
Pocket-Size Architectural Notebooks and the Codification of Practical Knowledge

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Abstract

Based on the study of five small-scale Italian architectural manuscripts, dated between 1470 and 1520, this article uses the practitioners' drawings to examine early modern artistic education, and the means by which architectural knowledge was systematized, developed, shared, and retrieved. To this end, the paper considers the books' contents in terms of differing divisions of architectural knowledge and modes of visualization. The function of the manuscripts' drawings—which include generic models, building diagrams, design “recipes,” and exercises in architectural *invenzione*—varied significantly depending on context, and although no single image served as a “working” plan, all were in some way immediately useful to the practitioner. The drawings may thus be understood as records of architectural practice, and as such, relate to the codification of design-based knowledge and the evolving language of early modern architectural representation.

In book six of his *Libro Architetonico*, Antonio Averlino “Filarete” (1400–1469) advises the student architect to carry with him a notebook, in which to record impressions, measurements and ideas. The drawings and annotations collected in the book, Filarete notes, will help the architect clarify and communicate his building projects, and in the case that details are forgotten, he “can turn to the book and find them again” (Filarete 1972, 148). The ubiquity and utility of such notebooks among fifteenth- and sixteenth-century artists and architects is amply evidenced. Correspondence records and last testaments from the period are filled with citations to *taccuini*, *libretti* and *vacchette* (“little books”). Similarly, contemporary chroniclers and theorists, figures like Marcantonio Michiel (1484–1552) and

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Giorgio Vasari (1511–1574), report directly on practitioners’ reliance on such books.¹ A well-known illustration by Maso Finiguerra (1426–1464) also captures the importance of drawing books in architectural training. The image presents a young artist diligently drawing in a small sketchbook, and bears the inscription: “I would like to be a good draftsman and I would like to become a good architect.”² Within the study of Italian Renaissance architecture, significant attention has been given to the practitioner’s drawing books, in particular to workshop model books and volumes of antiquarian studies.³ Yet, one category of early modern architectural drawing books has been substantially overlooked: the personal, “pocket-sized” reference book of the architect-technician. Scholarly neglect of these books is variously explained. For one, due to the small size of the volumes—conceived to be readily transferred between the workshop and building site—as well as to the high degree of wear they endured, relatively few of the pocket-sized manuscripts remain intact (Elen 1995, 55–6). Critical examination of the portable books has also been a casualty of the compositional and formal qualities of the volumes themselves. As manuals compiled for the purposes of personal reference, the drawings contained in the handbooks often lack the refinement and finish of those the architect prepared for patrons or meticulously copied into a shared, workshop model book. Thus, within the scholarship, the pocket-sized volumes have been considered “disorderly and chaotic,” prosaic, haphazard collections of loosely related remarks (Zwijnenberg 1999, 1).

But this study aims to show otherwise. Examining five exemplary, small-scale manuscripts of the fifty-year period between 1470 and 1520, this article argues that the often overlooked early modern practitioner’s manuals are in fact among the richest and most revealing documents of early modern architecture. The five manuscripts are those of Buonaccorso Ghiberti (1451–1516), grandson of the famed Florentine goldsmith and architect Lorenzo Ghiberti (1378–1455) (*Zibaldone* c. 1480–1490); the Siennese military architect Francesco di Giorgio 1439–1501 (*Codicetto Vaticano*, c. 1465–1475); Giuliano da Sangallo (1443–1516), favored architect of Lorenzo de’ Medici (1449–1492) (*Taccuino Senese*, c. 1490–1513) Leonardo da Vinci 1452–1519 (Codex Forster III, c. 1493–1497); and the mechanic and topographer Benvenuto della Volpaia (1486–1532) (*Libro di Macchine Diverse*, c. 1520–1524).⁴ These volumes, although each entirely unique in regards to form, media and subject matter, are alike in their essential function as personalized collections of architectural knowledge. The books codified the practice of those individuals who used them, and in the sense that they were carried with the architects, shared with collaborators or passed between generations, they were transmitters of knowledge. More so than building contracts, wooden models, and even the final constructions, the personal notebooks offer insight into how the early modern architect structured his thoughts, developed

¹On early modern citations to artists’ drawing books, see (Rushton 1976, 16–7). On M. Michiel’s references to drawing books, as well as on the collecting of drawing books in the sixteenth, seventeenth and eighteenth centuries, see (Elen 1995, 128–33).

²Maso Finiguerra’s “Apprentice Drawing” is conserved in the Gabinetto Disegni e Stampe degli Uffizi, U 115 F. See (Bambach 2003, 6–7).

³Notably, there has been considerable scholarship dedicated to early modern scholarly note-taking and academic notebooks. Principal recent studies include: (Blair 2010), (Campi et al. 2008), and (Yale 2011). The distinction between the artist notebook, model book, drawing book and album is addressed by (Elen 1995, 26–32). The definitive study on Renaissance drawing books of antiquities remains that of (Nesselrath 1986). On workshop model books and artist’s copybooks, see (Ames-Lewis 1981, 63–72).

⁴Buonaccorso Ghiberti, *Zibaldone*, codex Banco-Rari 228, Biblioteca Nazionale Centrale, Florence; Francesco di Giorgio, *Codicetto Vaticano*, codex Urb. Lat. 1757, Biblioteca Apostolica Vaticana; Giuliano da Sangallo, *Taccuino Senese*, S.IV.8, Biblioteca Comunale di Siena; Leonardo da Vinci, Codex Forster III, Victoria and Albert Museum, London; Benvenuto della Volpaia, *Libro di Macchine Diverse*, codex Italiani IV 41, 5363, Biblioteca Marciana, Venice.

building concepts and executed them.⁵ Their value as such has enormous importance in regards to our complicated understanding of the Renaissance architect, whose role was notoriously diffuse, adhering to neither a standard course of training or a set of technical requirements, and varying substantially on a case-by-case basis.⁶

The architecture presented in the books of Buonaccorso Ghiberti, Francesco di Giorgio, Giuliano da Sangallo, Leonardo and Benvenuto della Volpaia primarily concerns building mechanics—machines for pulling, lifting and transporting great weights, hydraulic works and mills, military structures, and urban defense systems. These are not comprehensive books on early modern architecture, and in no way provide a definitive image of the contemporary architect. Yet, examined together, they outline underlying principles that structured the discipline of architecture, as well as the means by which practical knowledge was systemized, developed, shared, and retrieved. Read carefully, the books' contents also suggest different divisions of architectural knowledge, how through varying modes of visualization, this material was translated into practice—such as in the copy of generic, building models, the diagrammatic representation of design “recipes,” or the realization of new architectural *invenzione*. None of the drawings presented in the books served as “working” documents as we understand them today, but all were in some way immediately useful to the practitioner. That the architects took the time to meticulously record and compile the figures, often including annotations rendered in miniscule script, is highly significant, and confirms that these were more than just idle sketches or cursory notes. Moreover, the fact that some of these figures were copied in more than one of the books indicates that the knowledge being transmitted belonged to a greater, collaborative field of contemporary architectural practice.

In the pages that follow, the notebooks of Ghiberti, Francesco di Giorgio, Giuliano da Sangallo, Leonardo da Vinci and Benvenuto della Volpaia will be examined in relation to the structuring of practical architectural knowledge at the turn of the sixteenth century. The intent is not to enumerate the contents of the five books, or to systematically outline the projects to which individual designs relate. Rather, this discussion explores the means by which the books were assembled, the types of knowledge they present, and how this knowledge was codified and used by the architect in practice. To this end, the knowledge illustrated in the books is divided into three principle categories: (1) shared and cumulative knowledge, which was developed within a given workshop or family, and disseminated through copy drawing; (2) operational knowledge, typically allied to specific project or problem, and pertaining to an understanding of when and where to access certain facts and employ certain procedures; and (3) experimental knowledge, that which was born in the creative mind of the artist. Notably, each of these divisions of knowledge was complemented by a different aspect of architectural *disegno*—a term used to refer to both the practice of drawing and the resulting product. The *disegno* which accompanied shared knowledge was largely rote; the *disegno* of operational knowledge was didactic and preparatory; and the *disegno* of experimental knowledge was creative. Still, it must be emphasized that the three categories of knowledge explored here are neither definitive nor absolute. Although they follow a certain hierarchical progression—shared knowledge being the most mundane, and experimental embodying the highest level of cognition—as evident in the notebooks, the three categories were integral to practicing architects at every stage in their careers. The categories “shared,” “operational,” and “experimental” refer not to the level of knowledge, but to the degree to which it was known and circulated, and the means by which it was generated within contemporary practice. In this way, they are useful lenses with which to consider the function of the notebooks, and are also instructive in delineating the underlying structures of early modern architecture.

⁵On the different media of early modern architectural representation and documentation, see (Goldthwaite 1980, 376–9).

⁶The nuanced character of the early modern architect is discussed in (Chaps. 8 and 9).

1 Sizing Up the Notebooks

The notebooks of Buonaccorso Ghiberti, Francesco di Giorgio, Giuliano da Sangallo, Leonardo and Benvenuto della Volpaia may all be classified as pocketbooks in the sense that they are relatively compact reference volumes, and were assembled by their owners as *aide-memore*.⁷ The small size of the manuals was directly related to their function as personal notebooks, easily added-to and amended, and readily transferrable. Yet in physical form and content, the five books are actually quite different. To begin, of the books examined here, only those of Francesco and Leonardo are truly pocket-sized. Measuring 59×81 and 62×94 mm, respectively, both of the books are small enough to be held in the palm of one's hand. The volumes of Buonaccorso, Giuliano and Benvenuto are slightly larger, measuring between 120 and 145 mm in width, and 180–210 mm in length, an appropriate size to be carried in a saddle bag. It is worth considering also the relationship between the size of the volumes and how the architects went about recording their drawings and annotations. Within Francesco di Giorgio's *Codicetto*, for example, the script is often so small that it is difficult to read without a magnifying device. In this case, the utility of such a compact a reference book presumably compensated for the compositional challenges imposed by its small size. In addition to the physical dimensions of the books, other features of their material composition also bear on the intended use of the volumes. The following section will provide a codicological overview of the five books, focusing on the media of the drawing support (paper or parchment), the binding and arrangement of quires, and the architect's preference of pen, pencil or charcoal.

The architect's decision to compose his notebook of either parchment or paper folios is perhaps the most telling material element of a volume's intended use. Parchment, made of the skins of sheep, goats or calves, is an extraordinarily durable material. In the early modern period, when parchment was cured and cut by hand, and supply was often limited due to poor weather conditions and livestock shortages, the acquisition of even a dozen parchment folios was quite expensive (Elen 1995, 32). Among frugal artists, therefore, parchment was seldom employed. In the thirteenth and fourteenth century, artists were known to render their ideas on boards or wax-tablets, or, if working with parchment, customarily scraped clean and re-used the folios until they virtually disintegrated. The artist's turn to paper occurred in the mid-fifteenth century, as the medium became increasingly affordable, and for the first time, he had the means to draw more, and to save his drawings (Ames-Lewis 1981, 19; Hiscock 2000, 173). Paper, moreover, was more suited to sketching than parchment, and opened up the possibility for artists to record rapid impressions (Ackerman 2002, 294). Still, for the purpose of model books and reference manuals, parchment was infinitely superior to paper. Francesco di Giorgio's and Giuliano da Sangallo's choice to construct their notebooks using parchment folios, as opposed to those made of paper, was most likely made in light of heavy use the books were to endure.

Francesco's *Codicetto*, at once both model book and notebook, originally contained approximately 235 folios, held together within two wooden cover plates, and secured with metal clasps.⁸ Because the book was disassembled in the 1980s for the purpose of making a facsimile volume and has since been made inaccessible to scholars, it is difficult to know how the volume was initially composed. Still, based on sequential ordering and grouping of folios, such as the commentary on cannons (fols. 42v–44r),

⁷Following Ann Moss's analysis of early modern commonplace-books, Alexander Marr characterizes the copybooks assembled by sixteenth- and seventeenth-century artists as "aide memoire"—customized collections of visual and textual information systematically copied and assembled in personal notebooks. See (Marr 2013).

⁸Nearly fifty of the folios are today missing. Beyond a few references to its contents and remarkable pocket-size, very little has been said about the *Codicetto*, why Francesco assembled it, or how exactly it was used. L.M. Tocci published a facsimile version of the *Codicetto*, accompanied by a short, somewhat speculative commentary. For codicological information on the book, see (Martini 1989, 22). The *Codicetto* has also been summarily reviewed by (Galluzzi 1991). See also (Prager and Scaglia 1972, 191–5) and (Scaglia 1992, 51).

or the exploration of siphon-pumps (fols. 142r–153r), it appears that at least a good portion of the *Codicetto* was pre-bound. Although the little book is undated, scholars generally agree that Francesco assembled it in the early 1460s, when he was first exposed to architecture in Siena, and continued to make additions through the mid-1470s (Mussini 2003, 25). Working with pen and ink, Francesco filled the *Codicetto* with a series of copy-drawings of design prototypes—over one-thousand drawings in total—illustrations of pumps, dams, bridges, aqueducts, mills, balances, construction and transportation mechanisms, as well as military machines and fortification plans. Most of this material was derived from the notebooks of Jacopo Mariano Taccola (1382–1453), the so-called “Archimedes of Siena,” although as we will see, Francesco substantially improved upon many of his predecessor’s ideas. The form and media of the *Codicetto* were compatible with its function as a personal, pocket-sized encyclopedia, which Francesco might easily carry between the local university, where Taccola’s books were held, the city’s workshops, and job-sites (Taccola 1984, 28–31). We might imagine that Francesco—still in his early stages of training, inundated with a large quantity of new information, and unable to differentiate the key points from the more minor details—copied everything into the notebook. Along with drawings, he translated passages from Taccola’s Latin commentary, which he recorded in an almost undecipherable minuscule script. As one turns page after page, it seems as if the composition of the *Codicetto* was a personal challenge for Francesco, as he endeavored to crowd into each page as much information as possible.

