Architecture and Mathematics in Early Modern Religious Orders

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For most of us, a familiar image from Raphael's *School of Athens* serves to illustrate our intuitive notions about the links between early modern architecture and mathematics. The artist's portrait of the great Renaissance architect Bramante as the geometer Euclid recalls the medieval traditions of Gothic architects and master masons using geometry (Fig. 1). Moreover, the inclusion of Zoroaster and Ptolemy—identified by celestial and terrestrial globes—in the group huddled around Euclid/Bramante further seems to associate geometry and architecture with astronomy, vaguely echoing the medieval quadrivium of arithmetic, music, geometry, and astronomy. In short, the architect as mathematician (or mathematician as architect) operating within a larger group of quantifiable crafts and sciences seems obvious, and not particular to the early modern world. Yet a closer look at a well-defined culture which produced such individuals illuminates much about the period's understanding of both architecture and mathematics.

The religious orders traditionally associated with the Counter Reformation, such as the Jesuits, Theatines, and Barnabites, provide rich material for investigating the relationship between architecture and mathematics, and they nurtured a specific type of priest-architect. In 1595, the architect Vincenzo Scamozzi remarked about the Venetian Theatines: "these fathers… are both good mathematicians and they understand architecture…," implicitly linking the priests' ability in these two fields.[1] This paper considers why this relationship flourished in the Italian Seicento and how the intellectual culture of these orders promoted architectural activity.

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Fig. 1 Raphael, *School of Athens*, Vatican, Stanza della Segnatura, c. 1510–1511, detail with Euclid/Bramante

The Orders

Two major factors account for the centrality of this phenomenon in the seventeenth century. First, the Seicento witnessed a dramatic expansion of the counter-reformational orders all across Europe, but particularly in Italy. This expansion created a pressing need for new churches and for designers or construction supervisors.[2] Second, as the century progressed, the gradual organization (and reorganization) of knowledge in the wake of the new sciences influenced these orders as they consolidated their educational programs for their members. In these curricula, architecture became systematized as a discipline related to applied mathematics. The orders maintained ambivalent—not entirely hostile—relationships to the new sciences, which to a great extent had their center in Italy with Galileo.[3] While the relationship between mathematics and architecture also developed in the secular world, in other religious orders, and outside of Italy—figures like Christopher Wren, Ignazio Danti, or the Belgian Jesuit François d'Aiguillon spring to mind—the new orders' institutional qualities as significant centers of mathematical learning and architectural patronage made them crucibles for the development of a mathematical approach to architecture, especially in Italy.[4]

How were the Jesuits, Theatines, and Barnabites trained in mathematics and the sciences? The Jesuits' *Ratio studiorum* (first edition 1586) outlined the course of study pursued by the order's aspiring priests.[5] The Theatines and Barnabites at first summarized their curricula in their constitutions; the Barnabites followed with a document similar to the *Ratio studiorum* in 1666.[6] In all three orders, the basic seven-year curriculum covered three years of philosophy and four (or sometimes five) of theology.[7] For the Jesuits and Theatines, the first year of philosophy dealt with logic; the second year with natural philosophy (via Aristotle's *Physics* and *De caelo*) as well as Euclid's *Elements*; the third year with metaphysics. The four years of theology were chiefly based on Aquinas.

Beyond the *Elements*, which comprised the basic mathematical education for most future priests, aspects of astronomy, perspective, optics, music, and mechanics were also treated in what was essentially an updated version of the medieval quadrivium.[8] For talented students, however, the Jesuits offered supplemental tutoring, exploring these topics in depth as well as other "mixed" or applied mathematics topics, such as surveying, navigation, instrument making, hydraulic engineering, and both civil and military architecture.[9] The term refers to the "mix" of abstract mathematical concepts with quantifiable, empirical properties of the real world. Christoph Clavius, professor of mathematics at the Collegio Romano, promoted this concept from the very beginning of his tenure as an integral part of the Jesuit curriculum.[10]

The second edition of the *Ratio studiorum* (1591) prescribed a kind of occasional mathematical forum to be held at the Collegio Romano that would present material related to the private lessons of individual students. Michael John Gorman has recently studied the *problemata* presented in this forum under the guidance (and disguised authorship) of Christoph Grienberger, professor of mathematics at the Collegio Romano off and on between 1595 and 1633.[11] Among the thirteen problems published and analyzed by Gorman, two treat broadly architectural topics: one on geometry and architectural design with specific reference to the Jesuits' Collegium nobilium in Bologna (1588–1601), the other speculating on the dimensions of Egyptian pyramids (based on descriptions of the Seven Wonders of the Ancient World) in the manner of Juan Bautista Villalpando. In the first, Grienberger also comments on a structural curiosity like the leaning Torre degli Asinelli in Bologna: "Without doubt that Bolognese structure had an outstanding mathematician as its architect by whose vigilance Geometry has come to inhabit that tower."[12] These *problemata* seem to confirm the place of architecture in the advanced mathematical tutoring offered at the Collegio, an innovation in architectural education that produced a new type of architect, emerging not from a background in crafts or the building trades, but rather from a scholarly approach supplemented by practical experience at the order's construction sites.

The Jesuit Antonio Possevino's *Bibliotheca Selecta* (first edition Rome, 1593) marks the first written record of architecture's place within the order's mathematical world. Possevino's monumental study, closely related to the discussions surrounding the early versions of the *Ratio studiorum*, offers summaries of virtually all fields of knowledge, with suggestions for further reading.[13] Book XV deals with mathematics, and within this mathematical section Possevino devoted three chapters to architecture, declaring at the outset that architecture is discussed immediately after the chief mathematical disciplines, since it depends on these, and in fact is perfected through their leadership.[14] In his encyclopedic ambition to present the knowledge necessary for Jesuits, Possevino concentrates on critical discussions of the architectural texts of antiquity, including both Vitruvius and the Bible, with its description of the Temple of Solomon. Possevino supplements these sources with references to Alberti, Palladio, and Barbaro's commentary on Vitruvius. The relevant booklist also cites the perspective works of Barbaro, Dürer, and Ignazio Danti. These treatises form the basic literature for early Jesuit architects.

Early inventories of Theatine and Barnabite libraries dating to around 1600—just a few years after Possevino—indicate that architectural and perspective treatises also played a role in the intellectual life of other counter-reformational orders. The larger Theatine libraries, such as Sant'Andrea della Valle and San Silvestro al Quirinale, both in Rome, San Paolo Maggiore in Naples, Santa Maria della Ghiara in Verona, or San Siro in Genoa, each possessed several of the standard architectural books in various editions, including those of Palladio, Serlio, Vitruvius (including Barbaro's edition), Alberti, and Labacco. The same works are listed in the Barnabites' libraries at San Paolo at Piazza Colonna in Rome, Santa Maria della Corona in Pavia, and San Paolo in Casale Monferrato. Other books, such as Alberti's *Della pittura*, Martino Bassi's *Dispareri in materia di architettura et perspettiva* (Brescia, 1572), Dürer's *Unterweysung der Messung* (Nuremberg, 1525), and Vignola's *Regola delli cinque ordini d'architettura* (Rome, 1562) also appear in single libraries of both orders.[15]

The Jesuits ultimately institutionalized the link between mathematics and architecture. From the early Seicento, a centralized architectural policy generally cast the professor of mathematics at the Collegio Romano as the order's *consiliarus aedificiorum*. The *consiliarus* reviewed designs for all Jesuit churches and houses across Europe before presenting them to the order's general for final approval. Beginning in 1613, the general required submission of plans in duplicate, so that one copy could be kept in the order's central archive in Rome; this is the source of the Jesuit plan collection now at the Bibliothèque Nationale, Paris. The *consiliarus* usually edited plans for structural flaws and budgetary extravagance rather than aesthetic concerns. As Vallery-Radot points out, editing the designs for style was uncommon since the plans sent to Rome for approval were rarely accompanied by sections and elevations. Typical reasons given for the rejection of a design were "inconvenience", "crowding", and "errors". Suggestions for revisions included adding windows or replacing a vault with a lighter, less expensive wooden ceiling.[16] The Barnabites, though not the Theatines, also had a similar office, the *prefetto delle fabriche*.[17]

As Steven Harris has shown, the Jesuits' involvement with the sciences must be seen in a specific theological, vocational, and ideological context. Rejecting the apparent contradiction between these pursuits, Harris links Jesuit scientific work with the order's ideology of "apostolic spirituality," an active engagement in "worldly labor, performed in service to their fellow-men and for the honor and greater glory of God."[18] Harris classifies six major categories of Jesuit scientific publications: (1) Aristotle's natural philosophical books; (2) Euclidean geometry and "mixed" mathematics; (3) astronomy; (4) experimental and natural philosophy; (5) natural history; and (6) medical and pharmaceutical topics.[19] Noting a combination of classical Aristotelianism and a new empiricism in these works, Harris suggests the empirical aspects stemmed from the order's active experience in the world. Although such empiricism characterized much seventeenth-century science, Harris argues that the order enthusiastically adopted only those forms of scientific endeavor that also proved useful in the Jesuits' three major "apostolates" or spheres of activity: education, European courts, and foreign missions. He concludes that for the Jesuits a "…supraconfessional doctrine of the sanctity of mundane labor, in conjunction with a high esteem for learning and reason, provided fertile ground for the acceptance and development of active-empirical forms of early modern science."[20] The consequence of this was that "…those forms of scientific activity that Catholic princes found either useful (e.g. navigation, surveying, hydraulics, military architecture) or entertaining (the 'virtuoso' sciences, curiosity cabinets, and telescopic astronomy) became part of the Jesuit scientific repertoire."[21] Of course, civil architecture also counted among the activities useful for Catholic princes, so it is no surprise to find it within the purview of Jesuit science.

