–191). The Baconian project to write histories of the trades aimed to make knowledge accessible to outside investigators and to advance technology through the application of the sciences, not to ease apprentices' acquisition of their crafts (Bertucci & Courcelle 2015, 165–6). The diarist and naval administrator Samuel Pepys may have learned how to use a slide rule from a printed book, John Brown's *Description and Use of the Carpenter's Rule*, but one imagines that few carpenters did (Glaisyer & Pennell 2003, 13).[8] The earliest English manual on printing, Moxon's *Mechanick Exercises* (1683) was firmly aimed at the scholarly outsider (Maruca 2003, 326–7). In practice, both the imagined reader of the Baconian history and the owner of the merchant's manual overlapped: both were wealthy, literate, often gentlemen or prosperous leaders in urban society. Both could afford these texts.[9] Both possessed the general skills to utilize them. A market for this form of instruction existed, in short, but few of those youths pursuing careers in the crafts were part of it.

4. Artisans and Theoretical Knowledge

Thus far, we have explored two, rather different ways into the problem of acquiring skills in the context of apprenticeship. Both are suggestive in that what they show was *not* happening in early modern England. Masters were not offering instruction in skills beyond occupational know how. Educational institutions such as academies and lectures were being used, but only in a few, quite specific areas, and they drew on alternative sources of inspiration for the manner of teaching they employed. Few apprentices would ever darken their doors before the twentieth century.

To think further about how artisans gained a grasp on theoretical knowledge, we need to move from the general to the specific, and study those rare individuals who left some record of their learning. Most of the people I discuss below are drawn from the group of individuals who made a substantial contribution to knowledge – artisan-inventors in the early industrial revolution.[10]

[8]Brown also sold him the slide rule.

[9]The impact of cost on reading choices is well illustrated in the one study of an apprentice's reading that I am aware of (Colclough 2000).

[10]The sample of inventors I examine here is based on Allen's list in (Allen 2009, 269-271), extended with additional individuals identified in the Oxford Dictionary of National Biography. The known former apprentices are: Richard Arkwright (1732-1792); Samuel Bentham (1757-1831); Joseph Bramah (1749-1814); William Cookworthy (1705-1780); Abraham I Darby (1678-1717); George Dolland (1774-1852); George Graham (1673-1751); Francis Home (1719-1813); Robert

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Alongside those heroic exemplars, twenty-two of whom are known to have served apprenticeships (more are suspected to have done so), I bring in some other early autobiographers and diarists who served an apprenticeship. This approach requires a note of caution: using such sources tends to push us towards the late eighteenth and nineteenth centuries, when memoirs become more abundant; we cannot assume that experiences would have been the same two centuries previously; and authors may also be biased towards emphasizing their own contributions over the part of others, such as masters. I concentrate on how these people developed skills and knowledge beyond their core occupational abilities. In these cases, we can see a variety of different modes of *learning*, and the presence – or more often the absence – of a range of modes of *instruction* as well.

These artisan-inventors were all apprentices, at least for a period. But of all the ways in which they learned, an apprenticeship in the relevant field for their later contribution was perhaps the *least* important. Only around half of these artisan-inventors were apprenticed within the trade where they later made their contribution. Exceptions did exist: John Kennedy, who developed fine spinning machinery at his firm Kennedy and O'Connell, had been apprenticed to a manufacturer of textile machinery. But equally common are stories such as that of Richard Arkwright, whose training as a barber offered little foundation for his advances in cotton spinning machinery.

This disjuncture between inventors' apprenticeships and their later contribution to knowledge is partly a systematic problem: getting involved in new areas of invention and creativity almost by definition meant moving outside of the scope of a traditional craft. In this regard, it makes sense that the only cluster of inventors amongst with clear inventive-master-to-inventive-apprentice ties were engaged in clock and instrument making: clockmaking was an organized and coherent set of trades at the start of this period, and retained a workshop model of production (albeit with extensive sub-contracting) into the nineteenth century. However, this disjuncture also reflects the position of apprenticeship within a life-course; apprenticeship occurred at an early stage within an individual's process of discovery about their interests, aptitudes, and opportunities.