In terms of its composition and intended use, Giuliano da Sangallo’s *Taccuino Senese* shares much in common with Francesco’s little book. Not only is Giuliano’s volume also composed of parchment folios—fifty-one in total—but like the *Codicetto*, it also appears to have been pre-bound. The presence of double-drawings, such as the plan and cut-way elevation view of the Colosseum on folios 6v and 7r, and the study-drawings of the Ionic columnar order on folios 34v and 35r, indicate that these figures were executed in previously bound quires (Hülsen 1910, LIII–LVI).⁹ Also like the *Codicetto*, the contents of the *Taccuino* appear to have been recorded over a prolonged period, between c. 1490 and 1513, and were compiled for the architect’s reference when traveling or on-site. But the *Taccuino* drawings are without question more refined than those of Francesco di Giorgio. The numerous parallels between the *Taccuino* and Sangallo’s generously scaled codex Barberini (ca. 1465–1510)—a collection of models and polished study drawings assembled on luxurious parchment folios—suggests that the former book was to serve as a condensed version of the more elaborate workshop volume. Like the codex Barberini, the *Taccuino* served as reference manual and display book, containing project drawings of the architect’s previously executed constructions, illustrations of machinery, significant structures and ornaments, all neatly rendered with dimensions and other relevant details. The images related to Sangallo’s antiquarian studies were not rendered *in situ*, but likely executed after-the-fact, with compass and rule and using the notes and sketches previously collected on-site. Still, a good portion of the material included in the *Taccuino* may be traced to existing model books and drawings—figures Giuliano copied from others. Taken as a whole, therefore, the neat little book may be understood as an accumulation of Giuliano’s lifelong study, offering insight into the diverse practices of the multiply talented architect (Elen 1995, 413; Brown and Kleiner 1983, 323).

The remaining three books of our set—those of Leonardo da Vinci, Buonaccorso Ghiberti, and Benvenuto della Volpaia—are composed of paper folios. For Ghiberti and Volpaia, the choice of paper was likely economical. Likewise for Leonardo—who was renowned for the breadth of his interests, fecundity of imagination, and proclivity to compile notebooks—paper was clearly the most desirable support media. Paper folios, moreover, were perfectly suited for red pencil or chalk, Leonardo’s favored drawing media, so that at a moment’s notice he could jot down an impression, image or idea.

⁹Like Francesco di Giorgio’s *Codicetto*, the *Taccuino Senese* is also incomplete, with approximately twenty-one folios missing. According to Hülsen’s reconstruction, the *Taccuino* was originally formed of seven quires.

Leonardo initiated the Codex Forster III in the early-1490s as a type of daybook, in which he recorded designs, recipes, and technical problems. In size, the Codex Forster III is comparable to Francesco's *Codicetto*, and just like Francesco, Leonardo used the pocket-size book both as mnemonic aide and didactic tool—a means to remember certain facts or details, and also to explain these to others. Yet, unlike the *Codicetto*, which is unique within Francesco's oeuvre, the Codex Forster III is just one of nearly a dozen pocket-sized notebooks composed by Leonardo (Zwijnenberg 1999, 7–8).¹⁰ Within these manuscripts, he recorded his thoughts, observations, studies and dreams—both exceptional and mundane—and in doing so, created an extraordinarily rich document of his intellectual activities. The Codex Forster III contains an assortment of material, from studies of portals, to notations on firearm projectiles, calculations for weighting pulleys, and sketches of horse legs, hats, and costumes. The codex does not solely concern architecture, but it might be considered an architect's notebook in the sense that it was composed by Leonardo, a practicing architect, and is exemplary of his proclivity to skip between disciplines. The cursory little notebook is an excerpt of his “*scrittura infinita*” (infinite writing), in which the boundaries between forms of expression, languages, intellectual disciplines and experiences are eroded (Vecce 2003, 75).

The notebook of Volpaia, composed of ninety-six folios and measuring 142×210 mm, was executed between 1520 and 1524. The book's contents are largely derived from the notes and drawings of Benvenuto's father, Lorenzo della Volpaia (1446–1512), a goldsmith, architect, mathematician, machine-designer and clock-maker who completed projects for the *signori* of Florence around 1500 and was a close collaborator of Leonardo da Vinci.¹¹ Benvenuto followed after his father, taking over his workshop, and led a fruitful career as instrument and machine designer, topographer and fortifications consultant. He appears to have composed the book in order to ensure he always had his late-father's knowledge on-hand. The volume opens with an unusual memorandum—a reminder to himself to devise a certain home security system when staying in Rome—and then continues, page after page, with recipes (for gun-powder, soap, painting varnishes), instructions for smelting, astrological charts, mathematical equations and formula, designs for wheels and mills, hydraulic instruments, and notes on geography and astrology.¹²

The final codex left to review is that of Buonaccorso Ghiberti, the so-called “*Zibaldone*” (or literally “jumble”), which dates to between 1480 and 1490. Like the Volpaia notebook, Ghiberti's was built upon material assembled within the family workshop, namely that of his grandfather, Lorenzo Ghiberti. The *Zibaldone* functioned as a personal model book and notebook, and is remarkably heterogeneous in its material and structural composition. The paper folios display two distinct watermarks, and are bound in quires of varying size—of three, four, five and eight bi-folios (six, eight, ten and sixteen leaves) (Elen 1995, 47, 411). From this complicated, and mixed arrangement of quires, scholars have been able to ascertain that the book was assembled piecemeal by the architect as he worked. Portions of the manuscript were pre-bound, while others were constructed from individual quires with drawn or written notes (Elen 1995, 47–8). As the book expanded, its function shifted as well. Whereas Ghiberti might have initiated the *Zibaldone* as a portable reference manual—the folio

¹⁰Over the course of his lifetime, Leonardo filled approximately 15,000 folios in total with text and drawings. Other notebooks of Leonardo comparable in pocket-size dimensions to the Codex Forster III include: Codex Forster I and Codex Forster II (Victoria & Albert, London); and the Leonardo da Vinci Paris Manuscripts E-M (Bibliothèque de l'Institut de France, Paris).

¹¹On Lorenzo and Benvenuto della Volpaia, see (Pedretti 1957, 23–6).

¹²On folio 1r, Benvenuto della Volpaia recorded: “To remind me when I go to stay in Rome to make a man of wood who stands inside the doorway, and when one opens the door, that man of wood confronts him either by lowering a stick on his head or catching and tying him with a cable” (“Per ricordarmi quando io vengo a stare a Roma di fare un uomo di legno che stia dentro a una porta e quando uno apre la porta quell'uomo di legno segli faccia innazi con un bastone per dargli in sulla testa hovero con una fune per pigliarlo e legarlo”).

dimensions measure a relatively modest 145 × 197 mm—expanding to include nearly 240 folios in its final form, it would have been too large for the architect to comfortably carry in hand. Still, the extensive wear evident within the book—most of the pages have finger stains on the lower-right corners—indicates that Buonaccorso, and likely dozens of other assistants and architects, made frequent use of the practical manual. Most of the material here, although quite varied in terms of subject matter, relates in some way to projects undertaken by the Ghiberti workshop. The volume opens with twenty-three folios, containing the partial transcription of Lorenzo Ghiberti’s translation of Vitruvius’ *De Architettura*. Then follows a series of images of reconstructed antique monuments, views of tombs and sculptural projects conceived by Florentine artists, machine designs, and annotated drawings of bronze-works—the field in which Buonaccorso appears to have been most active.¹³

The *Zibaldone* is the book of an architect whose commissions and interests continued to evolve, and like the volumes of Leonardo, Francesco, Giuliano and Benvenuto, the diversity of its contents speaks to the architect’s technical dexterity and wide ranging interests. Although architecture would become increasingly differentiated from civic, military and hydraulic engineering in the sixteenth and seventeenth centuries, at the turn of the Cinquecento the occupations of the architect, fortification designer, instrumentalist, and machine engineer still existed side by side as aspects of the same mathematically-based design practice, and all of the architects examined here were adept in all or most of these fields.

2 Shared Knowledge

On the most basic level, early modern artist notebooks were educational tools. Just as schoolboys of fifteenth- and sixteenth-century Italy were known to assemble commonplace books, filling them with exceptional passages to be memorized and then paraphrased in their writings, artists of this period compiled notebooks with the rudiments and “grammar” of their discipline (Ames-Lewis 1981, 16; Zwijnenberg 1999, 14–5). This material was then reiterated through extensive practice in *disegno*, by which the apprentice was tasked with the reproduction of his master’s works, and came to serve as the foundation for his subsequent career.

The manual process of copy-drawing, considered essential in the memorization and mastery of exemplary models, extended beyond the age of apprenticeship (Ames-Lewis 1981, 15). In the fifteenth and sixteenth centuries, artists and architects at all stages in their careers were known to assemble personal copy-books, the contents of which are as varied as the authors’ interests. These books often grew out of those the artist initiated in his early years of apprenticeship—replete with workshop formulas, recipes, and the master’s signature compositions. To this foundation, the artist added material drawn from his own practice, as well as selected material found in the notebooks of his contemporaries and collaborators—his access to which may have been brief or limited (Ames-Lewis 1981, 63–4). By means of such accumulation and assembly, the knowledge contained in the personal copy-book—primarily conveyed through drawing—invariably extended beyond a single workshop. Although at their origin the designs were born out of either experience or experimentation, over time and through copy and dissemination, they became general and mundane. Within the practitioner’s copybook, they belonged to a far more vast, widely circulated and collective body of practical knowledge, material which, in effect, provided a common foundation for the diffuse discipline.

¹³Gustina Scaglia has completed extensive research on the *Zibaldone*. See (Scaglia 1976) and (Scaglia 1979).

With the exception of Leonardo's Codex Forster III, all of the volumes examined here contain, in varying quantities, traces of such shared or collective architectural knowledge.¹⁴ Within the drawing collections of Buonaccorso Ghiberti, Francesco di Giorgio, Giuliano da Sangallo and Benvenuto della Volpaia one finds not only reproductions of the same designs, but also varied representations of the same design concept. In fact, the accumulation and transcription of shared knowledge was rarely literal or direct, and no two drawings recorded by our architects are exactly alike. When it came to copying, more often than not, the authors modified the material they studied, amending and restructuring it according to their own needs and interests. The following discussion will trace examples of copy-drawing in the notebooks of Buonaccorso, Francesco, Giuliano and Benvenuto, considering how such images' functioned, the value of the shared knowledge they contained, and how this knowledge was applied to practice.

Folio 104r of Buonaccorso Ghiberti's *Zibaldone* features an illustration of Filippo Brunelleschi's revolving lantern crane, a construction device engineered by the celebrated architect while at work on the Duomo of Florence (Fig. 1). While the concept of a building crane was in itself not unique, Brunelleschi's device improved upon the basic model in its ability to rotate, thus transporting materials to exactly where they were needed, on all sides of the dome. The essential component of Brunelleschi's crane was the grooved, horizontal beam, along which an engaged block could slide. Within this block, a screw mechanism could be used to lift and lower weights by means of worm-gear hangers—which Ghiberti illustrated in detail alongside the crane (Prager and Scaglia 1972, 74). The novel crane is included in an almost identical illustration in the *Taccuino Senese*, and also appears in Francesco di Giorgio's notebook, although in a slightly different version (Figs. 2 and 3). Leonardo also made a copy of the crane as well, although not in the Codex Forster III.¹⁵

Clearly the drawings of Buonaccorso Ghiberti, Francesco and Giuliano were based on second-hand knowledge, reproduced from a previously recorded, "original" design. Although Ghiberti and Francesco had indirect ties with Brunelleschi—Buonaccorso's grandfather, Lorenzo, was co-architect of the Duomo, while Francesco's intellectual mentor, Taccola, was a close friend and confidant of Brunelleschi—in terms of the formal qualities of the drawings alone, which of the three is most accurate is not readily apparent. And while Ghiberti's representation has been traditionally granted the most authority—significantly, the *Zibaldone* features several additional mechanisms devised by Brunelleschi, including his "secret hoist" and specific notes on the Florentine Duomo—what is noteworthy here is the degree to which designs of the crane were disseminated (Prager and Scaglia 1972, 67–70). Due to Brunelleschi's celebrity, and the awe inspired by his great dome, his designs were extensively studied by contemporary practitioners, and then circulated and reproduced by subsequent generations of architects. Considering only the *Zibaldone*, the *Codicetto*, and the *Taccuino Senese*, one can see how quickly an authorial invention like the rotating crane came to be incorporated into a more diffuse body of shared knowledge.

In addition to Brunelleschi's crane, the books of Buonaccorso, Giuliano, Francesco and Benvenuto also contain analogous representations of roller-beam hoists, obelisk haulers, column-lifting devices, water-wheels, siphon-pumps, and load positioners. Yet, the significant degree of imprecision evident in many of these drawings introduces new questions in regards to the function of the images, and the quality of knowledge they contained. Such imprecision is highlighted in the comparison of two machines illustrated in Benvenuto's *Libro*—one of a clock designed by his father, shown in section with detailed annotations regarding the diameters, placement and division of the wheels (fol. 31v) and

¹⁴This is not to say that Leonardo never executed copy-drawings. In fact, his Codex Madrid II (Ms. 8937, Biblioteca Nacional, Madrid), Leonardo reproduces numerous designs of Francesco di Giorgio.