The Architects

Who were these early modern priest-mathematician-architects? We now survey six careers, exemplary for the range of activities in which these men operated. The phenomenon, however, includes dozens of other figures, a few of whom are briefly mentioned in notes below.[22] Their work covers the spectrum of higher, "mixed", and practical mathematics in which architecture was embedded. Some priests excelled more in one area than others—perhaps geometry, astronomy, perspective, or indeed architecture—while others worked across the entire spectrum. Well-known figures such as Orazio Grassi or Guarino Guarini have entered history as notable astronomers or architects, with only cursory mention of their other work in the broader world of seventeenth-century mathematics. Contemporaries, however, seem to have perceived all their efforts as various parts of a single discipline.[23]

The first generation of Jesuit architects—Giuseppe Valeriano (1542–1596), Giovanni Tristano (c. 1505–1575), and Giovanni De Rosis (1538–1610)—received architectural training and experience before entering the order.[24] Although Valeriano assisted Possevino in composing the architectural chapters of the *Bibliotheca Selecta,* there is little further evidence to suggest that these men viewed architecture as a primarily intellectual or mathematical undertaking. The first accomplished Theatine architect, Francesco Grimaldi (1543–1613), also came from a background in the crafts.[25] It seems the immediate needs of the orders for churches in these early years outweighed any impulses to enhance the status of architecture. Yet the groundwork laid by the first generation of Jesuit architects was instrumental. Actively running a number of construction sites, they provided the hands-on training required to turn academically-trained priests into practicing architects. Although the tradition of priest- or lay brother-architects from a crafts background continued through the seventeenth and on into the eighteenth century, it gradually waned as the numbers of scholar-architects increased. The systematization of architecture as a mathematical discipline became consolidated throughout the course of the Seicento.

Orazio Grassi (1583–1654) illustrates virtually all aspects of a mathematical-architectural career within the Jesuit order.[26] He was an advanced student who devoted an entire supplemental year to mathematics during his studies at the Collegio Romano (1605–1606). In 1612, he led an unsuccessful attempt to found a Jesuit architectural academy there, perhaps even offering courses under its auspices for a short time. He was professor of mathematics at the Collegio Romano from 1616 to 1624 and 1626 to 1628, serving thus for 10 years as *consiliarus aedificiorum*. During the latter period he designed the Jesuits' Sant'Ignazio (Fig. 2) in Rome and an adjacent wing of the Collegio Romano. His other major church for the order was San Vigilio in Siena. His manuscript Vitruvius commentary survives in Milan, and an album in Rome of his (mostly autograph) drawings mixes architectural and perspectival studies with further scientific material in cartography, instruments, and natural history. Grassi worked in other areas of mathematics as well, notably astronomy. Writing under the pseudonym Lotario Sarsi, he gained particular notoriety as Galileo's adversary in their dispute over the nature of comets, culminating in the latter's publication of *Il Saggiatore* (Rome, 1623).[27]

Another such figure, of a generation or two later, was Francesco Eschinardi (1623–1703), a professor of mathematics at the Collegio Romano and thus the *consiliarus aedificiorum* during his tenure. Historians of science today emphasize the importance of Eschinardi's work in optics or in the development of the thermometer. Yet he published two architectural treatises: *Architettura civile* (Terni, 1675) and *Architettura militare* (Rome, 1684), both under the pseudonym Costanzo Amichevoli (Fig. 3). He also produced, under his own name, a learned commentary on Giovanni Battista Cingolani's map of the Roman countryside, *Topografia geometrica dell'agro romano* (Rome, 1692), which included a concise guide to the city.[28]

In contrast to Grassi, Eschinardi seems to have had little impact on actual building within the Jesuit order—as *consiliarus aedificiorum*, he is known only for his work overseeing the early planning stages of the Jesuit church in Vercelli—but his involvement in the art took place in the same context of contemporary mathematical science. Eschinardi's architectural treatises were apparently written in connection with the Roman Accademia Fisico-Matematica, sponsored by Monsignor Giovanni Giustino Ciampini in his palace near Piazza Navona; Costanzo Amichevoli was Eschinardi's academic pseudonym.[29] The scope of the academy's activities was defined as philosophical, medical, mathematical, and mechanical, all subsumed under the heading "Fisico-Matematica". Here the category "mechanical" included the "mixed mathematical" disciplines such as optics, horology, civil and military architecture, and the use of perspective in painting, sculpture, and theater. Eschinardi's treatises are unremarkable in content—his treatment of the orders relies chiefly on Vignola—but the context of their origins sheds further light on architecture's systematization within the intellectual culture of the Jesuit order.

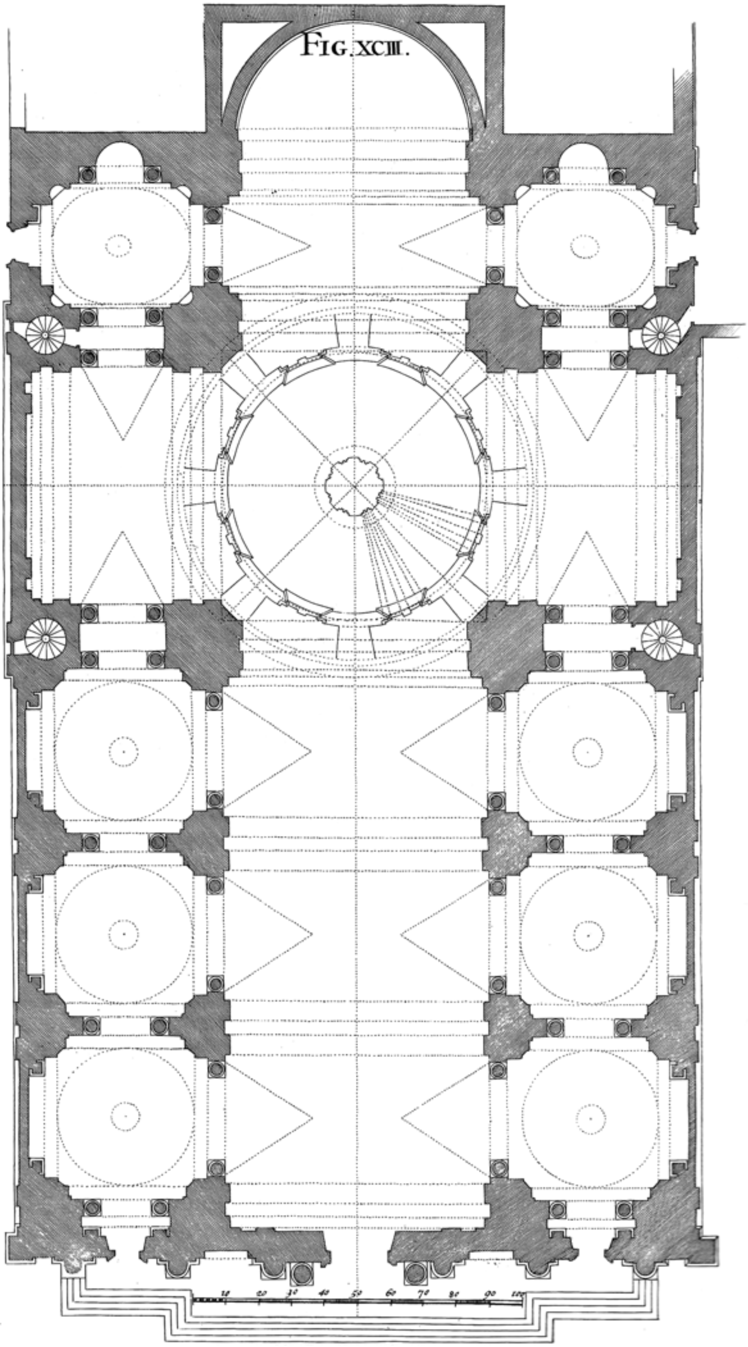


Fig. 2 Orazio Grassi, Sant'Ignazio, Rome, 1626–1628, plan (From Pozzo (1707, repr. 1989, 200))

ARCHITETTVRA CIVILE
RIDOTTA
A' METODO FACILE, E BREVE
DA
COSTANZO AMICHEVOLI

IN TERNI,
Appreſſo Bernardino Arnazzini M. DC. LXXV.
Con licenza de' Sig. Superiori.