Even when artisan-inventors had apprenticed themselves in the relevant trade, they were rarely taught by a master who was at the cutting edge of their field. With the interesting exception of a few dynasties where fathers and sons produced significant contributions (such as the Dollonds in lenses and optics, the Champions in metals, or the Spodes in ceramics), most inventors beget few inventors *ab initio*. Indeed, few inventors appear to have taken many apprentices, so far as we can tell. It was far more common for those who would later make substantial contributions to acquire advanced training in a center of skill after their initial apprenticeship. This kind of learning by "advancement," as More styled it in his study of nineteenth-century training, could involve an artisan seeking a position as a journeyman, or arranging some form of contract for advanced instruction with a leading master (More 1980, 108–117). For instance, the clock and instrument maker George Graham moved from an apprenticeship with an average master (Henry Aske) to employment as a journeyman with one of the trade's leading innovators, Thomas Tompion (ODNB, s.v. Graham). Similarly, when James Watt came to London to advance himself as a mathematical instrument maker, he arranged a year's instruction from John Morgan, for which he paid 20 guineas (ODNB, s.v. Watt). Looking further afield, the many young artists who spent periods in Rembrandt's studio offer a further example of advancement (Prak 2008).

This form of peripatetic, progressive learning was widespread. It was innate in the systems of tramping that led artisans through a series of workshops as journeymen (Epstein 1998 and 2004; Reith 2008). It is central to Liliane Hilaire-Pérez's notion of artisan technology as an "open technique" (Hilaire-Pérez 2007). It was a method heavily employed by Klein's "hybrid experts" (Klein 2017). Even where tramping was not formalized, as in seventeenth-century England, we see all

Hooke (1635-1703); Benjamin Huntsman (1704-1776); John Kay (1704-1781); John Kennedy (1769-1855); John Lombe (1693-1722); Thomas Lombe (1685-1735); Thomas Mudge (1715-1794); Matthew Murray (1765-1826); Thomas Newcomen (1664-1729); Jesse Ramsden (1735-1800); Jedediah Strutt (1726-1797); Charles Tennant (1768-1838); Josiah Wedgwood (1730-1795); Isaac Wilkinson (1695-1784).

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kinds of artisans using movement to learn. For example, the shoemaker Benjamin Bangs worked with two masters before deciding he understood his trade reasonably well and "was a little ambitious in my mind to become master of it." He left his second master and "got into the company of the best workmen, which caused me to spend what I got amongst them, although I then earned considerably" (Hobson 1757, 7). It is useful to distinguish advancement from the initial period of training that occurred during apprenticeship, as we can see here two important elements of the process of skill acquisition: firstly, the agency of the learner; and, secondly, the revealed aptitude that both learner and teacher can recognize after the youth has completed their early training. If apprenticeship was life-cycle learning, in the sense of a necessary and well-defined transitional stage into the world of artisanal work, advancement was life-course learning, a fluid, reflexive period that depended on the abilities, interests, opportunities, and ambition of the artisan.

The other aspect of learning that we see in these life histories and memoirs is somewhat different: it is *self-instruction*. In many ways, self-directed learning is more important than apprenticeship in explaining how aspects of theory and science were acquired by artisans and their peers in early modern Europe. By self-instruction I mean all forms of self-directed learning – reading books, talking to people, attending lectures, joining societies, and so on – the same melange of sources that were employed by entrepreneurs and engineers in this period (Jacob 2007). The distinction here is between learning within a defined framework, such as apprenticeship or schooling, and learning outside of one.

Self-instruction could take collective forms, but when this occurred it did so in an associational, voluntary manner. One useful example appears in the memoir of an apprentice printer in early nineteenth-century Bristol, Charles Manby Smith. Manby Smith heard of group of other youths who planned a club:

> with a view to mutual improvement. The plan was, to hire a room for three-and-sixpence a week, and to stock it with books, papers, and drawing materials, each one contributing what he could. Subjects were to be discussed, essays written and criticised, the best authors read aloud, and their sentiments subjected to our common remark. I joined at once, without hesitation, and have congratulated myself that I did so to this day ... and thus, for six pence a week each, we had an imperfect, it is true, but still an efficient means of improvement at our command. (Manby Smith 1853, 15)

Another, slightly different illustration is offered by Charles Whetstone, an eighteenth-century shopkeeper's apprentice in Derby, who found in his master's house:

> a small library of books, to which I had free access. I read them all: but the work that most engrossed my attention, was "Derham's Physico Theology, or a Demonstration of the Being and Attributes of God from his Works of Creation". This very valuable and instructive work I perused with more pleasure and attention, and a greater number of times, than I had ever read any book before. (Whetstone 1807, 76)

He investigated it "and from examining the structure of such plants, birds, quadrupeds, or fishes, as fell in my way, I naturally proceeded to the anatomy of man." Whetstone then befriended a surgeon's apprentice who lived nearby who "was acquainted with several who at their leisure studied Geometry, Chemistry &c. and by borrowing and lending books, they mutually assisted each other." However, he was hampered as he "had very few books to lend; [and] I had less opportunity in the day time to partake of these advantages." When he did manage to get one, "I found more gratification in reading them, than I found in sleep" (ibid., 76–77, 84).