¹⁵Brunelleschi's lantern crane appears on folio 808v of the codex Atlanticus (dated c. 1478–1480). For discussion on the lantern crane, and other devices of Brunelleschi copied by Leonardo, see (Reti 1965).

Fig. 1 Filippo Brunelleschi's revolving lantern crane. From (Ghiberti c. 1480–1490, fol. 104r). Courtesy of *Ministero dei beni e delle attività culturali e del turismo – Biblioteca Nazionale Centrale, Firenze*. Prohibition of further reproduction or duplication by any means

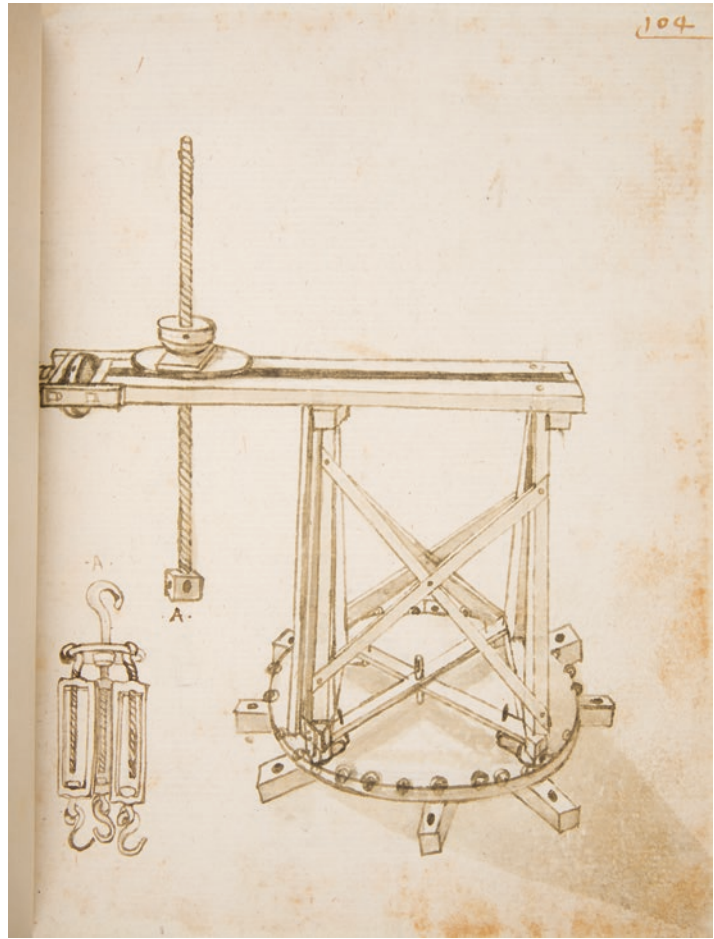


Fig. 2 Filippo Brunelleschi's revolving lantern crane. From Giuliano da Sangallo, *Taccuino Senese*, Codex S.IV.8, Biblioteca Comunale, Siena, c. 1490–1513, fol. 12r (Falb 1902, unnumbered plate)

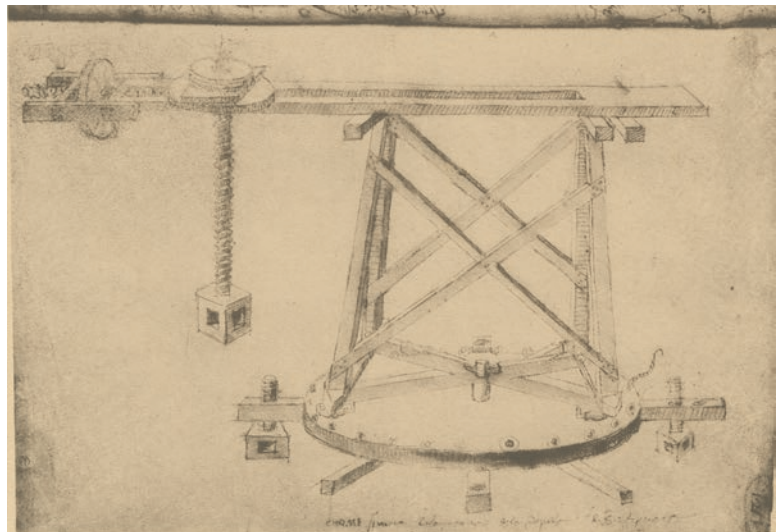
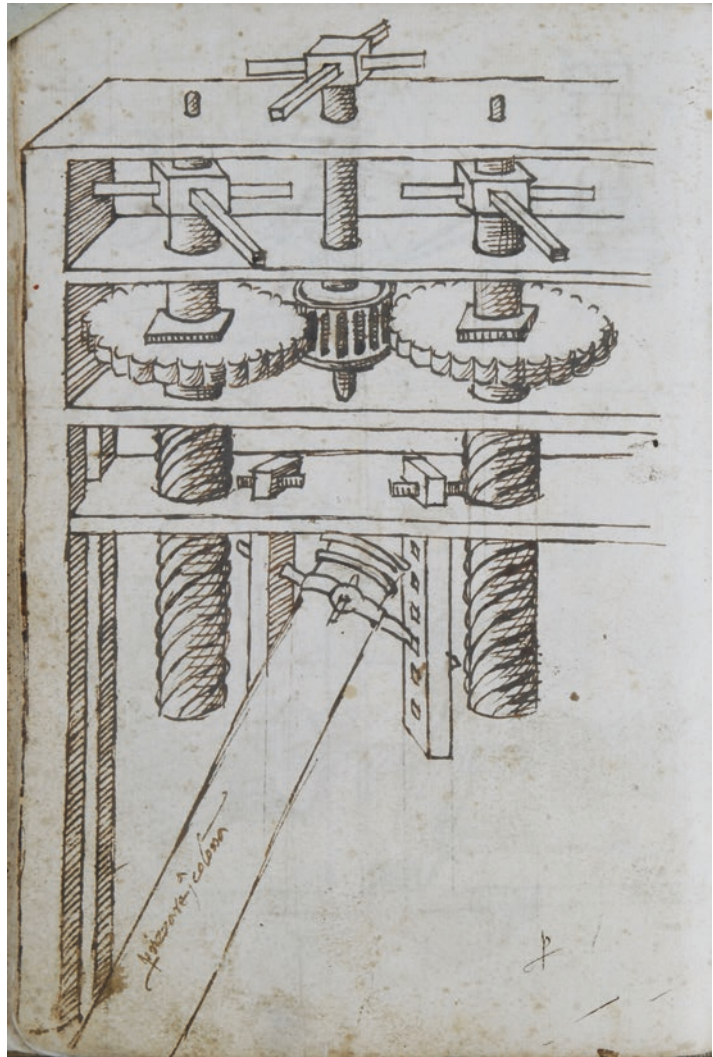


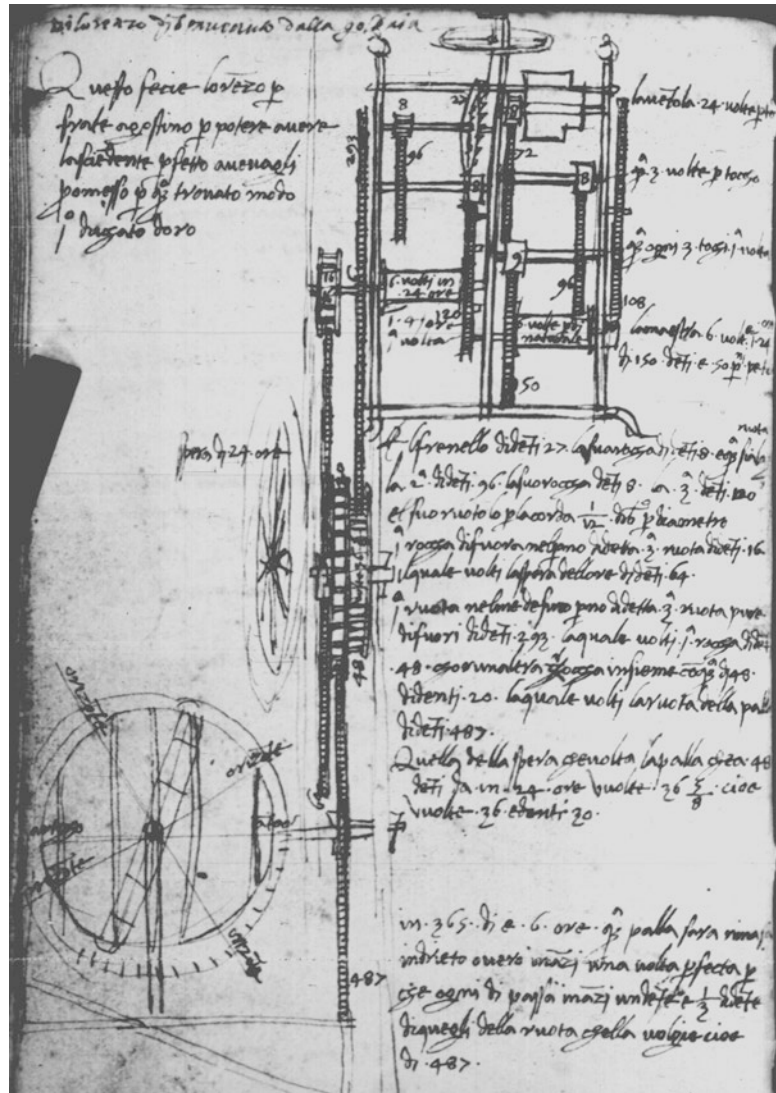
Fig. 4 Column-lifting device. From (della Volpaia c. 1520–1524, fol. 52v). Courtesy of Ministero dei Beni e delle Attività Culturali e del Turismo – Biblioteca Nazionale Marciana. Prohibition of further reproduction or duplication by any means



does not mean that the knowledge contained in the designs was lost or in any way compromised. As elucidated in the studies of David McGee and Wolfgang Lefèvre, machine drawings like those rendered by Francesco on *Codicetto* folio 100r, or by Benvenuto on folio 52v of his *Libro*, were never intended to function as blueprints or comprehensive instructional guides (Lefèvre 2004, 223–4; McGee 2004, 58–63) (Figs. 3 and 4). These were shorthand models, which practitioners could identify at a glance, and which, if the need arose, they could reference in the realization of one of the devices. Even the “original” machine renderings, therefore, would not have been terribly detailed.

The function of architectural drawings as reference tools is elucidated by Francesco di Giorgio in his *Trattato di Architettura*, following his chapter on building machinery. Summarizing his intent for the treatise, which includes general descriptions of design processes and simple, undetailed images, he explains: “This work is ultimately not a set of instructions ... but rather it is for those who think and have some intelligence in *disegno* ... and because the complete architect must invent in many unforeseen circumstances ... and because I cannot clarify everything, these parts are left to the

Fig. 5 Section of weighted clock designed by Lorenzo della Volpaia. From (della Volpaia c. 1520–1524, fol. 31v). Courtesy of Ministero dei Beni e delle Attività Culturali e del Turismo – Biblioteca Nazionale Marciana. Prohibition of further reproduction or duplication by any means



discretion of the architect” (Martini 1967, 505–6).¹⁷ That is to say, working with a team of trained craftsmen, the architect would ultimately have to tailor his designs according to the limitations and needs of each specific project. For the purpose of communicating a machine or building type to workmen, moreover, a drawing such as that of *Codicetto* 119r was perfectly adequate. From this, they could comprehend the general composition of the device and arrangement of its parts. And even if the architect did develop more detailed orthogonal and section drawings, it is not clear that these would have been legible to the workmen.

¹⁷“Uno documento ultimamente non è da pretermettere al quale dieno avere avvertenza quelli che di questa mia operetta desiderano conseguire alcuno frutto, e questo è che questi tali s’ingegnino avere qualche intelligenza del disegno, perché senza quello non si può bene intendare le composizioni e parti dell’architettura perché le superficie esteriori comprano le interior e d’ogni parte longo saria dare esempli, e perché il complete architetto richiede la invenzione per molti casi occurrenti indescritti che senza disegno é impossibile conseguire, e perché non possendo ogni minima parte dichiarare, quelle che restano sono nella discrezione dell’architetto.”