Fig. 3 Title page, Eschinardi [Costanzo Amichevoli] (1675)

Perhaps the most famous Jesuit architect of the Seicento was Andrea Pozzo (1642–1709), who came to architecture via another mathematical discipline, perspective painting.[30] His built works consist mainly of altars and other church furnishings, though he also designed or remodelled several provincial churches for the

Jesuits such as the Gesù in Montepulciano or Sant'Ignazio in Dubrovnik. Having risen from a background as a craftsman and as a lay brother, Pozzo lacked a priest's scholarly education. Yet his theoretical aspirations demonstrate how much the academic culture of mathematics had permeated the Jesuit order by the late seventeenth century. His two-volume treatise *Perspectiva pictorum et architectorum*, (Rome, 1693–1700) was published in a parallel Latin-Italian text, presumably aimed at a dual audience of erudite scholars and vernacular practitioners. The treatise chiefly addresses the problems of painting fictive architectural settings in perspective. Although not a work of architectural theory *per se*, Pozzo repeatedly emphasizes the similarities and connections between perspectival painting and architectural design. Both, for instance, utilize the same drawing skills: "The Geometrical Plan… is no less necessary for painting a Design in Perspective, than it is for raising a Structure with Solid Materials."[31] The accompanying plates demonstrate how such plans are transformed geometrically into perspectival constructions and how Pozzo relied on geometry for both perspective painting and architectural designs (Fig. 4).

Among the Barnabites, the two most prominent priest-architects were Lorenzo Binago (1554–1629) and Giovanni Ambrogio Mazenta (1565–1635). Binago served for many years as *prefetto delle fabriche*, but Mazenta more clearly reflects the intellectual culture of the counter-reformational orders. The patrician Mazenta joined the Barnabites at the relatively late age of 25, ultimately rising to become the order's father general from 1612 to 1618. He and his two brothers Guido and Alessandro all demonstrated an early interest in architecture, and Giovanni Ambrogio was apparently encouraged by his early patron Federico Borromeo and the latter's Accademia degli Accurati, devoted to the "exact sciences and architecture." This academic experience thus recalls the case of Eschinardi, but unlike the Jesuit, Mazenta was a prolific designer and builder. His works stand chiefly in Bologna. The innovative designs for the Barnabites' San Paolo, San Salvatore (Fig. 5), and the nave of the cathedral of San Pietro confirm his standing as one of the leading priest-architects of the century.

The erudite and wide-ranging Mazenta studied Leonardo manuscripts, corresponded with Cassiano dal Pozzo, and directed Barnabite colleges in Pisa and Bologna. He also wrote *pareri* on the restoration of the Pantheon and the Lateran basilica. Mazenta cannot be considered a full-blooded mathematician as Grassi or Guarini. None of his scholarly works deal specifically with mathematics and architecture, nor does he seem to have taught mathematics within the order. Yet when we look carefully at his entire career, we see telltale signs of an architect trained in mixed mathematics. He designed and supervised construction of bridges, barracks, fortifications, as well as the harbor mole at Livorno for Grandduke Ferdinando I Medici in 1600–1602. He was an expert consultant during a dispute between Bologna and Ferrara regarding a tributary of the Po. Hydraulics also played a role in his unexecuted designs for enormous columns crowned with crosses to be placed at major intersections in Milan. These crossroad monuments would have continued Carlo Borromeo's post-Tridentine project of punctuating Milan's urban fabric with crosses erected throughout the city, while also serving practical functions as reservoirs and clepsydrae.[32]

The Theatine Guarino Guarini (1624–1683) emerged as the greatest architectural talent in this group of seicento mathematical priests, and he is best known today for

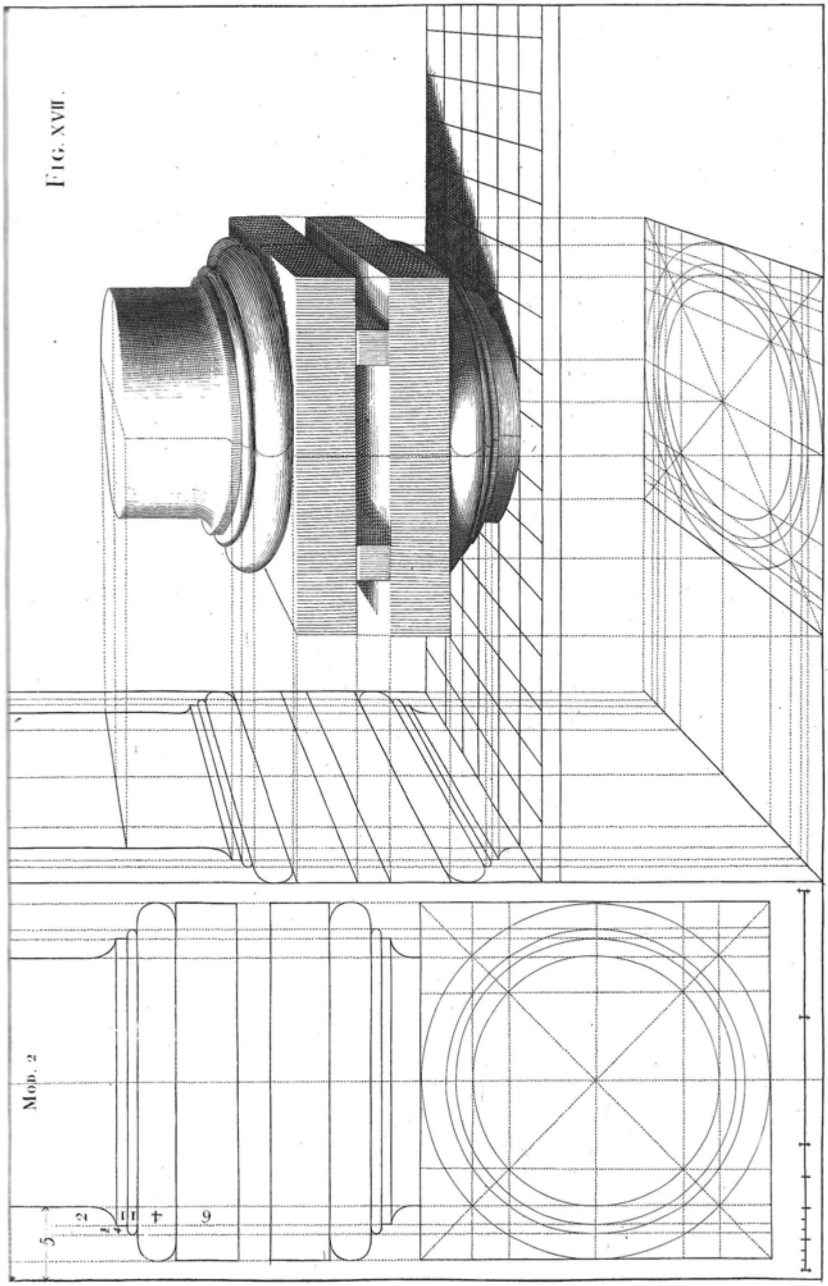


Fig. 4 Perspective study of Doric base (From Pozzo 1707, Plate 17)

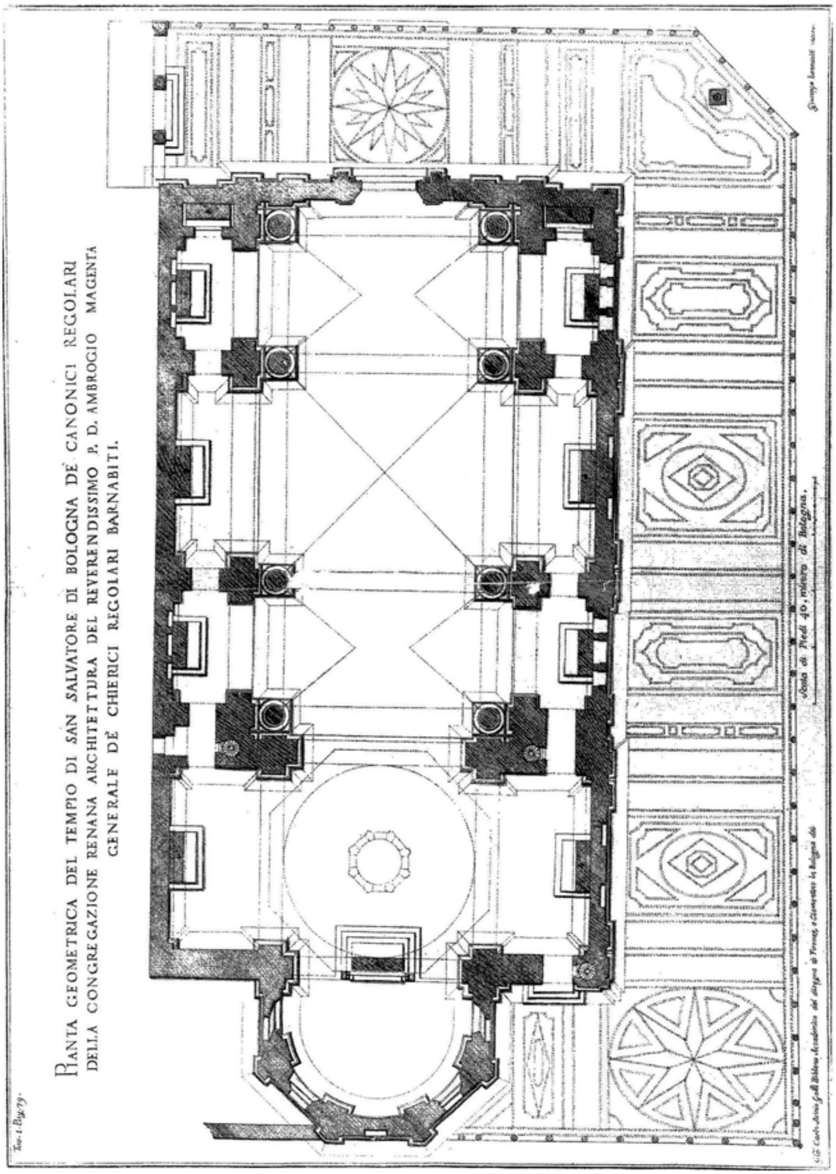


Fig. 5 Giovanni Ambrogio Mazenta, San Salvatore, Bologna, 1605–1623, plan (From Trombelli 1752, Plate 1)