One of the later founders of the Mechanical Institution, the whitesmith Timothy Claxton, illustrates the chance and agency involved when youths sought knowledge beyond the confines of their trade. His master's workshop supplied a "great variety of work," but beyond that, gaining wider

knowledge and skills depended on Claxton's own initiative. He spent his box-money on a "good thick cyphering-book" to practice arithmetic. He took evening lessons from a journeyman carpenter who had "several books full of examples in mensuration of superficies and solids, embracing the methods of measuring various kinds of artificers' work." He spent his spare time "in divers curious experiments," building himself a clock. As an apprentice he never "heard a lecture on anything, or read a book connected with the arts and sciences, save what I have mentioned, or a poor geography borrowed for a short time." It was not till he was 25 years old and working in London that he attended a course of lectures on natural philosophy (Claxton 1839, 7–16). Claxton's reflections were likely refracted by his desire to encourage youths to improve themselves, but if so, they only serve as a better guide to his ideas of how artisans might gain skills.

Masters rarely supported such wider learning. They may not have opposed it: the master of our Bristol printer's apprentice, Manby Smith, apparently thoroughly approved of his evenings improving himself (likely the opposite, evenings debauching himself, were less appealing), but this was definitely not his initiative (Manby Smith 1853, 15). Similarly, Timothy Claxton spent his mealtimes preparing parts for mechanical experiments in his master's workshop: as he recorded, his master never objected, "in fact, he did not trouble himself about it" (Claxton 1839, 13).

In these narratives of self-improvement, we see, almost for the first time, the importance of books, sociability, and civil society. This introduced the potential for virtuous cycles of creative reinforcement, particularly as the volume of publishing grew. This kind of independent learning would have become easier and more common over the seventeenth and eighteenth centuries. The books these apprentices read were not didactic literature containing guidance on their craft. They were the opposite: sources on learned and scientific knowledge. Quite what they gained from undertaking these studies is lost to us, but the memoirs convey a strong sense that for these individuals such learning was important in gaining a broader perspective on the world and in shaping themselves into enlightened artisans. We can also see the significance of an ardor for learning within a context in which general knowledge was widespread and increasingly accessible, whether or not one would go so far as to argue with Joel Mokyr or Margaret Jacob that this amounted to an industrial enlightenment (Mokyr 2009; Jacob 2014). In short, we see the importance of the individual, of aptitude, of enthusiasm, and of opportunity.

5. Conclusion

If we return to the questions of how apprentices learned and how apprenticeship developed with which we began, we have the basis for some provisional answers. Apprenticeship was a mechanism for training that was vital for artisanal skills, but it was rarely the mechanism through which more general skills such as literacy or numeracy were gained, and it was not the medium through which insights into learned, scientific or advanced technical knowledge were acquired by artisan-practitioners. In turn, the kind of training that most apprentices received appears to have been little changed by the intellectual developments of the sixteenth to eighteenth centuries. The bifurcation between apprenticeship and academic forms of learned knowledge reflected a fundamental characteristic of vocational skill acquisition that persisted until the twentieth century, when a combination of state-funded classroom instruction in technical principles and experiential learning on the shop floor became established as a new hybrid form of apprenticeship across the western world.

Early modern artisanal training centered on access to a space for *learning*, but not the action of *instruction*. Apprentices came to embody skills by participating in situated production, surrounded by exemplars and committed to repetitive practice – their own agency was central to succeeding. Apprenticeship was an effective solution to the problem of supplying training. The increasing availability of books and instruction within academies and schools had little effect.

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The skills that apprentices obtained were shaped by technological changes embodied in the production process, but were otherwise untroubled by shifts in cosmologies or scientific conceptions.

To understand artisan practitioners' acquisition of advanced skills, we need to adopt a model of learning across the *life-course* that extends beyond the life-cycle learning stage represented by apprenticeship, with its clearly defined structure tied into and reinforced by legal, civic, and guild norms. In some ways, these artisans experienced a U-shaped educational path, curving from the widely-applicable skills of basic literacy and numeracy acquired in childhood, through the embodied, narrowly focused "know how" of their craft or trade that they learned as apprentices, and back into more abstract, theoretical kinds of knowledge, only gained by the minority who pursued further learning in the sciences or arts. This was a life-course of learning, not the predictable series of stages in a life-cycle; it was a path that was selected and revised, altered by events, inflected by aptitude, opportunity and enthusiasm. It was determined by self-reinforcing cycles of revealed interest, growing skill, mobility, and advancement that depended on an individual's agency, desire, and willpower. The how of learning in these instances is, therefore, mostly invisible in part, because it was so personal.

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