The lack of detail evident in the copy-drawings may thus be traced to the high degree of technical know-how possessed by early modern architects, as well as to the collaborative nature of their practice. The Renaissance architect never worked alone, and a great portion of his work involved the development of designs to be executed by others. The shared knowledge he recorded in his pocket-book, therefore, should be understood as having been the complement to that of the many technicians and building specialists who were employed within his workshop. In the notebooks Buonaccorso Ghiberti and Benvenuto della Volpaia, the knowledge recorded was that of the family workshop—material which had accumulated over generations, enriched or refined through contributions of numerous practitioners, from a variety of different projects. The knowledge of Francesco's *Codicetto*, in turn, came from the Communal building workshop of Siena, where specialists from all fields of design and construction came together, and where copies of Taccola's *De Ingeniis* (ca. 1433) and *De Machinis* (ca. 1449) were widely studied and reproduced by young practitioners (Taccola 1984, 28–31). The contents of Taccola's books, which relate primarily to defensive architecture and hydraulic systems, constituted the general canon of knowledge required of any Sienese architect, and as evidenced in the *Codicetto*, Francesco's appropriation of this material formed the knowledge basis of his own practice.¹⁸

The shared knowledge recorded in the notebooks may also be regarded as autobiographic. This is particularly evident Giuliano da Sangallo's *Taccuino* (Nesselrath 1986, 127). Like Buonaccorso's *Zibaldone*, Francesco's *Codicetto* and Benvenuto's *Libro*, the *Taccuino* appears also to have been born out of a workshop model book, and reveals strong ties to its author's practice. Yet, unlike these volumes, the contents of which may be substantially linked to a single workshop, the material assembled within the *Taccuino* appears to derive from a broader range of sources. Trained within the thriving workshop of the Florentine woodworker and military architect Francesco di Giovanni "il Francione" (1428–1495)—who was active in Rome and Florence, and completed major commissions for the city of Florence and the Medici—Giuliano was exposed at a young age to diverse body of workshop knowledge. Correspondingly, the material of his *Taccuino* was also assembled from diverse origins. While some of this is original—collected by Giuliano during his investigations in Rome—much was taken from secondary sources. The plans of the Santo Spirito and San Lorenzo in Florence, for example, were likely copied from model books held within the workshop, as were the drawings of Brunelleschian machinery.¹⁹ The copy-drawings after Francesco di Giorgio on folios 49v indicate that Giuliano must have had also access to one of the Sienese architect's notebooks, or a copy of the notebooks. The origins of the architect's studies of the columnar orders are less obvious, but these too derive from sources of shared knowledge. On folio 31v, Giuliano paraphrases Alberti's commentary on the proportions of the orders, and on folios 34r/v and 35r illustrates variations of Ionic bases, capitals and entablatures according to Alberti's instruction (Günther 1988, 130–1). The profile illustration of an Ionic entablature on the right-hand side of folio 34v is also a copy. The image here is akin to that included in the Sélestat manuscript of Vitruvius' *De Architectura*, which, significantly, also appears in Buonaccorso Ghiberti's *Zibaldone*.²⁰ Even the design of the roasting machine given on folio 50r appears to have been shared knowledge—as it was copied in contemporary drawing-books, including

¹⁸As overseer of the Siena's aqueducts (1469–1472), Francesco likely made good use of the illustrations and notes he had recorded on pumps, siphons, and door locks, modifying and elaborating upon the models, just as he explained in the *Trattato*, according to the "many unforeseen circumstances" of the work. Likewise, traveling between the dispersed fortifications of the duchy of Urbino, the fortification plans, schemes of earthwork defenses and recipes for gunpowder recorded in the *Codicetto* would have been invaluable references.

¹⁹Within the *Taccuino*, the plans of Santo Spirito and San Lorenzo appear on folios 5r and 21v, respectively.

²⁰These folios are reproduced in (Scaglia 1979, 9, 11, 18).

that of Leonardo (Borsi 1985, 332; Hülsen 1910, LIX).²¹ But in the copying process, the shared knowledge recorded by Giuliano in the *Taccuino* became personalized. In its visual reformulation, knowledge which was formerly anonymous and unbound was given authorship, while at the same time being incorporated into a body of specialized knowledge of the individual practitioner.

The repetitive nature of copy-drawing meant that the shared knowledge contained in the images very rarely retained an authorial connection.²² The image of Brunelleschi's revolving lantern crane was an exception, due to the monumental celebrity of its inventor, and even in this case, it is not certain that everyone who copied the crane knew of its exalted origin. In most instances, as individual copy-books gave way to new copybooks, the authors' names were lost, but the designs they contained were incorporated into an expanding corpus of general knowledge. Thus it might happen that an architect working in the sixteenth century would reproduce an image according to a signature variation by Giuliano da Sangallo or Francesco di Giorgio, without having any conception of these architects.

3 Operational Knowledge

Whereas the shared knowledge employed by early modern architects was essentially receptive—copied, referenced and exchanged through notes and drawings within the workshop—operational knowledge was born out of active practice—whether from the architect's work on the building site, his direct examination of a form or structure, or his longtime study of certain natural processes. Such knowledge, an understanding of when and where to access certain measures, and when and where to employ certain procedures was often situational, in its associated with a given place and circumstance. At the same time, the operational knowledge of the early modern architect might also be characterized as strategic, in that it often corresponded to a specific skill set or process of design.²³ Leonardo's efforts to re-direct the course of the Arno River, for example, meant that he acquired a significant amount of site-specific information regarding the waterway—its tight bends, dramatic variations in level, and numerous sub-basins (Heydenreich 1980, 36). But at the same time, he would also learn about trench digging, the design of sluice gates and locks, and the natural movement of water—knowledge which he in fact recorded in the Codex Forster III, and which might be applied to other circumstances.

According to the contemporary theorists, knowledge acquired through practice and experience was invariably superior to that found in a book. Architects who wished to excel were thus encouraged to learn through direct observation, and to make notes and drawings in the field to record their findings. As explained by Filarete, in reference to the preparation of a preliminary site survey, the material gathered by the architect *in situ* could later be re-worked, synthesized in the creation of knowledge-based designs (Spencer 1965, 158).²⁴ Francesco di Giorgio also emphasized the importance of the architect's direct, first-hand knowledge of the building environment, reminding his reader that this fundamental context not only determined the strength of the building, but also the lives of its inhabitants

²¹In the codex Atlanticus (fol. 5v) Leonardo includes a drawing of the roasting device with the caption: "This is the true way to cook roasts, as according to whether the fire is mild or strong, the roast is turned slowly or quickly" ("Questo è il vero modo di cuocere gli arrostiti, imperocché secondo che'l fuoco è temprato o forte, l'arrostito si volge adagio o presto").

²²The unauthorized reproduction of printed images in the early modern period is an interesting corollary to this. On the efforts that were made to discourage or inhibit the re-use of woodblocks and engravings, see (Chaps. 7 and 15).

²³Here, I am following the essential classification system provided by (de Jong and Ferguson-Hessler 1996, 106–7).

²⁴*Libro Architectonico*, Book XII. Addressing the Prince, Filarete comments on the importance of making a preliminary site survey: "Before we go on, I would like to draw this countryside in order to have it better in my mind.... I will draw it roughly on a tablet so that I will not forget it." The Prince, after seeing the drawing replies, "That is good. When we send it off, make it more finished and on a sheet of good paper."

(Martini 1967, 303). “The architect,” he warned his reader, “must be alerted to these conditions and the causes [of the site], just as he is to the time, place, and possibilities of the locations, so that he may mitigate the despised elements, which produce disease in men and lead to destruction” (Martini 1967, 310). Leonardo also wrote extensively on the importance of the artist’s first-hand experience and observation of nature, noting in one of his notebooks that “sciences which begin and end in the mind cannot be considered to contain truth, because such discourses lack experience, without which nothing reveals itself with certainty” (Zammattio et al. 1980, 7). Echoing this same sentiment in the pocket-sized Codex Forster III, he reminded himself that “knowledge is the daughter of experience.”²⁵

Within the five practitioner’s notebooks of our survey, operational knowledge is codified in two principal modes: (1) in recipes and formulae, which provide step-by-step explanations of specific procedures; and (2) in annotated figures, in which text and image complement one another to elucidate original designs and practices. The first mode of knowledge transmission may be related to the practical, instructive texts of the early modern period, such as the letters on ale written by Colonel Edward Harley and the recipe book of Johannes Kunckel, discussed by Elaine Leong and Sven Dupré, respectively (Chaps. 3 and 6). Like these texts, the recipes of the architects’ notebooks either provide instructions, for the preparation of materials or certain working techniques, or direct the user to secondary sources which might provide this information. Although the recipes were inextricably tied to practice—experience which is discernable in the degree of detail they take, and in the authors’ knowledge of specific sources of secondary expertise—in their condensed, textual form, they retain an anonymity. By contrast, the second form of operational knowledge evident in the notebooks—the annotated figure—is more frequently tied to the practice of an individual architect, and the information it conveys is more complex than that transferred in text or image alone. Here, the two media work hand-in-hand, the drawings making immediately visible the architect’s ideas and discoveries, and the text supplying the details which inevitably could not be contained in a single image (Vecce 2003, 69–70). Still, as discussed by Pamela Smith in her contribution to this volume (Chap. 14), the documents which come down to us record only the traces of the architect’s empirical knowledge. The notebook drawings and annotations are more narrow and specific in what they tell us, relating to the on-site investigations, mechanical training and workaday processes that were of greatest concern to the practitioner at a given time and place.²⁶

The recipes included in the architects’ notebooks—which varying considerably in both form and content—are in essence shorthand for certain practices, procedures and formula (Vecce 2003, 64). Whereas some recipes appear cryptic and incomplete—omitting instructions or material that was considered “general knowledge”—others provide more extensive, detailed instructions (Clarke 2001, 7). Recipes of the former type are found throughout the *Zibaldone*. The book opens with one such recipe, a rather common formula for imitating gold by applying a yellow glaze to silver. It reads: “one-half *denaro* of salt. One-fourth *denaro* of rubber. One-fourth *denaro* of both sulfur and saffron. Put to boil.”²⁷ The Codex Forster III includes similarly epigrammatic recipes—formula for, among other things, producing oil from mustard seed, using spit as ink, making vermilion, and drawing shadows. On casting bronze in plaster Leonardo writes: “For every two bowls of plaster take one scoop of burnt

²⁵Codex Forster III, fol. 14r: “La sapienza è figliola della sperienza.”

²⁶These notes might well not address the issues most relevant to a modern audience, answers for which may need to be found in other documentary sources.

²⁷“Per colorire airento dorato. 1/2 denaro di sale comune. 1/4 denaro di groma. 1/4 denaro e zolfo e zafferana. E metti a bolire.” For transcription and notes, see (Scaglia 1976, 496). Recipes for imitation gold are also referenced by (Clarke 2001, 3).

pitch [*bo*'], mix together and cast."²⁸ The brevity of these recipes—which are more like ingredient lists than detailed explanations for making—may be related to the practical function of the books. Both Buonaccorso and Leonardo were accustomed to using and preparing materials, and thus neither needed to be told where to find ingredients, how to mix them or for how long. They only needed to be reminded of the elements required, and the ratios or amounts which were necessary.

In contrast to such cursory, schematic recipes, the notebooks of Francesco di Giorgio and Benvenuto della Volpaia provide longer, more detailed instructions for making and doing. In both cases, the authors' elaborated instructions relate a common theme or set of procedures. For Francesco, the subject is firearms and ammunition—recipes for which fill the final fifteen-folios of the *Codicetto*. The inconsistent quality of the author's handwriting, the presence of varying inks, and inclusion of several blank and half-filled folios, suggests that the content of these pages was compiled over an extended period of time. Most of the recipes are a variation on a given type, and it is likely that Francesco had not tested them all. But in compiling them, he amassed a compendium of practical knowledge, so that, for example, at any given moment he had at his immediate disposal a handful of variations by which he might combine sulfur with carbon and salpeter to make gunpowder.²⁹

The recipes compiled by Benvenuto in the *Libro* also form a set, in that all may be tied to projects undertaken in the Volpaia family workshop. The first dozen folios of the notebook contain a series of recipe-alternations, related to both processes—for welding silver and engraving letters, for example—and to the production of materials—such as tin, soap, and vermilion. Some of these are rendered shorthand, similar to those recorded by Leonardo and Buonaccorso, while others are elucidated in full paragraphs. Benvenuto's recipe for salpeter, for example, specifies where the soil should be taken from, how long it is boiled, what the resulting crystals should look like and how they are to be extracted.³⁰ Benvenuto was, moreover, quite conscientious to record the source of his information. Here as elsewhere, he included the name of the individual who provided the formula. As much of the *Libro* derives from material within the Volpaia family workshop, many of his citations are to its progenitor—"Lorenzo nostro," or "mio padre." Other recipes are attributed to unknown collaborators of the workshop, such as "maestro Jacopo," "maestro Piero da Chassa," and "Andrea di Piero." The care with which Benvenuto recorded these citations suggests that the value of the information was to a certain degree contingent on its source. The efficacy of a recipe had to be proven in practice, and thus its origin carried significant ramifications. If the named practitioner was held in low esteem or thought to have less experience, the value of the knowledge he provided was somewhat diminished.

Within the *Libro*, an analogous system of valuation is conveyed in annotated illustrations—designs for clocks, pumps, mills and wheel mechanisms. Just as the recipes, almost every device surveyed in the *Libro* is accompanied by a name. In addition to the numerous citations to Lorenzo della Volpaia, one also finds references to the well-known inventors Domenico Boninsegni, Lorenzo Serristori, Lorenzo Bartolini, and Leonardo da Vinci.³¹ By citing these exceptional figures, Benvenuto provided the authority for the inventions while also supplying the knowledgeable practitioner with a general context for each project, such as approximate date, place of origin, purpose. But unlike the recipes—well-worked formulae that could be transmitted with simple text alone—the customized mechanical devices Benvenuto sought to record in his *Libro* were far more complicated, and the means by which he codified these were correspondingly more sophisticated. Here, the image was key. Using various

²⁸Codex Forster III, fol. 39v. "Per gittare bronzo in gesso. Togli per ogni 2 scodelle di gesso una di corno di bo' bruciata, e mischia insieme e gitta."

²⁹Codex Urb. Lat. 1757, fol. 182v.

³⁰Codex Italiani IV 41, 5363, fol. 15r.

³¹For overview of the *Libro* and references it contains, see (Pedretti 1957, 26–8).

modes of technical drawing—transparent and cutaway views, abstract orthogonal views and sections—Benvenuto presented each mechanism as an illustrated diagram.

Such annotated illustrations are a staple within early modern architectural manuals and feature in every one of the personal notebooks of this study. These figures were almost always composed in the same manner—image first, text second—with the drawing invariably occupying the center of the page, and the writing confined to the periphery. The essential structure of the annotated illustrations, therefore, gives testimony to the primacy architects bestowed on drawing as a didactic and expository tool. As emphasized by architects like Mariano Taccola, Francesco di Giorgio, and Buonaiuto Lorini, among others, drawing was the principal means by which an architect communicated his ideas, and translated abstract experiences into a tangible, readily comprehensible format.³² But unlike work-site templates or polished presentation drawings, the annotated illustrations of the architects' notebooks were intended as personal references, and are thus characteristically rather elementary in terms of technique and execution. The schematic contours, cursory over-drawings and quick notes contained in these illustrations might be read as the traces of the architect's systemization of practical knowledge.