Fig. 6 Engraving of Guarino Guarini and Gaetano Fontana (From Bianchi 1768, 108)

his works in Turin: the church of San Lorenzo, the chapel of the Holy Shroud, and the Palazzo Carignano.[33] Although he was never as prominent a scholar as Grassi, the early modern age nonetheless considered him primarily as a mathematician. One eighteenth-century biography described Guarini and fellow Theatine Gaetano Fontana in just such terms: "they were formed by nature to adorn sanctity, the sciences, and particularly the mathematical disciplines…."[34] The accompanying engraving reinforces the point, showing his colleague taking measurements from a celestial globe, while Guarini applies a set square to the design of a building (Fig. 6).

Here, astronomy and architecture illustrate different aspects of "the mathematical disciplines" within the Theatine intellectual world.

Like other priest-architects, Guarini received practical training at his order's various building sites, but extensive travel within Italy (including Sicily) and France greatly augmented this experience. Paris, in particular, offered Guarini direct contact with the architecture of Louis Le Vau and François Mansart, as well as the great French mathematical and constructive tradition of stereotomy. During his entire career, Guarini was producing architecture for the order and court patrons, as well as learned treatises on philosophy and mathematics.

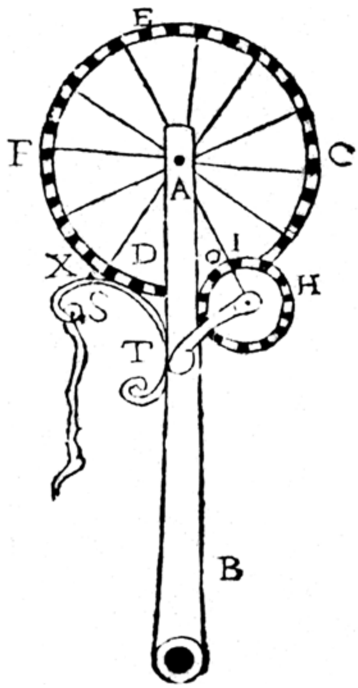
Most of Guarini's writings can be understood as textbooks for the various subjects within the Theatine curriculum. In 1665, he published the *Placita Philosophica*, a compendium of Aristotelian logic, physics, astronomy, and metaphysics. In the broad field of mathematics, both pure and "mixed", we find three astronomical publications, as well as the *Euclides adauctus* (Turin, 1671), an encyclopedic treatment of the *Elements* studied in the second year of the Theatine curriculum, supplemented with further material.

Guarini's three architectural publications, however, belong to a different category. The *Modo di misurare le fabriche* (Turin, 1674), the *Trattato di fortificatione* (Turin, 1676), and the posthumous *Architettura civile* (Turin, 1737) are also works of "mixed" mathematics, yet they clearly sought a larger audience than his scholarly books, since they were written in the vernacular. Like Pozzo's perspective treatise, they straddle academic and practical genres. The *Modo di misurare* (a handbook for *stimatori* or construction surveyors) includes a mini-odometer for measuring irregular surfaces such as those of vaults (Fig. 7), demonstrating Guarini's interest in mathematical instruments and their applications. Although the principle can be traced back to Vitruvius, and larger odometers were commonly used for surveying land, Guarini apparently thought this application deserved wider dissemination.

Of the five *trattati* comprising Guarini's *Architettura civile*, only the third conforms more or less to the traditional structure and content of architectural treatises on the orders. The other four sections are overwhelmingly mathematical in character, presenting geometric axioms, surveying principles, mensuration, instructions for constructing geometric figures with straightedge and compass, and the basics of stereotomy. Indeed, if Guarini's mathematical understanding of architecture is intuitively visible in his domes, and explicitly stated in his treatise, it is almost palpable in his drawings. A plan for the Palazzo Carignano in Turin—pitted with scoring, compass pricks, and construction lines—captures him in the process of design, "thinking" with straightedge and compass (Fig. 8).

Guarini's Theatine colleague Girolamo Vitale (1624–1698) is the last of our six examples. A friend of Guarini's since 1640—they were novices together at San Silvestro al Quirinale in Rome—Vitale was not a practitioner and played little or no role in the construction of any buildings for the order. Nonetheless, Vitale arrived at architectural theory through mathematics, conceiving the second edition of his *Lexicon mathematicum* (Rome, 1690) as a dictionary of pure and applied mathematics.[35] Approximately a third of the entries treat the vocabulary of civil and military architecture, and several of these are illustrated with plates (Fig. 9). The *Lexicon*

Fig. 7 Handheld odometer (From Guarini 1674, 48)



presents an updated treatment of common architectural topics for readers, citing standard architectural writers like Vitruvius, Alberti, Barbaro, Palladio, Serlio, and Vignola as well as more recent authors such as Bernardino Baldi and Gioseffe Viola-Zanini. In addition to examples from antiquity, Vitale uses contemporary buildings to illustrate his points. St. Peter's and Bernini's colonnade in Rome make appearances, as do many churches from the counter-reformational orders: Sant'Andrea della Valle, Santa Maria in Vallicella, the Gesù, Sant' Ignazio and Sant'Andrea al Quirinale, all in Rome, and Santi Apostoli and San Paolo Maggiore in Naples.[36] The prominent position of architecture in Vitale's *Lexicon* demonstrates the broad definition of mathematics supported by the counter-reformational orders, a definition that included both architectural theory and practice.

Architecture, Science, and Vocation

As Steven Harris has argued, for these priest-architects, the intellectual and the spiritual were inseparable. Architecture, too, was part of this mix. An example involving both Guarini and Vitale illuminates this interplay. Vitale's *Viaggio al cielo di S. Gaetano Thiene* (Rome, 1671) documents a novena marking the 1671 canonization of San Gaetano, cofounder of the Theatine order. Each day of the novena—a nine-day cycle of prayers and devotions—was named after a heavenly body, and traced events in Gaetano's saintly life as stages on his way to heaven and canonization.

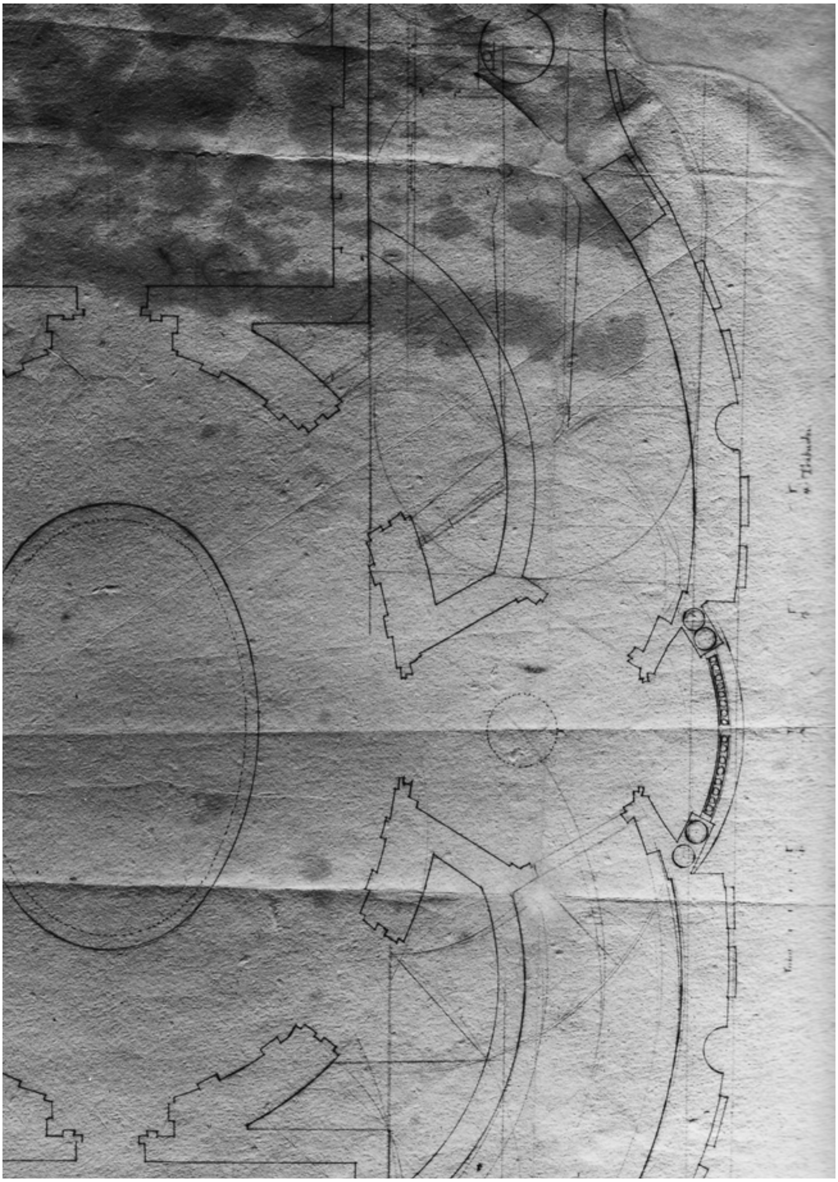
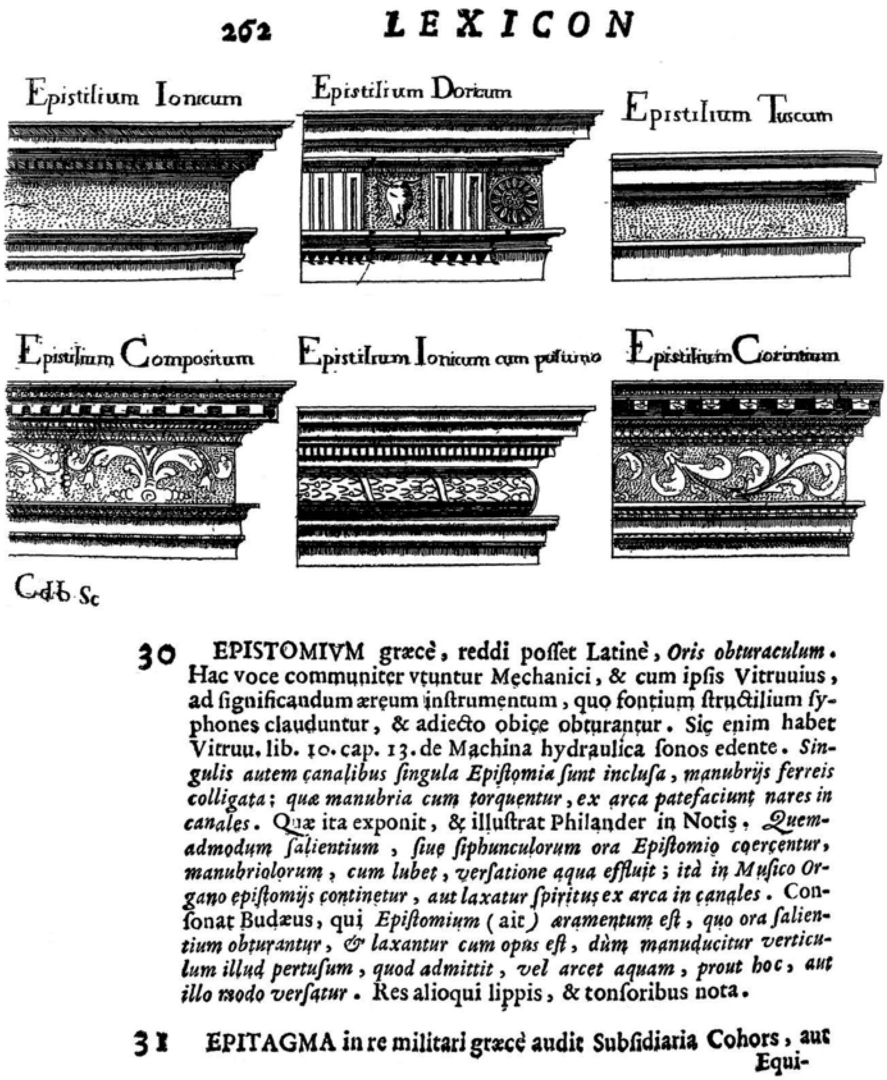


Fig. 8 Guarino Guarini, study for Palazzo Carignano, Archivio di Stato di Torino, Azienda Savoia-Carignano, cat. 53, mazzo 1, fasc. 9, n. 30 r, detail in raking light



262 LEXICON

Epistilium Ionicum

Epistilium Doricum

Epistilium Tuscum

Epistilium Compositum

Epistilium Ionicum cum pulvino

Epistilium Corintium

Cdb Sc

30 EPISTOMIVM græcè, reddi poſſet Latinè, *Oris obturaculum*. Hac voce communiter vtuntur Mechanici, & cum ipſis Vitruuius, ad ſignificandum æreum inſtrumentum, quo fontium ſtructilium ſyphones clauduntur, & adiecto obice obturantur. Sic enim habet Vitruu. lib. 10. cap. 13. de Machina hydraulica ſonos edente. *Singulis autem canalibus ſingula Epiſtomia ſunt incluſa, manubrijs ferreis colligata; quæ manubria cum torquentur, ex arca patefaciunt nares in canales*. Quæ ita exponit, & illuſtrat Philander in Notis, *Quemadmodum ſalientium, ſiue ſiphunculorum ora Epiſtomio coercentur, manubriolorum, cum lubet, verſatione aqua effluit; ità in Muſico Organo epiſtomijs continetur, aut laxatur ſpiritus ex arca in canales*. Conſonat Budæus, qui *Epiſtomium* (ait) *aramentum eſt, quo ora ſalientium obturantur, & laxantur cum opus eſt, dùm manuducitur verticulum illud pertuſum, quod admittit, vel arcet aquam, prout hoc, aut illo modo verſatur*. Res alioqui lippis, & tonſoribus nota.

31 EPITAGMA in re militari græcè audit Subſidiaria Cohors, aut Equi-

Fig. 9 Plate illustrating entry "Epistilium," (From Vitale 1690, 262)

The frontispiece visualizes this process: San Gaetano rises toward heaven, indicated by a Ptolemaic diagram of planetary orbits above (Fig. 10). The novena and this image seem to have inspired Guarini's design for the unexecuted church of San Gaetano in Vicenza (1675), in which the angel-borne saint rises from the altarpiece to a frescoed representation of heaven in the dome (Fig. 11). Vitale may have

Fig. 10 Teresa del Po, engraved frontispiece of Vitale (1671)

intended the connection between the devotion and this iconography. He claimed that his novena presented a view of San Gaetano that was "foreshortened and in perspective," much in the same way that the saint would appear in the altarpiece and the frescoed dome of Guarini's church, and probably to be surrounded by the same astronomical references. Here, devotion is inextricably intertwined with astronomy, perspective and architecture, central aspects of the priests' work in mathematics and mathematical natural philosophy.[37]

Such references were by no means unusual. Vitale and Guarini were building on a deeply ingrained tradition of visual and spiritual allegory coupled with mathematical practice. A half century earlier, Mazenta's Milanese water column designs united architecture, mechanics, and hydraulics with the iconography of the Holy Cross and Moses' staff. Orazio Grassi had used a similar metaphor to link the use of mathematical instruments with religious belief, when he compared the salvation of the soul entrusted to the Virgin Mary (here in the roll of *Stella Maris*) with the salvation of the navigator who relies on his measurement of the heavens.[38] Although this particular example does not involve architecture, the metaphor reveals the mentality of the priest-mathematicians who sought to reconcile the methods and results of their scientific pursuits with their religious vocations. Pozzo, too, employed such rhetoric in the preface of his perspective treatise. "My Advice," he addressed his readers, "is that you chearfully begin your Work with a Resolution to draw all the Points thereof to that true Point, the Glory of GOD…."[39]

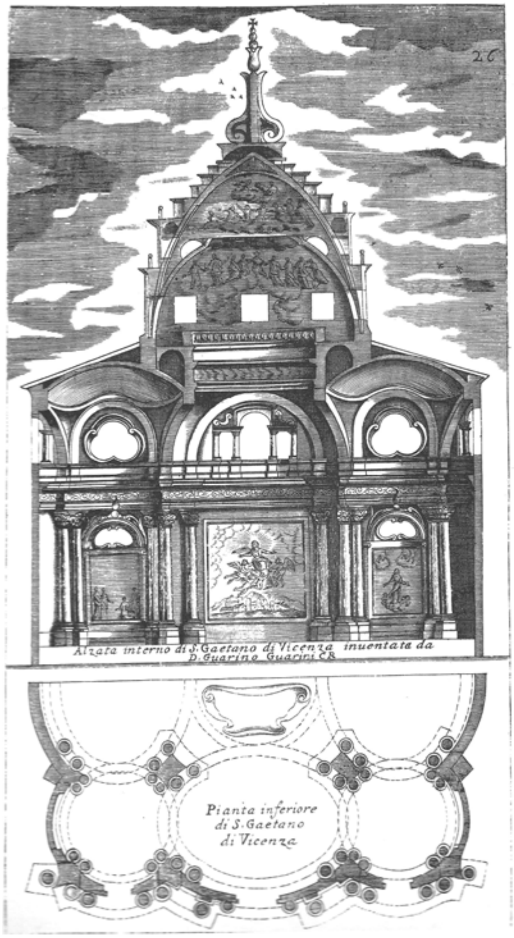


Fig. 11 Section and half-plan of San Gaetano, Vicenza (From Guarini 1686, Plate 26)