Comparing folios from Benvenuto della Volpaia's *Libro*, with those of Buonaccorso Ghiberti's *Zibaldone* and Giuliano da Sangallo's *Taccuino*, one can discern some of the principle modes by which such images codified knowledge. Folio 31v of the *Libro* shows in section one of Lorenzo della Volpaia's weight-driven clocks, which according to the note in the upper left corner, was made for one "father Agostino" and provided a perfect system of timing (Fig. 5). The illustration is one of a learned practitioner, and reads as an encyclopedic entry on an exemplary clock type. Within the single, self-contained page, simple lines and brief annotations provide Benvenuto with the information necessary to manufacture the clock: the distribution of the fifteen wheels, the circumference and number of dentils of each, and the frequency of their rotations. The compact, unpunctuated explanation, which includes few verbs, and references the different clock wheels by their number of dentils, assumes a thorough knowledge of clock-making. The diagram does not explain how to assemble a clock, nor does it detail the component parts. Rather, it elucidates the mathematics of a specific mechanism for someone who already had extensive training in the field.

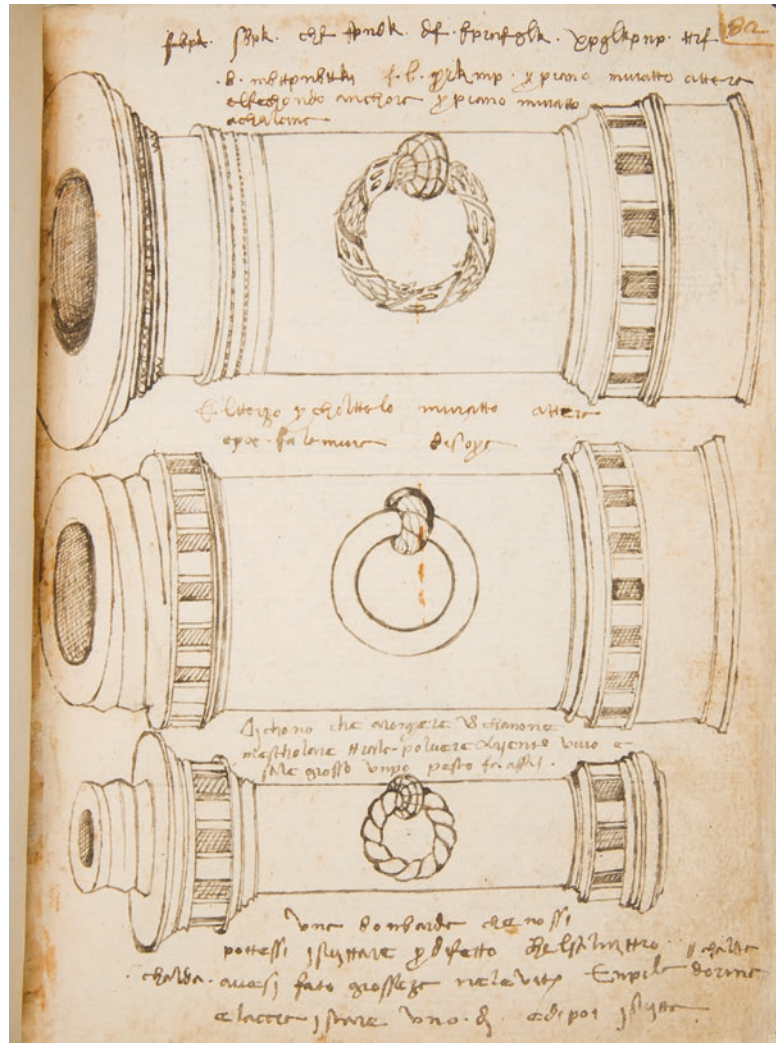
The illustrations of the *Zibaldone* are also those of a specialist, and despite their crude, almost amateurish appearance, they relay knowledge achieved from first-hand practice. But the way in which this knowledge is codified, within the images and within the book as a whole, is substantially different than in the *Libro*. Let us take for example folio 82v, a page which features three seemingly unremarkable cannon drawings and several brief annotations (Fig. 6).

In comparison to Bevenuto's intelligent composition of folio 31v, in which the elongated clock section structures the form and content of the page, laying out the clock's technical framework while also leaving ample space for the addition of corresponding annotations, Buonaccorso's page is simplistic. But for the practitioner, the annotated drawing bears significantly more information than an untutored glance would comprehend. Illustrated here is a novel, three-part cannon, the segments of which are connected by means of screw heads, visible on the left-hand side of the two lower pieces. As early modern bronze cannons typically weighed several tons, making their transport a slow and grueling process, the partible gun was a decisive innovation.³³ The increased speed of cannon transport meant

³²Taccola's affirmation of the efficacy of drawing as a didactic tool is found within the pages of his *De Ingeineis*, which includes numerous references such as "as seen in the design" or "although obvious from the drawing." In his *Trattato di Architettura*, Francesco di Giorgio dismisses theorists who have written on architecture without images, commenting that: "Although to the writers it seems that they have elucidated their designs according to their intentions, to us it seems that through lack of drawings there are few who can understand them." See (Martini 1967, 489). On Lorini's discussion of *diseño* see (Henninger-Voss 2004, 149–54).

³³With carriage, a sixteenth-century cannon weighed over 8000 pounds or four tons. See (Pepper and Adams 1986, 11).

Fig. 6 Annotated illustration of three-part cannon. From (Ghiberti c. 1480–1490, fol. 82r). Courtesy of Ministero dei beni e delle attività culturali e del turismo – Biblioteca Nazionale Centrale, Firenze. Prohibition of further reproduction or duplication by any means



also increased agility of a military unit and the pace of warfare. From the text surrounding the drawing—which relates not cannon design specifically, but to the broader practical framework of their manufacture and function—we learn of Buonaccorso’s expertise with such guns. At the top of the page he notes the basic structure and materials of a three-part furnace, the chambers of which were used for melting, working and temper metal, and at the base, he explains how to disengage the nut and screw of two units of the cannon in the case they are stuck. The annotation between the second and third cannon parts—apparently squeezed in as an after-thought—offers an alternative for breaking a cannon into pieces using a paste of “*ariento vivo e sale grosso*” (Scaglia 1976, 503–4). This information is augmented with the information provided in the adjacent folios, which taken together, provide step-by-step instructions for designing, manufacturing and using cannons. As seen here, the codification of practical knowledge is an additive process. Unlike Benvenuto, who acquired his experience and knowledge through his father, and thus with the benefit of time could assemble this information as a series of distinct case studies, Buonaccorso’s knowledge as presented in the *Zibaldone* is the product of his ongoing explorations in armaments. The accumulative form of the *Zibaldone*, therefore, might be understood as mirroring Buonaccorso’s own incremental acquisition of practical knowledge.

The annotated illustrations of Giuliano da Sangallo's *Taccuino*—careful renderings of entablatures, columns and capitals, building plans, sections and elevations that derived from his investigations of antiquities—provide one final example of how architects employed this expository format to record their empirical findings. In terms of form and subject matter, the *Taccuino* illustrations clearly differ from those previously highlighted in the *Libro* and *Zibaldone*. Whereas both Buonaccorso and Benvenuto paired drawings with significant portions of text, Giuliano's annotations rarely extend more than a few words. The exceptional refinement displayed in the drawings is also noteworthy. Giuliano's are not figures jotted down by the architect offhand, or pieced together from surviving workshop notes, but derive from the author's own existing study- and copy-drawing. As many of these also appear in the codex Barberini, it is safe to believe that Giuliano rendered a good portion of the *Taccuino* images more than once.³⁴ The subject of Giuliano's investigation—classical antiquities—is the final, definitive feature of his work that distinguishes it from the more technically-oriented explorations of Buonaccorso and Benvenuto. As we have seen, the problems confronted by these architects—such as the functioning of a clock or the design of a three-part cannon—found clearly defined solutions through the practitioners' hands-on experience. Giuliano's studies, by contrast, sought to answer a larger and more abstract question: the principal forms, materials, proportions, and techniques of excellent, *all'antica* architecture. Although Giuliano was certainly not alone in this investigation—the study of the Vitruvian orders and ancient remains was a definitive component of Renaissance architecture, and significantly, the notebooks of Buonaccorso and Leonardo also include material regarding the classical orders—the *Taccuino* is unique among the books of our survey in the extent and degree to which it addresses this material. What is significant here, however, is not so much the content of his studies, but the correspondence they find with the other notebooks of our study in the manner in which they structure and transmit the architect's operational knowledge.

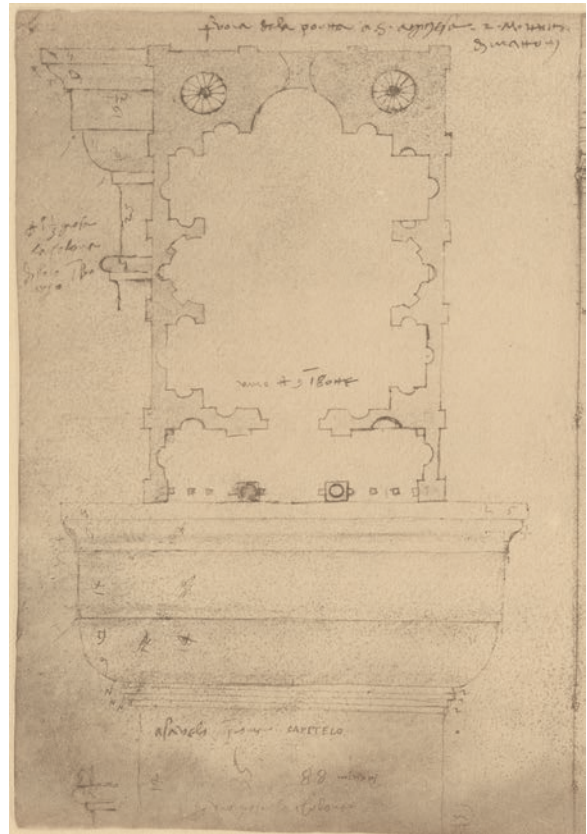
Folio 33v of the *Taccuino* in many ways exemplifies Giuliano da Sangallo's process of antiquarian research (Fig. 7). The page derives from a series of study-drawings executed by the architect in Rome between 1488 and 1492, and illustrates, from top to bottom, a Doric column of the Theater of Marcellus, the plan of a sepulcher near Sant'Agnese, and a capital of the Basilica Aemilia (HülSEN 1910, LIV-LV). The unusual composition of these figures—with no concern for scale, the plan drawing shares contour lines with the two capital studies—as well as the presence of stylus under-drawing, indicates that Giuliano assembled the page some time after he completed his on-site investigations. The fact that he took the time to so painstaking re-render the figures, applying wash shading and noting dimensions, is in itself a clear indication of the studies' importance. Further affirmation of this is found in the secondary annotations. Just as Buonaccorso did with the *Zibaldone*, Giuliano returned to the illustrations of his little notebook on multiple occasions, each time emending the information he had previously recorded.³⁵ At the top of the page, he added the location of the tomb: “*fuora dela porta a. s. agnesa*.” His notations elsewhere are more cursory—he modifies the measurements of the capitals, crossing some out, and includes notes about the supporting columns, and the proportions of the abacus and echinus of the two capitals. In as much as these marks record the architect's expanding understanding of the monuments, they also convey his process of empirical study.

Giuliano da Sangallo's ongoing investigatory process is again evident on *Taccuino* folio 45v. This page presents seven profile drawings of Doric entablatures—four in dark ink with place-name annotations (“*i[n] Roma*” and “*i[n] Monte Chavalo*”), and three at the base, rendered with quick, light pen

³⁴The order in which Giuliano da Sangallo recorded drawings in the *Taccuino* and codex Barberini is unclear. Scholars generally conclude that the two books were assembled concurrently.

³⁵Clear proof of this is found on folio 7r, which contains a plan drawing of the Colosseum. Based on what is known of Giuliano's travel and antiquarian study, the drawing had been dated to between 1488 and 1492. However, the annotations included on the page record the date of 1513. See (Borsi 1985, 257).

Fig. 7 Mixed folio of antiquarian studies; Doric column of the Theater of Marcellus (top left); plan of a sepulcher near Sant' Agnese (center); Doric capital of the Basilica Aemilia (bottom). From Giuliano da Sangallo, *Taccuino Senese*, Codex S.IV.8, Biblioteca Comunale, Siena, c. 1490–1513, fol. 33v (Falb 1902, unnumbered plate)



strokes, and likely added at a later date. As with folio 33v, these classical models are examined in regards to their measurements and proportions, and notably, the means by which this information is structured bears strong parallels to the examples previously discussed. To begin, we might consider Giuliano's application of place-names. On folio 45v, as elsewhere in the *Taccuino*, the inclusion of place-names served not only to document the figures' locations, but also to recall the architect's experience with the monuments. Like the individual names so carefully recorded by Benvenuto della Volpaia, the place-associations added by Giuliano bestowed authority on what would otherwise be a schematic, disconnected rendering. The appellations "*fuora dela porta a. s. agnesa*," "*i[n] Roma*" and "*i[n] Monte Chavallo*" were signifiers of practice that was incommunicable with pen and ink. Folios 33v and 45v also relate to those of the other architects of our study in illustrating the architect's proclivity to compile data. Just as Francesco di Giorgio sought to amass an inventory of gunpowder recipes, formula he could quickly reference when in the field, Giuliano assembled a catalog of variations of the Doric entablature, which at a moment's notice he could show to workmen or a potential patron.