The work of both Grassi and Pozzo spanning the Seicento in Rome focuses our attention on the incubator of the priest-mathematician-architect phenomenon: the Collegio Romano, with its associated church of Sant'Ignazio, stood at the center of this development throughout the century. They—along with the activities pursued inside the complex—form a "unified cultural field," as Joseph Connors has termed it (adapting Bourdieu), asking: "Will we be able one day to look at Pozzo's frescoes, Kircher's museum, the distillery, and the mathematics classes and see their interaction? Will Grassi's architecture and his astronomy ever be studied together?"[40] The understanding of architecture as a part of mathematics arose from this cultural field. Embodied in the *consiliarus aedificiorum* and combined with the recognition of the utility of architecture in realizing the order's aims, it permeated not only the entire Jesuit order, but also most other counter-reformational orders during the course of the seventeenth century.

Most priests who benefited from the orders' architectural-mathematical education had undistinguished careers and thus remain largely unknown. Serving as building superintendents, local consultants, or occasional designers, their individual contributions may have been modest, but their cumulative effect was nonetheless important. Consider, for example, the Theatine Antonio Spinelli (1630–1706), provost of the order's Munich house, who discovered a serious error during the construction of the Munich Theatinerkirche. Spinelli replaced the secular architect Agostino Barelli as construction supervisor and went on to design the Theatine library in Munich.[41] On the other hand, the mathematical culture of the orders also produced authors like Eschinardi or Vitale, who apparently considered themselves qualified to publish works of architectural theory despite little or no practical experience as architects. Such scholars remain relatively unknown in the history of architecture, as does the impact of their writings on the wider reception of the art, defined no longer as a trade but as an object of formal study and quasi-scholarly discipline. The Savoyard Jesuit Claude-François Milliet Dechales (1621–1678), for example, was a prolific and widely translated author on mathematical topics. His encyclopedic *Cursus seu mundus mathematicus* (Lyon, 1674) aimed to provide a complete mathematical course of instruction, eliminating, in the process, the confusion caused by reliance on many different authors.[42] The 31 chapters of the work cover all aspects of mathematics, from Euclid and trigonometry to pyrotechnics and astronomy. Four are devoted to architecture, pointing again to the subject's consolidation within the Jesuit mathematical curriculum by the second half of the century.

But what separated a major priest-architect like Guarini from a competent priest serving as a local building superintendent, apart from the elusive quality "talent"? In his treatise, Guarini affirms that architecture, "as a discipline which utilizes measurements in all of its operations, depends on geometry." But the statement is quickly qualified: "architecture, even if it depends on mathematics, nonetheless is a flattering art, which does not offend the senses in order to satisfy reason." For Guarini, architecture's reliance on mathematics is interdependent with the pleasure it gives the senses. He thus qualifies it as both an art as well as a branch of mathematical science.[43] Here we reach the limits of what "mixed mathematics" could offer seicento architects.

It was perhaps inevitable that the tradition, as it continued into the next century, would be transformed. The orders continued to produce priest-practitioners in the mold of a Grassi or Guarini. The Somaschan priest Francesco Vecelli (1695–1759) provides a case in point. As the librarian at Santa Maria della Salute in Venice and later *preposito generale* of his order, he designed two Somaschan churches: Sant'Agostino, Treviso and Santa Croce, Padova, as well as the libraries of the Salute and the Camaldolesi on Mattia near Murano.[44] But over the course of the eighteenth century, the relationship between architecture and mathematics within the orders gradually merged with a modern understanding of engineering. The Jesuit scientist and polymath Roger Boscovich (1711–1787), professor of mathematics at the Collegio Romano was brought in to consult on structural problems at the dome of St. Peter's. The Barnabites Francesco De Regi (1720–1794) and Paolo Frisi (1728–1784) similarly advised on engineering questions at Milan Cathedral and the sanctuary at Rho. They published on mathematics and engineering education, statics, and Gothic architecture.[45]

A distinct architectural culture emerges from this survey. It was, in the first place, international, the European and global expansion of the orders acting to spread this culture far and wide. It was also comprehensive, addressing both theory and practice within the orders' programs of mathematical education. On both levels, the historical consequences of this culture were profound. Although the orders were not "schools of architecture" in any strict sense, the training they offered their members can nonetheless be viewed as an early kind of professional architectural education. Oriented to lecture hall rather than the building site, this form of instruction predated the foundation of various architectural academies in the late Seicento. On a physical level, too, the orders' architectural impact was considerable. Priest-architects provided designs for churches and houses for their orders all across Europe, particularly in smaller provincial towns. Like the Jesuit complex of San Vigilio in Siena—built by a succession of Jesuit architects including Grassi and Pozzo—such buildings shaped substantial portions of the fabric of early modern cities. Priest architects attracted noble patronage as well. Working in the "court apostolate," gifted architects like Mazenta or Guarini built churches outside of their orders as well as secular buildings and even fortifications. The orders' mathematical-architectural culture thus nurtured a rich variety of architects ranging from pure theoreticians through competent builders in the early modern vernacular idiom all the way to—in the exceptional case of Guarini—a master of the Baroque.

Notes

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1. "essi Padri…sono anche buoni Mathematici et intendono anche l'Architettura…," Quoted in Gallo (1958–59, 120).
2. For a survey of architecture in the counter-reformational orders in Italy, see Bösel (2003).
3. The literature on seventeenth-century Jesuit science and education is extensive. See for example the following recent contributions for further bibliography: Harris (1996); O'Malley et al. (1999–2006); and Feingold (2003a). The literature on Theatine and Barnabite science is paltry by comparison, but see Masetti-Zannini (1967) and Bianchi (1993). On early modern science in Rome, see now Romano (2008).
4. This phenomenon was by no means an invention of the seventeenth century. Renaissance priest-architects with mathematical or engineering backgrounds include the Franciscan Fra Giovanni Giocondo (1433–1515) and the Dominicans Danti (1536–1586), and Giuseppe Donzelli. The latter, known as "Fra Nuvolo", was active in Naples from c.1600 to 1630. The Augustinian

Giovanni Maria da Bitonto (1586-?) excelled at perspective constructions, such as the high altar tabernacle of the Barnabites' San Paolo in Bologna or the perspective colonnade at Palazzo Spada in Rome, where he worked with Borromini. For further details and bibliography on these and other figures, see Klaiber (1993, 43–46).

5. The 1586 edition was solely for internal use in the order; the first public edition dates from 1599. All editions also outlined the order's educational programs for secular students. On the *Ratio studiorum*, see Pachtler (1887–1894) and Lukács (1965–1992, esp. vol. 5, *Ratio atque institutio studiorum Societatis Iesu*).
6. See the Theatines' *Constitutiones congregationis clericorum regularium* (1604) with many subsequent editions; the Barnabites' *Constitutiones clericorum regularium S. Pauli decollati* (1617), and Gorini (1666).
7. To some extent the comments here on the Theatines and Barnabites proceed by analogy with the Jesuits, given the relative lack of research on their educational systems and scientific enterprises in comparison with the larger order. When appropriate material for comparison is available, however, the similarities between the three orders are confirmed (perhaps also due to the Theatines and Barnabites modelling themselves on the successful Jesuits).
8. Pachtler (1887–1894, vol. 2, 256, 348). For an exhaustive account of the early evolution of the Jesuit mathematical curriculum, see Romano (1999). On the practice of Jesuit mathematical education, see de Dainville (1954); Cosentino (1970, 1971); and Baroncini (1981). Compare also Dear (1995, ch. 2).
9. On the Jesuits and military architecture, see now De Lucca (2012).
10. Harris (1989, 42, note 23).
11. Gorman (2003). Grienberger was the first professor of mathematics at the Collegio Romano to serve as *consiliarus aedificiorum*, and he himself designed a few buildings for the order: the college at Aurillac and Santo Spirito in Sora, see ibid., p.70. For the attribution of the latter church, see Bösel and Karner (1986–2007, vol. 1, 294–295).
12. Cited in Gorman (2003, 23, 71, and 109, n. 96).
13. Possevino (1593). On Possevino and mathematics, see Romano (1999, 146–153). On Possevino and architecture, see Tessari (1983); Balestreri (1990); McQuillan (1992); Kiene (1996); Oechslin (1999, 213–214); and Carpo (2001, 113–118).
14. "De Architectura, post principes Mathematicas disciplinas dicen dum est, quandoquidem illę ab his pendent, earumq. ductu perficiuntur," Possevino (1593, vol. 2, 207). Possevino's architectural chapters are titled: "Architecturae origo. Cap. XVI", "An Aedificandi ratio peti debeat ex uno Vitruvio. Num item ex Salomonici Templi, quae olim extabat structura. Cap. XVII", and "Architecturae partes, atque divisio: Quaenam spectanda priusquàm aedificia inchoëntur, praesertim ea quae ad viros religiosos attinent. Cap. XVIII"
15. The inventories are found in Vat. Lat. 11267 (Theatines) and 11300 (Barnabites), Biblioteca Apostolica Vaticana, Rome. They belong to a group of such inventories catalogued (but not transcribed) in Lebreton and Fiorani (1985). Janis Bell kindly informed me of the existence of these MSS. Jesuit libraries were not

included in the group of inventories, and other orders (for instance the Padri Somaschi and the Cappuccini, Vat. Lat. 11275 and 11326 respectively) had no notable holdings of architectural books at the time. For the books listed here, see Vat. Lat. 11267, fols. 25v, 134r, 167r, 183r, 412r, 489r and Vat. Lat. 11300, fols. 89v, 95v, 109v, 113r, 120v, 133v, 134r, 136v, 157v, 165r, 166r.

16. On the *consiliarus aedificiorum* and for the Jesuit plan collection, see Vallery-Radot (1960, 8*–11*). For a list of the mathematics professors at the Collegio Romano see Villoslada (1954, 335). According to my own count, identifiable architectural activity—architectural designs, significant work as a consultant or building superintendent, or authorship of architectural publications—can be attributed to approximately 8 out of these 34 professors of mathematics at the Collegio Romano between 1553 and 1773, beyond their usual responsibilities as *consiliarus aedificiorum*. Finally, the work of Richard Bösel is fundamental for any consideration of Jesuit architecture: Bösel and Karner (1986–2007).
17. On the Barnabite office of the *prefetto delle fabriche* and the practice of architecture within the Barnabite order, see Repishti (1991), Gauk-Roger ([1991]); and Gatti Perer and Mezzanotte (2002).
18. Harris (1989, 48–49).
19. Harris (1989, 42 and n. 23).
20. Harris (1989, 60).
21. Harris (1989, 56).
22. For the Cinquecento, see note 4, above. Important seventeenth-century figures not mentioned in this study include the Jesuits Étienne Martellange (1569?–1641), a lay brother, the priest François Derand (1588–1644), and the Belgian François d'Aiguillon (1567–1617). For further information and bibliography on these men, see Klaiber (1993, 40–42, 67, notes 72–75). Among the Italian Theatines, Bernardo Castagnini (*ca*. 1603–1658) was one of Guarini's architectural mentors; the two men worked together at San Vincenzo, Modena in the early 1650s. Castagnini presented a design for the *casa* at San Vincenzo in 1646; at least one corridor and the library seem to have been completed to his design. He had earlier worked on a remodelling at San Bartolomeo, Bologna, begun in 1632. Documents describing this campaign refer to the priest and another Theatine involved with the project as "assai intendente delle matematiche," again stressing the connection between mathematical knowledge and architectural or engineering skill. See Sandonnini (1890). On Castagnini's work in Bologna, see Ravaglia (1909). The early Barnabite Pier Paolo D'Alessandro (1514–1591) built the cupola and upper loggia at Santa Maria di Canepanova, Pavia, and left manuscripts on painting, architecture, "poesia," and mathematics. See Boffito (1933–1937, vol. 1, 19–20), and Scotti (1985).

    Spanish priest-mathematician-architects include the Cistercians Juan Caramuel de Lobkowitz (1606–1682) and his teacher, Angel Manrique (1577–1649), Bishop of Badajoz. On Caramuel, see Filippo Camerota in the present volume (A Scientific Concept of Beauty in Architecture: Vitruvius Meets Descartes, Galileo, and Newton). A Spanish Augustinian, Fray Lorenzo de San Nicolás (1595–1679), wrote *Arte y uso de architectura*, 2 vols., (Madrid, 1639–1664), a treatise which emphasized the role of arithmetic and geometry in architecture and, significantly, contained Spanish translations of Euclid's fifth and seventh books. A second edition of Fray Lorenzo's first volume, published in 1667, added a translation of Euclid's first book, which then appeared in all subsequent editions. Fray Lorenzo also enjoyed a prolific career as an architect, building several churches throughout Spain. See Thieme and Becker (1929, vol. 23, 393); and de Llaguno y Amirola (1829, vol. 4, 20–26).

23. See, for example, the contemporary descriptions of Guarini's career in Klaiber (1993, 1–3).
24. On Tristano, see Pirri (1955); Bösel and Karner (1986–2007, vol. 1, 129–133, 164–165, 181–182, 212–213). On De Rosis: Pirri and Di Rosa (1975); Bösel (1991). On Valeriano, see Pirri (1970); and Bösel (1996).
25. Grimaldi is best known for the order's Sant'Andrea della Valle, Rome (begun 1591) where he worked with Giacomo della Porta under the patronage of Cardinal Alfonso Gesualdo. Most of Grimaldi's works survive in Naples however, including three Theatine churches and the Cappella del Tesoro di San Gennaro in the cathedral. Unfortunately, the details of Grimaldi's architectural training remain obscure, and no publications by him are known. On Grimaldi, see Savarese (1986) and Hibbard (1961).
26. On Grassi, see Bösel (2004), with complete further bibliography.
27. For an illustrated catalogue of Grassi's Roman album, see Bösel (2004, 59–310). On Grassi and Galileo, see for instance P. Redondi (1987) and the recent reassessment in Feingold (2003b).
28. This work appeared under the title *Espositione della carte topographica Cingolana dell'agro romano* (Rome, 1696). Eschinardi also taught at the Collegio Inglese and was therefore well-known to English travelers in Rome, including early members of the Royal Society. On Eschinardi, see Middleton (1966, 54–55); Muccillo (1993); Payne (1999, 157, 167); Cook (1999, esp. 180); and Cook (2004). On Eschinardi's *Cursus physicomathematicus* see Feldhay and Heyd (1989). For Eschinardi and the Jesuit church at Vercelli, see Bösel and Karner (1986–2007, vol. 2, 411–424); for a further example of his work as a consultant (at Pozzo's Cappella di Sant'Ignazio in the Gesù, Rome) see Levy (2004, 235 n.21).
29. On this academy, see Middleton (1975).
30. On Pozzo, see the following recent works, including older bibliography: De Feo and Martinelli (1996); Battisti (1996). A convenient summary of Pozzo's architectural work is provided by Kelly (1982). Also see Andersen's contribution in this volume (The Master of Painted Architecture: Andrea Pozzo, S. J. and His Treatise on Perspective).
31. Here quoted from the first English edition, Pozzo (1707; reprint 1989, 206).
32. On the Accademia degli Accurati, see Grammatica (1919, 14). Further on Mazenta, see. Mezzanotte (1961); Gatti Perer and Mezzanotte (2002) both with earlier bibliography, and now Stabenow (2011). On Mazenta's writings, see Boffito (1933–1937, vol. 2, 451–463). On the monumental columns for Milan, see Schofield (2004, 79–120, esp. 92–94).
33. For the most recent overview of Guarini's career, see Dardanello et al. (2006), with a complete bibliography of earlier studies.

34. Bianchi (1768, 108).
35. On Vitale and his *Lexicon* see Vezzosi (1780, vol. 2, 481–484); Masetti-Zannini (1967); and now Rabassini (2012). In the preface to the second edition Vitale himself criticized the much shorter first edition of his work (Paris: Ludovic. Billaine, 1668).
36. Vitale also mentions the Roman churches Sant'Agnese, Santa Maria della Pace, Santa Maria degli Angeli, and San Pietro in Montorio; villas at Frascati and Caprarola; and a prominent non-Italian example, Hagia Sophia.
37. See Klaiber (2006).
38. Bösel (2004, 24–25).
39. [*sic*]: the Latin gives "lineas" for "point". See Pozzo (1707; reprint 1989, 12).
40. Connors (1999–2006).
41. On Spinelli, see Dischinger (1988, vol. 1, 141–42, 145–46); and Klaiber (1993, 36, 64 n. 60).
42. Claretta (1878, vol. 2, 585), referring to a 1674 letter from Dechales to the duke. On Dechales, see Dainville (1947–1948); De Backer et al. (1890–1932, vol. 2, cols. 1040–44).
43. Guarini (1737, I.ii, I.iii.intro, 3).
44. See Pilo (1964). Vecelli's manuscript "Problemi di geometria pratica," dealing with geometry and fortifications, survives in a posthumous copy (1767) at the University of Pennsylvania.
45. For Boscovich, see the article by Pascal Dubourg Glatigny in this volume (Epistemological Obstacles to the Analysis of Structures: Giovanni Bottari's Aversion to a Mathematical Assessment of Saint-Peter's Dome (1743)). For De Regi and Frisi, see Boffito (1933–1937, on De Regi: vol. 1, 640–644; on Frisi, vol. 2, 72–98). Also see Baldini (1998) and A. Bianchi (1993, 143–164).