Similar examples of the architects' near-obsessive recordkeeping, and continuous compilation of data, clues and exempla are found throughout all five books of our study. In every one of these cases it is evident that the value of the knowledge recorded was inextricably linked to the personal, referential quality of the notebooks in which it was contained. The seven Doric entablatures Giuliano rendered on folio 45v carried a significance which only he could fully discern. Why he appended the three additional studies at the base of the folio is as unclear to the modern eye as it would have been to one of Giuliano's contemporaries. What is clear, however, is that each of these drawings corresponded with the architect's practice, and that even as fragmentary studies, lacking consistent scale and without comprehensive dimensions, they functioned as "working" drawings.

4 Experimental Knowledge

On folio 4v of the Codex Forster III, beneath a diagram of a weighted A-frame beam, Leonardo poses the question: “If the beams and the [hanging] weight *O* is 100 lb, how much must the length *AB* weigh in order to resist this weight and so not to sag?”³⁶ The question, as posed here, is rhetorical, and complements the exploratory studies of the adjacent folios concerning framework and basic structural systems. Within many of his notebooks, Leonardo employed such statements as an analytical structuring device, and as presented here, the query reflects a complex reciprocal relationship between empirical observation and thinking on paper (Kemp 2006, 100).³⁷ While the study of structural forces belongs to the physical world, requiring observation of nature and an understanding of the physical laws of gravity, the calculations it entails are conceptual and might be worked out by the architect off-site. Such paper-based explorations, which took into account just enough empirical knowledge so as to retain relevance for future application, were the definitive traces of experimental knowledge. These previously unknown designs proposed to change the form, composition and function of architecture. The early modern architect’s ability to devise and discover was considered all-important, and within the context of his greater training, such artistic exploration was deemed complementary to his imitation of exemplary models, empirical work and examination of nature (Kemp 1977, 350).

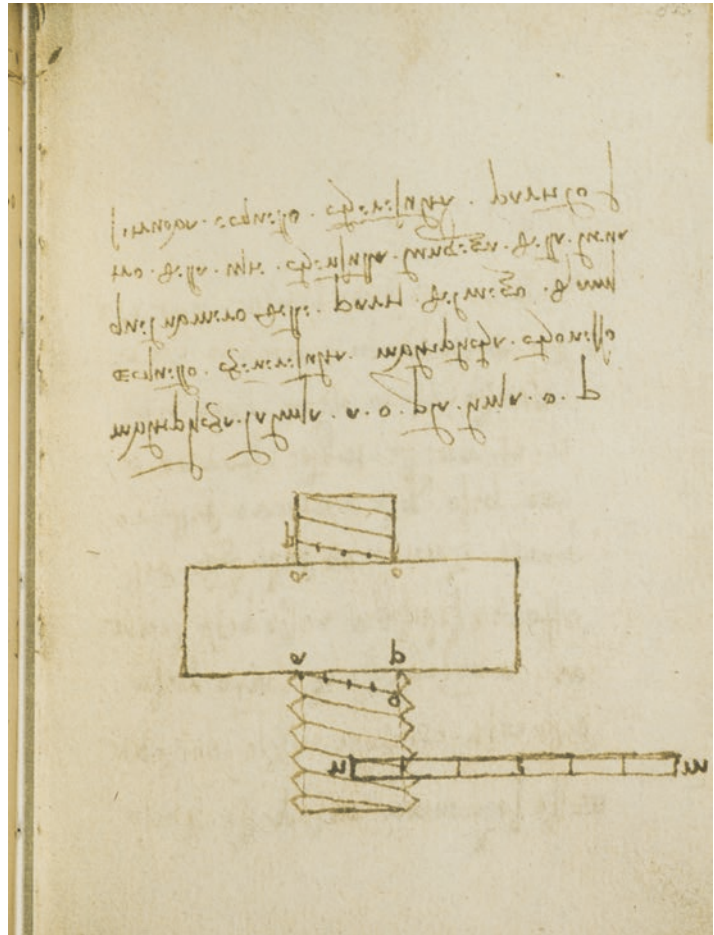
With few exceptions, the architect used *disegno* to explore his ideas. These images produced within this process were not model-drawings or project studies, but abstract manifestations of the architects’ *invenzione*, freewheeling searching, and generative thought processes. The concept of *invenzione*, as understood and employed by early modern architects, was closely linked to discovery and creation, and ultimately, served as the conduit for the uncovering of truth. Accordingly, contemporary theorists emphasized invention and experimentation as vital to good architecture, routinely echoing Vitruvius’ assertion that “the inventive architect always cleverly arrives at an original and correct solution to an old or new problem.” Still, architectural theorists were emphatic in pointing out that *invenzione*—which was frequently associated with *ingegno*, skill, and diligence—was not something that could be taught, precisely conveyed or described. Thus also, the knowledge born from *invenzione*, founded upon the architect’s discretion and judgment could never be fully transcribed (Kemp 1977, 353). The following discussion then focuses not on architectural knowledge per se, but the processes by which experimental knowledge was generated, the form it took in drawing, and how it was applied to practice. Examples from the notebooks of Leonardo, Francesco and Giuliano demonstrate three different forms of experimental knowledge, which, to varying degrees, incorporate shared knowledge, empirical knowledge, and pure fantasy.

The questions Leonardo addressed in the Codex Forster III, were, with few exceptions, essentially the same as those which concerned Ghiberti, Francesco, Benvenuto and Giuliano. Like these four architects, Leonardo endeavored to find solutions for excavation works, building machinery, hydraulic systems, the proportions of the columnar orders, and military devices. Yet, Leonardo was less reliant than his peers on the general information which was available to him, and almost never reproduced models verbatim. He wanted to find and confirm the answers for himself, and within his notebooks, he presented these ideas in a manner which made most sense for his own understanding. Leonardo’s study of the screw on folio 82r, a standard mechanical element that also features in more cursory form in the four other notebooks considered here, is a perfect example of how he approached common architectural problems independently (Fig. 8).

³⁶The Italian reads: “Si i travi e ‘l peso *o* sia 100 libbre, quanto peso sarà in *ab* a fare resistenza a esso peso che non caggi in basso?”

³⁷Other folios of Codex Forster III that include rhetorical questions are 19v, 20r, 50v, 53v 73r.

Fig. 8 Study of a screw.
From Leonardo da Vinci, *Codex Forster III*,
Victoria and Albert
Museum, London, c.
1493–1497, fol. 82r (da
Vinci 1992, vol. 3, fol.
82r)



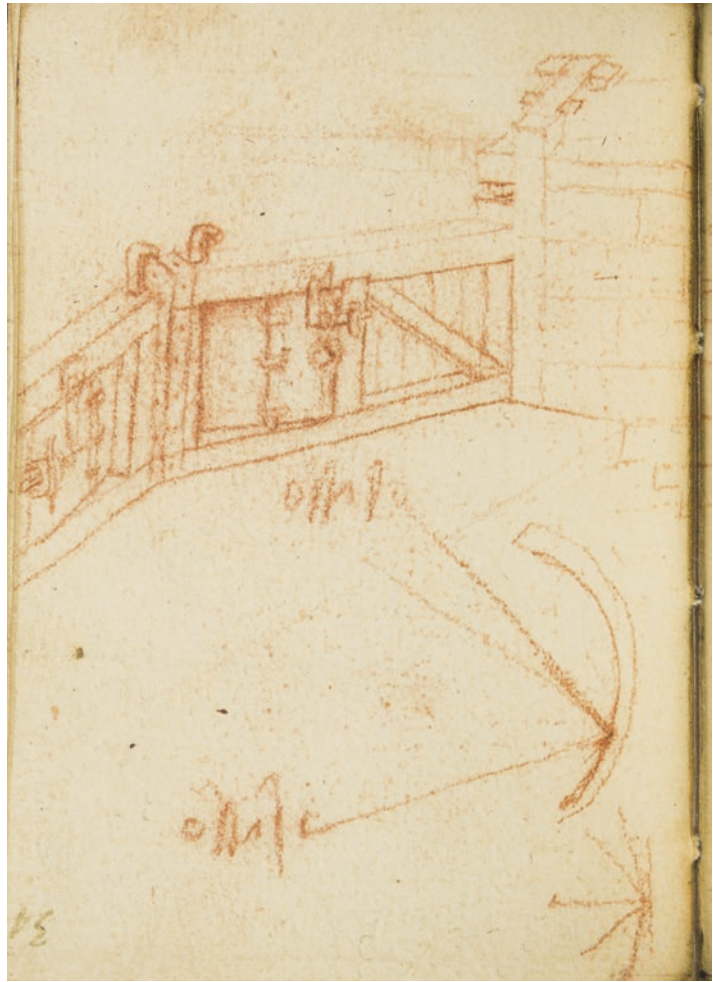
Leonardo placed great emphasis on the screw in his mechanical investigations, due to its infinite uses and the various ways it could be modified and adopted. Thus, even though his exposition on the screw on folio 82r is not particularly novel, the illustrated study displays experimental knowledge in its original form, as well as in its correlation to Leonardo's empirical understanding of the element. The purpose of the diagram was to elucidate how to calculate the spacing of a screw's threads, without "armatures or other structures that might hinder ... study." And Leonardo achieved this in his simplified, orthogonal projection (Reti 1980, 144–8).³⁸

Within the *Codex Forster III*, we also see traces of Leonardo's unfettered, probing exploration, which resulted in the creation of entirely new devices. Original projects referenced here include those for a sluice gate, mechanical loom, method of relief etching, and excavation machinery, devices Leonardo was working on in the final decade of the fifteenth century, and which he further developed in the *codex Atlanticus* (Galluzzi 1987, 84, 87; Reti 1999, 378–86).³⁹ It is possible, therefore, that the studies of the *Codex Forster III* represent Leonardo's initial thoughts—his on-site inspiration—which

³⁸Quote from *Codex Madrid*, fol. 82r.

³⁹Drawings of Leonardo's weaving machine appear on folios 43v, 60v, and 61r. Folios 14v, 15r, 17r and 18r concern excavation processes and machinery. Leonardo's innovative process for relief etching is referenced on folio 59r.

Fig. 9 Study of sluice gate. From Leonardo da Vinci, *Codex Forster III*, Victoria and Albert Museum, London, c. 1493–1497, fol. 57v (da Vinci 1992, vol. 3, fol. 57v)

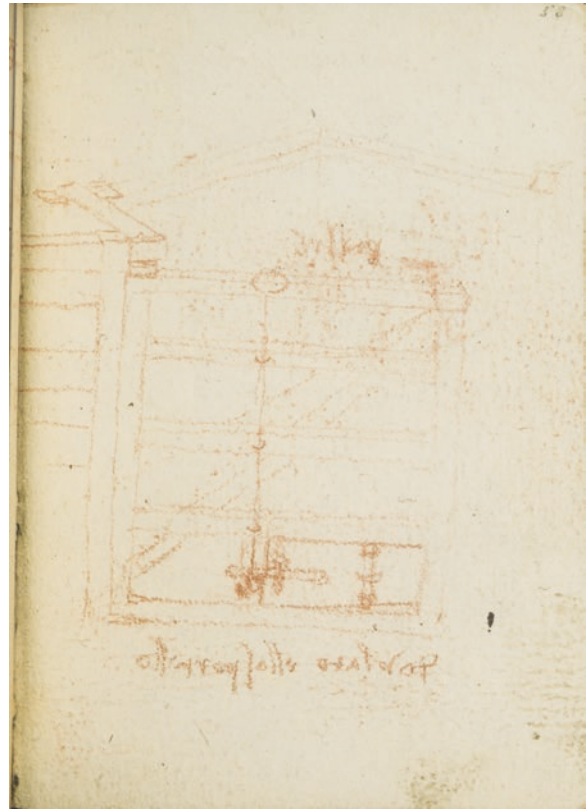


he subsequently developed in his workshop, or as he often did, when sitting by candle-light in the evening at home (Kemp 2006, 100).

Leonardo's studies for the sluice gate (fols. 57v and 58r) are particularly remarkable in that they represent his excellence in hydraulic engineering—expertise which helped him gain highly prestigious commissions from the city of Florence, Cesare Borgia, and King Louis XII of France (Figs. 9 and 10).

Within the *Codex Forster*, moreover, the two folios of sluice gate designs may be related to Leonardo's diagrammatic schemes for the diversion of the Arno (fols. 32v and 33r), and designs for a double-pulley excavation machine, which were to be employed in the construction of new canals. As mentioned previously, Leonardo had an abiding interest in extending the course of the Arno River, a project which would open Florence to the sea, bringing the landlocked city extensive economic and agricultural benefits (Heydenreich 1980, 28). The purpose of sluice gate was to help control water levels within a river or canal system by closing the flow of water from one section to another. The essential element of the gate was a trap door, which as rendered by Leonardo on folios 57v and 58r might take different proportions in relation to the gate as a whole. The trap door was operated by a latch mechanism, placed at the top of the gate, which when opened would allow water to flow into the canal, equalizing water pressure on both sides of the gate so that it could be fully opened (Reti 1980, 136).

Fig. 10 Study of sluice gate. From Leonardo da Vinci, *Codex Forster III*, Victoria and Albert Museum, London, c. 1493–1497, fol. 58r (da Vinci 1992, vol. 3, fol. 58r)



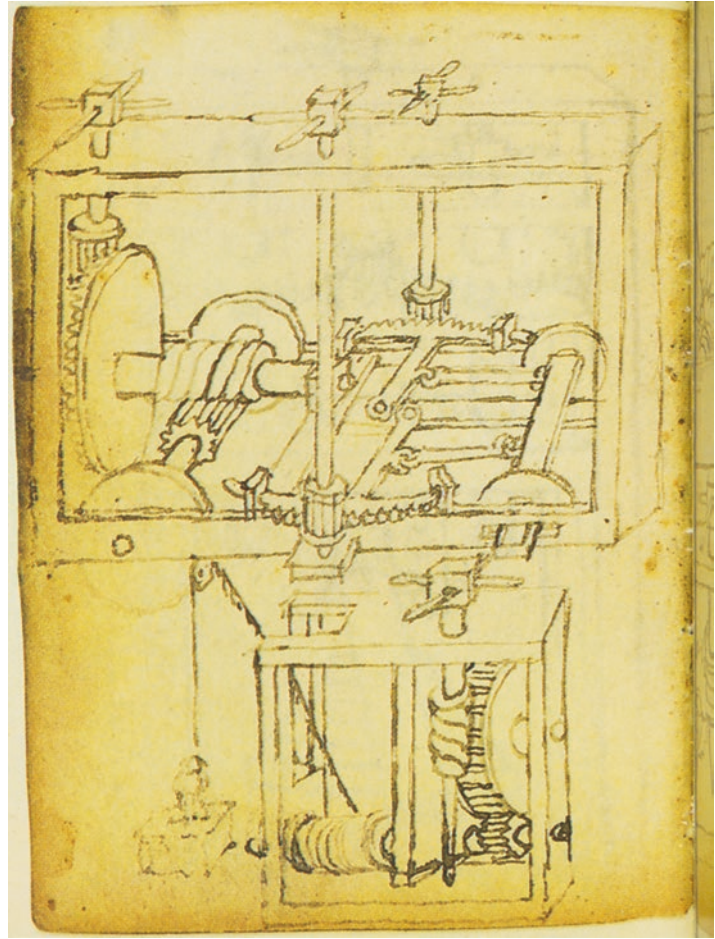
The drawings themselves, rendered in red chalk—the ideal media for laying down thoughts in a quick, cursory manner—reveal the architect’s exploratory process.⁴⁰ As characteristic of Leonardo’s notebook studies, this exploration concentrated on the intrinsic components of device in question, and how these elements would respond to the forces exerted upon them by nature. On folio 57v, where the opening of the trap door comprises half of the gate, Leonardo considers the force of the water pressing against the gate. The joint of the center gate opening buckles slightly in response to the water’s impact, which is illustrated by an arch on the right hand side of the folio. Radiating lines, labeled “sasso”—“thrust”—indicate the great force of the surging water.⁴¹ The image of folio 58r, presents the sluice gate in an entirely different form. The gate shown here is akin to the figure given in the codex Atlanticus, but only the door with the opening of the trap door is illustrated. The tentative lines of the figure suggest that Leonardo was still very much working out his concept for the weir. He barely traces out the walls of the canal, which extend above the left-hand side of the gate at a 45° angle, and hesitantly renders the contours of the gate. The only component of the illustration which Leonardo appears certain of is the trap door, which he outlines with a heavier hand, including the note: “On one side is the trap door.”⁴² The annotation above the latch at the top of the gate, never much more than a scribble, is now indecipherable. Taken together, then, folios 57v and 58r illustrate the

⁴⁰On the ease of drawing with chalk and artists’ preference of this medium, see (Brothers 2008, 213–4).

⁴¹“Sasso” is literally translated as “stone” but as used by Leonardo, refers to the pressure of a heavy force or impulsion.

⁴²The Italian reads: “Da un lato è lo sportello.”

Fig. 11 Design for car (top), and roller-beam hoist. From Francesco di Giorgio, *Codicetto Vaticano*, Codex Urb. Lat. 1757, Biblioteca Apostolica Vaticana, c. 1465–1475, fol. 119v (Martini 1989, fol. 119v)

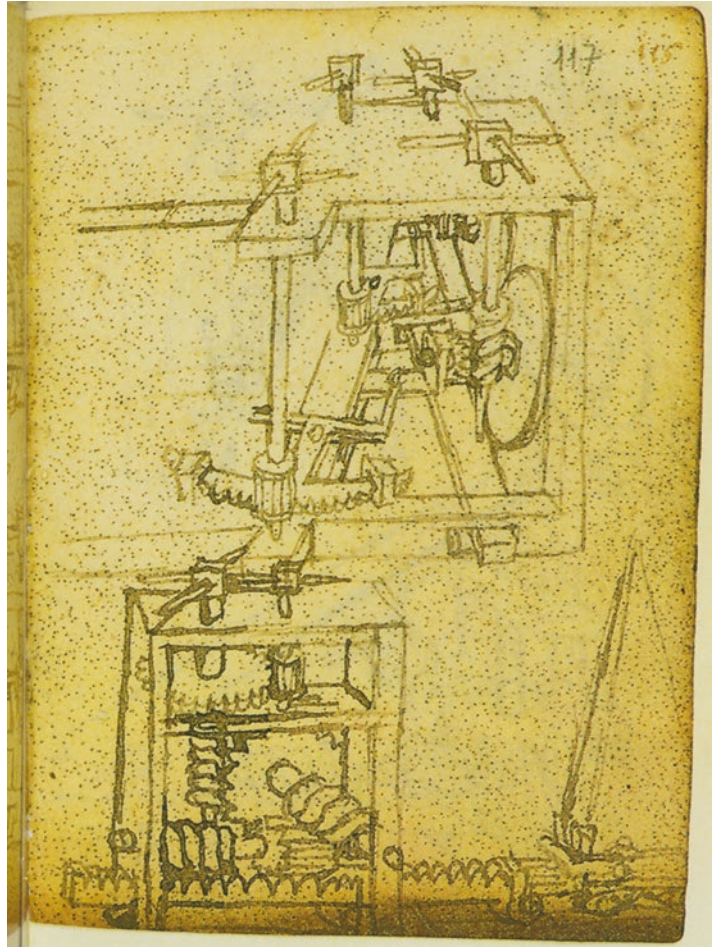


architect working out the formwork of his sluice gate, using his knowledge of the river as a means to spur invention.⁴³

Francesco di Giorgio's *Codicetto* also served its owner as a vehicle for working out mechanical problems and devising new solutions. But as evident in comparing the minute drawings of the *Codicetto* with those of the Codex Forster III, Francesco's process of creation was much different from that of Leonardo. As previously discussed, the *Codicetto* originated from Francesco's study of Taccola's notebooks, and even though much of this material is original, the essential design concepts—aqueducts, mills, canals, roof-beam supports, and even mobile attack dragons—may be traced back to Taccola. But the *Codicetto* is by no means a rote copy-book. The hundreds of drawings that fill the little book attest to Francesco's approach to analytic experimentation, a rational process of design development pursued in the reproduction of the same devices in drawing (Vecce 2003, 71). Thus, beginning with one of Taccola's models—for example, a four-wheel motorized car, which as rendered in *De Ingeineis* includes few mechanical details—Francesco explored the form and function of the device in a series of innovations. This method closely corresponds to his theoretical understanding of architect's inventive capacity and ability to produce an almost infinite number of works, of infinite variety ("*quasi infinite, infinito varia*") (Martini 1967, 505; Kemp 1977, 354) (Figs. 11 and 12). Within the abundance of

⁴³The idea that experience could stimulate invention is discussed by (Kemp 1977, 364).

Fig. 12 Detail of foreshortened view of car design. From Francesco di Giorgio, *Codicetto Vaticano*, Codex Urb. Lat. 1757, Biblioteca Apostolica Vaticana, c. 1465–1475, fol. 117r (Martini 1989, fol. 117r)



car-variations recorded on *Codicetto* folios 114r–122r, Francesco tests different configurations of the transmission mechanism—using toothed wheels, worm-gears, pin-and-axle crank system, and click wheels—and also modifies the type of wheels the car might take.

Among the car-variations illustrated on folios 114r–122r, those which display Francesco’s experimentation with new formats of technical representation are particularly noteworthy. For Francesco, just as for Leonardo, drawing was not only a mode of thinking, but was also a means of visualizing things previously known only in the abstract. The architect’s understanding of the mechanism—not just as a generic concept, but as a complex, multi-part construction—might therefore be correlated to the visual language by which he transmitted it. Illustrating a car akin to that given on 119v in foreshortened perspective (folios 117r/v), Francesco demonstrated the internal structure of the mechanism in a manner which was not possible in the standard, elevation projection. Whereas the elevation view usefully displays the horizontal transmission apparatus, the new view shows the distribution of the axels and connecting rods of the crankshaft.

Francesco di Giorgio’s ability to develop a concept through drawing, varying its formal characteristics as well as the manner by which it was transmitted, is also evident in his studies of mills. Within folios 133v to 164v, Francesco renders approximately eighty different mill types—variously formed and powered by running water, pumped water, wind, animals and humans. As with the car designs,

these mills are not in themselves exceptional—comparable constructions appear in contemporary architectural copybooks—but are distinguished in the means by which they are represented. Working carefully with pen and ink, Francesco framed the mill-variations in foreshortened “open boxes.” The boxes do not represent a literal formwork, but rather provide an abstract visual structure for the machines. By removing the mills from their environmental context, condensing and delineating their parts with box-partitions, the architect could better demonstrate the relationships of the different parts (Kemp 1991, 108). The focus of these drawings is not explicitly mechanical, but concerns the degree to which a given mechanism might be modified and reformed. In contrast to Leonardo, whose inventions express an immediate concern for the physical forces of nature, Francesco took environmental conditions as a given, leaving this aspect of the design process to be resolved by the individual architect, according to parameters of the site.

The distinction between invention born within a specific context, and that which considers empirical evidence, but is developed only to exist on paper, is a subtle one, but is critical to our understanding of the architect’s experimental knowledge. In Leonardo’s process of invention, the objects of his creation were always subjected, implicitly or explicitly, to the forces of nature. Thus, the designs of even his most daring contrivances intrinsically convey an astute understanding of the natural environment (Marinoni 1987, 130). The strength of Leonardo’s invention lay in his extensive empirical knowledge, experience which he continually referenced as a means to spur his creative facility. Francesco’s experiments also relied on cognitive thought and empiricism, but as realized in the *Codicetto* were merely conceptual. The primary function of the *Codicetto* drawings was to provide the architect with ideas and inspiration while on site. It is not that Francesco did not have the practical knowledge to realize the machines he rendered—there is ample documentary evidence that he did—only that as represented in the *Codicetto* they were not intended to be realized.

We find a similar correspondences between drawing content, empiricism, and experimental processes in Giuliano da Sangallo’s *Taccuino*. Giuliano’s inventive facilities are presented in his reconstruction of classical buildings, approximately twenty of which feature in the *Taccuino*. Many of these may be correlated with images of the codex Barberini, and it is by means of comparison—between the representation of a given monument in *Taccuino*, with that provided in the codex Barberini and other contemporary sources—that we come to understand the experimental knowledge contained in Giuliano’s drawings. *Disegno* was for Giuliano, just as it was for Leonardo and Francesco, a means by which to represent that which is absent and a catalyst for creative thought. But whereas Leonardo visualized something that might be, and Francesco represented conceptual hypotheses, Giuliano sought in drawing to illustrate structures which no longer existed. His drawings were to discover, or to uncover, a lost truth. Moreover, unlike the designs of Leonardo and Francesco, Giuliano’s reconstructions did not require even a pretense of functionality, and thus allowed for a greater degree of artistic license.

Giuliano’s restored plan on the Septizonium, a large nymphaeum erected by the Emperor Septimius Severus at the base of the Palatine Hill, illustrates the degree of license with which he approached his study of the antiquity. Although building’s remains were entirely disassembled by the end of the sixteenth century, in period leading up to this the Septizonium attracted significant attention from artists and architects, who frequently studied its monumental, three-level columnar façade. From the surviving study-drawings of Maarten van Heemskerck (1498–1574), Giovannantonio Dosio (1533–1609), Vincenzo Scamozzi (1548–1616) and Etienne Du Perac (1520–1607), among others, all showing three bays of the façade elevation, we may reasonably assume that this portion of the structure remained intact through the Cinquecento.⁴⁴ There is no indication that enough of the theater survived

⁴⁴Giovannantonio Dosio, 1774Ar (ca. 1557–1570), Gabinetto Disegni e Stampe degli Uffizi; Etienne Du Perac, Du Perac Sketchbook, fols. 22v and 23r (ca. 1570), The Morgan Library, New York; Vincenzo Scamozzi, fol. 9r, Ms. It. IV 149 (ca. 1560–1590), Biblioteca Marciana, Venice. For references and images, see (Nesselrath 1984).

to understand its plan—which from recent excavation efforts is known to have been rectilinear, approximately ninety-three meters in length—a supposition confirmed by the Heemskerk sketches that show the theater’s ruinous surroundings (Gorrie 2001, 653–7). Yet this is not the impression one gets from the plan Giuliano renders in the *Taccuino*. Here, the Septizonium is shown as a perfect square, encircled by a portico which includes ten columns per side, and centered on an open, porticoed atrium. This is not a precise study-drawing, but an imaginary recreation; a plan loosely based on the architect’s empirical findings and significantly enriched with his greater knowledge, or notions, of ancient architecture.

The inventive character of Giuliano’s plan is further elucidated when it is compared to a study-sheet of the same structure composed by Francesco di Giorgio. Francesco’s studies are more fragmentary and exploratory than Giuliano’s, and were likely rendered on-site by the Sienese architect during one of his visits to Rome.⁴⁵ Within the page, Francesco notes some of the same interior walls apparent in the *Taccuino* drawing, but also includes a partial plan of the theater with measurements, as well as a smaller, schematic plan and an accompanying elevation sketch. The startlingly distinction between Giuliano’s and Francesco’s studies—not only in terms of finish, but also in the degree to which Giuliano completed the ruinous structure—prompts reflection about the credibility of the other antiquarian drawings in the *Taccuino*. How do these relate to what Giuliano actually saw? And what function did the reconstructed, partly fantastical vision fill that a more literal depiction could not?

Giuliano’s elevation drawing of the Arch of Argentarii, folio 22r of the *Taccuino*, offers insight into these questions, as unlike the Septizonium, the Trajan era arch was largely intact when Giuliano studied it (Fig. 13).

As presented in the *Taccuino*, the Arch of Argentarii, which in the seventh century was partially incorporated into San Giorgio al Velabro in Rome, is freestanding and surmounted by an unusual quadrangular portico. This squat portico is shown open on all four sides, each centered by an arched portal and ornamented with symmetrically placed niches. The image includes two annotations in the form of inscriptions, which provide information of the monument’s location—“*di Sangiorgo i[n] Roma*”—and origin—“*Questo è sì dicie che è l’archo di Decio in Roma.*”⁴⁶ If this were Giuliano’s only rendering of the Arch of Argentarii, we would assume that it was a relatively accurate representation of the structure, based on his direct study. However, the illustrations he provides of the arch in the codex Barberini confirm that the *Taccuino* representation was not completely factual (Fig. 14), as here, the overall character and form of the arch is entirely changed.

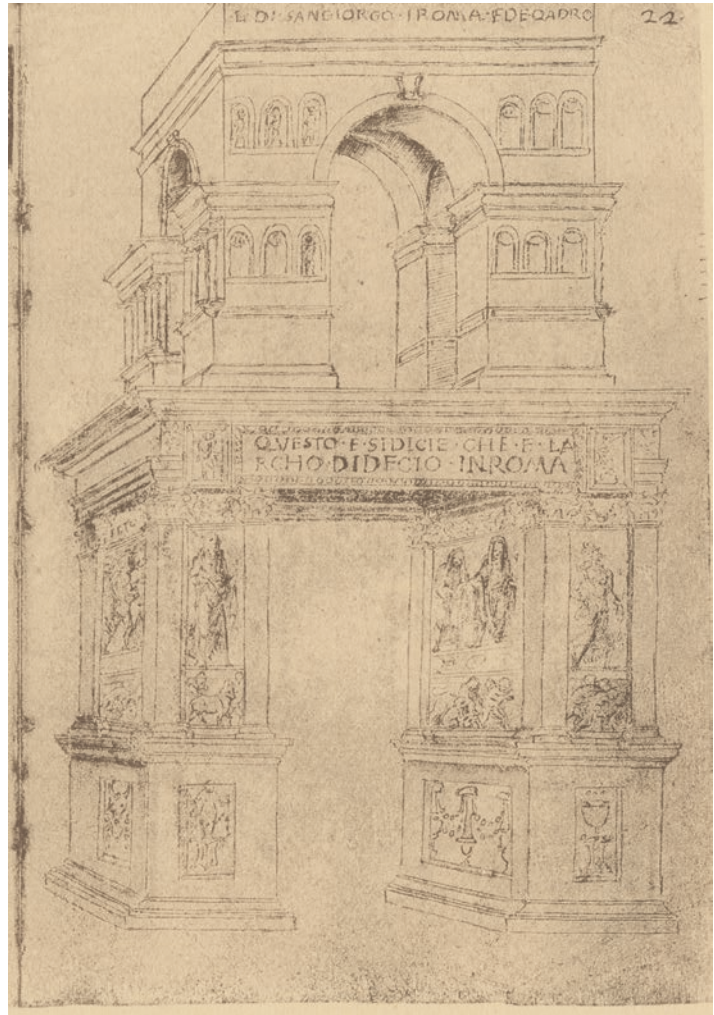
In the significantly more detailed Barberini study, a triangular pediment sits atop the arch, not a portico, and elaborate relief carvings encircle the base. The absence of the ornamental detail in the *Taccuino* image is an implicit indication of Giuliano’s limited knowledge of this section of the monument. Yet, as both studies attest, the architect clearly believed that some aspect of the arch was missing. It is likely that both the portal crown of the *Taccuino* version and the pediment of the Barberini study derived from monuments known to Giuliano. However, these pieces did not necessarily originate from the Arch of Argentarii. As applied to this monument, they were inventions, pieced-together by Giuliano in an attempt to “correct” the ruined monument (Brown and Kleiner 1983, 325, 333).

The comparison of Giuliano’s differing versions of the Arch of Argentarii in the *Taccuino* and the codex Barberini also illustrates the architect’s process of cognitive experimentation. Like Leonardo and Francesco di Giorgio, Giuliano used repetition in drawing as means to examine and develop the objects of his study. As evidenced in the examples previously discussed, all three architects were accustomed to render their subjects multiple times, introducing and testing new ideas with each version.

⁴⁵Francesco di Giorgio, UA 323r/v Gabinetto Disegni e Stampe degli Uffizi, Florence. The drawing is reproduced in (Burns 1993, 337). Giuliano also includes a plan of the Septizonium in the codex Barberini on folio 30r.

⁴⁶“Decio” refers to the Roman Emperor Decius, who ruled from 249–251 AD.

Fig. 13 Arch of Argentarii, Rome. From Giuliano da Sangallo, *Taccuino Senese*, Codex S.IV.8, Biblioteca Comunale, Siena, c. 1490–1513, fol. 22r (Falb 1902, unnumbered plate)

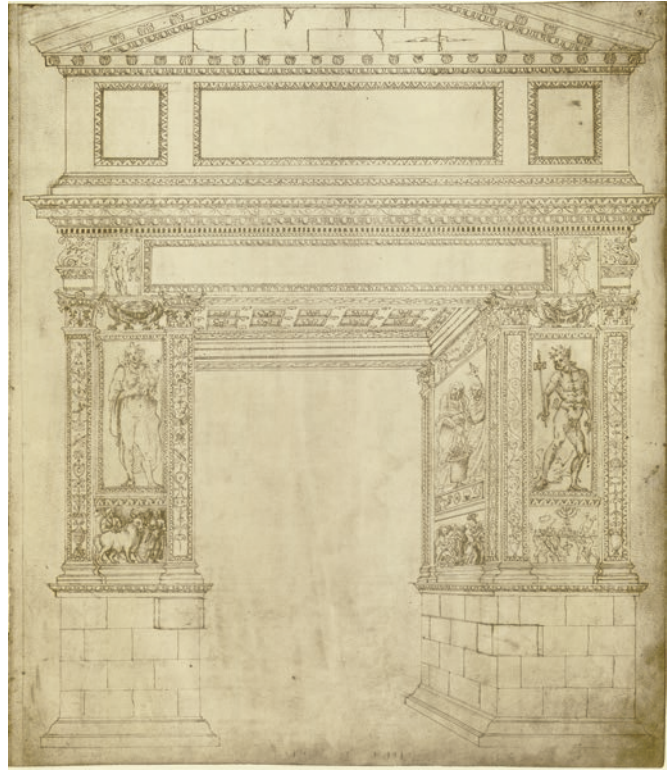


The development of the sluice gate, just as the invention of new mill types or the discovery of antiquarian models, was a systematic and analytic process. It would thus be incorrect to dismiss Giuliano's renderings of the Septizodium and Arch of Argentarii as mere fantasies, or to say that in reconstructing the ruins he demonstrated a disregard for empirical observation. Giuliano, just like Francesco, Leonardo, Benvenuto della Volpaia, and Buonaccorso Ghiberti, was looking for answers, and beyond this, for faithful models that he could apply in practice. He found these in accumulating and copying secondary material (shared knowledge), making first-hand observations (operational knowledge), and in the case that he was still unsatisfied, which was not infrequently, he found his answers through invention and experimentation.

5 Conclusion

As noted in the introduction, one of the intentions of this study is to shed light on the elusive role of the early modern architect, who lacked both an established system of training and a distinct professional affiliation. To this end, the notebooks of Buonaccorso Ghiberti, Francesco di Giorgio, Giuliano

Fig. 14 Arch of Argentarii, Rome. From Giuliano da Sangallo, Codex Barberini, Codex Vaticano Barberiniano Latino 4424, Biblioteca Apostolica Vaticana, c. 1465–1510, fol. 33r (Hülsen 1910, fol. 33r)



da Sangallo, Leonardo da Vinci and Benvenuto della Volpaia are informative not in the degree to which they differ—as personal handbooks of individual practitioners, variation should be taken as a given—but in their implicit agreement on certain fundamental principles of architecture. Within the notebooks, we find affirmation of the architects’ fundamental reliance on *disegno*, a tool which served them in all aspects of his work. The manuals also illustrate the architects’ dependence on models and exempla, their propensity to accumulate these, along with other sources of information, and their habit of creating handy, readily accessible records of the material related to their practice. For the architect of the twenty-first century, who has access to countless images, databases, computational aids and reference guides, and is generally subject to the unprecedented information overload of our age, such recording and codification of knowledge is relatively routine. As noted by the distinguished architect and scholar Bill Lacy, “Architects are known for carrying sketchbooks and journals wherever they go to record fleeting ideas and impressions” (Serrazanetti and Schubert 2009, 11). Yet, prior to the fifteenth century, there is little surviving evidence of this practice.⁴⁷ In fact, the five notebooks of this study are among the earliest known examples of practitioners systematic writing and recording. The books, therefore, are relevant not only in their form and contents, but also by their essential character as personal reference volumes. They mark a turning point in the history of architecture, and in the character of the practicing architect.

⁴⁷Surviving architectural manuscripts from pre-1450 are primarily either lodge books, kept within the workshop and passed between generations of architects, or theoretical texts, written in Latin and dedicated to distinguished patrons. The Late Hellenistic bronze statue of an artisan, conserved today in the Metropolitan Museum of Art, is perhaps the earliest reference to architects’ reliance on pocket-sized notebooks. This figure, who carries a notebook in his belt, has been identified as an architect (possibly Daidalos) due to the prominently placed notebook. See (Picon and Hemingway 2016, 161–62).

Considered within the greater framework of early modern architecture—which on the one hand received unprecedented theoretical attention with the “re-discovery” of Vitruvius’ *De Architectura* and spate of architectural tracts that followed, while on the other, was substantially driven by the ever-increasing need for new technologies—the notebooks of Buonaccorso Ghiberti, Francesco di Giorgio, Giuliano da Sangallo, Leonardo da Vinci and Benvenuto della Volpaia may be understood as the architects’ attempts to mediate the two, seemingly incongruous aspects of their discipline. Was the architect a theorist, as Leon Battista Alberti argued, who provided the design concept but stayed at arms-length from the worksite? Or was he a practitioner, developing stronger defenses, better mill-systems, and quicker building processes using the empirical knowledge he gained in the field? Beyond this, what constituted the basis of architectural training? Was it enough to be a skilled draftsman with an eye for pleasing forms and proportions? Or did the architect need to know structural systems, material properties and force loads? Despite individual architects’ attempts to define their discipline, and to establish it as an autonomous profession, at the turn of the sixteenth century, the state of architecture remained as obscure as ever. Inundated with information, and faced with rising expectations regarding their humanistic knowledge and technical expertise, architects of the period eagerly sought to structure their diffuse practice. The personal note- and drawing books offered a solution. In composing these manuals, the architects became authors, ascending to the level of humanists, while at the same time elevating technical processes of their discipline (Galluzzi 2003, 50).

This is not to say that the architects were entirely secure in their professional role. All five of the books considered here display a certain self-consciousness, one might even say an uncertainty, on the authors’ behalf. Benvenuto della Volpaia is quite explicit in this regard, systematically referencing the names of the many individuals with whom he was in contact, and whose collaboration affirmed the validity of his own practice. Likewise, the drawings of Giuliano da Sangallo’s *Taccuino* are those of an architect who is questioning both his subject matter and his role in relation to it. Giuliano’s inscriptions are replete with miss-spellings, which he oftentimes subsequently corrected in a different ink. The cursory annotations added to many of the more polished antiquarian studies are also suggestive of his irresolution. As conceived, the *Taccuino* was to convey Giuliano’s artistic mastery and knowledge of antiquities. Yet as he matured, this understanding of antiquarian architecture was shown to be increasingly precarious and the value of his early, meticulous study drawings became increasingly unclear. The extremely small size of the *Codicetto* and the Codex Forster III may also be indicative of the authors’ extreme self-awareness. For the sake of portability alone, the books could have been twice or three times as large. Yet, both Francesco di Giorgio and Leonardo deliberately chose far more compact formats for their books, and we should assume that they did so for a reason. Were Francesco and Leonardo trying to hide their knowledge? Did Francesco seek to disguise the fact that he carried with him a reference manual of design prototypes? Or was Leonardo anxious that someone might steal his ideas, claiming his *ingegno* and all the rewards which it bestowed? As attested to in the writings of Mariano Taccola and Francesco di Giorgio, such appropriation or plagiarism of artistic material was not uncommon in the Renaissance, and evidently, Buonaccorso also felt some threat of this, as several annotations in the *Zibaldone* are recorded in cryptogram.⁴⁸ While this is not the place to delve into early modern intellectual property and authorial secrecy, it is worth reiterating that Buonaccorso, like Francesco, Leonardo, Benvenuto, and Giuliano, were doing something substantially new in composing their notebooks. Although still uncertain about the status of the architect, and the supposed scope of his expertise, they could be sure of their own practices and investigations. In codifying this material, and in turn the knowledge it produced, they began to delineate the contours of a new structure of architectural knowledge.

⁴⁸On Francesco di Giorgio’s and Taccola’s reluctance to share information (Long 2001, 112–23). On the “secret” character of material in the *Zibaldone*, see (Prager and Scaglia 1970, 67–9).

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