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References

Baldini, Ugo. 1998. Paolo Frisi. Dizionario Biografico degli Italiani. http://www.treccani.it/biografie.
Balestreri, Isabella. 1990. L'architettura negli scritti della Compagnia di Gesù. In *L'architettura della Compagnia di Gesù in Italia XVI-XVIII sec*, ed. L. Patetta, I. Balestreri, C. Coscarella, and D. Zocchi, 19–26. Brescia: Grafo.

Baroncini, G. 1981. L'insegnamento della filosofia naturale nei collegi italiani dei Gesuiti (1610–1670): un esempio di nuovo aristotelismo. In *La "Ratio studiorum": Modelli culturali e pratiche educative dei Gesuiti in Italia tra Cinque e Seicento*, ed. G.P. Brizzi, 192–202. Rome: Bulzoni.
Battisti, Alberta (ed.). 1996. *Andrea Pozzo*. Milan-Trent: Luni.
Bianchi, Ignazio Lodovico. 1768. *Le immagini di alcuni uomini e alcune donne per pietà illustri della Congregazione de'cherici regolari*. Venice.
Bianchi, A. 1993. *L'instruzione secondaria tra barocco ed età dei lumi: Il Collegio di San Giovanni alle Vigne di Lodi e l'esperienza pedagogica dei Barnabiti*. Milan: Vita e Pensiero.
Boffito, G. 1933–1937. *Scrittori Barnabiti*. Florence: Olschki.
Bösel, Richard. 1991. Giovanni De Rosis. Dizionario Biografico degli Italiani. http://www.treccani.it/biografie.
Bösel, Richard. 1996. Giuseppe Valeriano. Oxford Art Online. www.oxfordartonline.com.
Bösel, Richard. 2003. L'architettura dei nuovi ordini religiosi. In *Storia dell'architettura italiana: Il Seicento*, vol. 1, ed. A. Scotti Tosini, 48–69. Milan: Electa.
Bösel, Richard. 2004. *Orazio Grassi architetto e matematico gesuita*. Rome: Argos.
Bösel, Richard, and Herbert Karner. 1986–2007. *Jesuitenarchitektur in Italien 1540–1773*. Vienna: Österreichische Akademie der Wissenschaft.
Carpo, Mario. 2001. *Architecture in the age of printing*. Cambridge, MA: MIT Press.
Claretta, G. 1878. *Storia del regno e dei tempi di Carlo Emanuele II duca di Savoia*. Genoa: R. Istituto de'sordo-muti.
Connors, Joseph. 1999–2006. Reflections. In *The Jesuits: Cultures, sciences, and the arts 1540–1773*, 2 vols., ed. J.W. O'Malley, G.A. Bailey, S.J. Harris, and T.F. Kennedy, 1, 705–706. Toronto: University of Toronto Press.
Constitutiones clericorum regularium S. Pauli decollati. 1617. Milan: Apud hær. Pacifici Pontij, & Ioan. Baptistam Piccaleum.
Constitutiones congregationis clericorum regularium. 1604. Rome: Stefano Paulini.
Cook, Alan. 1999. Our foreign correspondence. *Notes and Records of the Royal Society of London* 53(2): 179–182.
Cook, Alan. 2004. Rome and the Royal Society 1660–1740. *Notes and Records of the Royal Society of London* 58(1): 3–19.
Cosentino, G. 1970. Le matematiche nella 'Ratio studiorum' della compagnia di Gesù. *Miscellanea storica ligure* n.s. 2(2): 169–213.
Cosentino, G. 1971. L'insegnamento delle mathematiche nei collegi gesuitici nell'Italia settentrionale. *Physis* 13: 205–217.
Dardanello, Giuseppe, Susan Klaiber, and Henry A. Millon (eds.). 2006. *Guarino Guarini*. Turin: Allemandi.
De Backer, Augustin, Aloys De Backer, and Carlos Sommervogel. 1890–1932. *Bibliothèque de la compagnie de Jésus*, 10 vols. Brussels/Paris: Schepens/Picard.
de Dainville, François. 1947–1948. Foyers de culture scientifique dans la France méditerranéenne du XVIe au XVIIIe siècle. *Revue d'histoire des sciences et de leurs applications* 1: 289–300.
de Dainville, François. 1954. L'enseignement des mathématiques dans les Collèges Jésuites de France du XVIe au XVIIIe siècle. *Revue d'histoire des sciences* 7, 8: 6–21, 109–123.
De Feo, Vittorio, and Valentino Martinelli (eds.). 1996. *Andrea Pozzo*. Milan: Electa.
de Llaguno y Amirola, Eugenio. 1829. *Noticias de los arquitectos y arquitectura de España desde su restauración*. Madrid: En la Imprenta Real.
De Lucca, Denis. 2012. *Jesuits and fortifications: The contribution of the Jesuits to military architecture in the Baroque Age*. Leiden: Brill.
de San Nicolás, Lorenzo. 1639–1964. *Arte y uso de architectura*. Madrid.
Dear, Peter. 1995. *Discipline and experience: The mathematical way in the scientific revolution*. Chicago: University of Chicago Press.
Dischinger, Gabriele. 1988. *Zeichnungen zu kirchlichen Bauten bis 1803 im Bayerischen Hauptstaatsarchiv*. Wiesbaden: Reichert.
Eschinardi, Francesco [pseud. Costanzo Amichevoli]. 1675. *Architettura civile, ridotta a metodo facile e breve*. Terni: B. Arnazzini.

Eschinardi, Francesco [pseud. Costanzo Amichevoli]. 1684. *Architettura militare, ridotta a metodo facile e breve col modo distinto di formare ciascuna parte*. Rome: A. Bernabò.

Eschinardi, Francesco [pseud. Costanzo Amichevoli]. 1696. *Espositione della carte topographica Cingolana dell'agro romano*. Rome.

Feingold, Mordechai (ed.). 2003a. *The new science and Jesuit science: Seventeenth century perspectives*. Dordrecht: Kluwer.

Feingold, Mordechai. 2003b. The grounds for conflict: Grienberger, Grassi, Galileo, and Posterity. In *The new science and Jesuit science: Seventeenth century perspectives*, ed. Mordechai Feingold, 121–157. Dordrecht: Kluwer.

Feldhay, R., and M. Heyd. 1989. The discourse of pious science. *Science in Context* 3(1): 109–142.

Gallo, R. 1958–59. Vincenzo Scamozzi e la chiesa di S. Nicolò da Tolentino di Venezia. *Atti dell'Istituto veneto di scienze, lettere ed arti: Classe di scienze morali e lettere* 117: 103–122.

Gatti Perer, M.L., and G. Mezzanotte. 2002. Lorenzo Binago e la cultura architettonica dei Barnabiti. *Arte Lombarda* [special issue] 134.

Gauk-Roger, N. The architecture of the Barnabite Order 1545–1659, with special reference to Lorenzo Binago and Giovanni Ambrogio Mazenta. Ph.D. dissertation, Cambridge [1991].

Gorini, M. 1666. *Exterarum scholarum disciplina apud clericos regulares S. Pauli…*. Milan: Francesco Vigoni.

Gorman, Michael John. 2003. Mathematics and modesty in the Society of Jesus: The problems of Christoph Grienberger. In *The new science and Jesuit science: Seventeenth century perspectives*, ed. Mordechai Feingold, 1–120. Dordrecht: Kluwer.

Grammatica, Luigi. 1919. *Le memorie su Leonardo da Vinci di Don Ambrogio Mazenta*. Milan: Alfieri e Lacroix.

Guarini, Guarino. 1674. *Modo di misurare le fabriche*. Turin: Heredi Gianelli.

Guarini, Guarino. 1686. *Dissegni d'architettura civile, et ecclesiatica*. Turin: Paulino.

Guarini, Guarino. 1737. *Architettura civile*. Turin: Gianfrancesco Mairesse.

Harris, S.J. 1989. Transposing the Merton thesis: Apostolic spirituality and the establishment of the Jesuit scientific tradition. *Science in Context* 3(1): 29–65.

Harris, S.J. 1996. Jesuits and the knowledge of nature. *Early Science and Medicine* [special issue] 1(3).

Hibbard, Howard. 1961. The early history of Sant'Andrea della Valle. *Art Bulletin* 43: 289–311.

Kelly, C. 1982. Pozzo, Andrea. In *Macmillan encyclopedia of architects*, 4 vols., ed. Adolf K. Placzek, 3, 469–472. New York: Macmillan.

Kiene, M. 1996. Bartolomeo Ammannati et l'architecture des jésuites au XVIe siècle. In *Les jésuites à l'âge baroque (1540–1640)*, ed. L. Giard and L. de Vaucelles, 183–206. Grenoble: J. Millon.

Klaiber, Susan. 1993. Guarino Guarini's Theatine architecture. Ph.D. dissertation, Columbia University.

Klaiber, Susan. 2006. L'iconografia di San Gaetano nel progetto per Vicenza. In *Guarino Guarini*, ed. Giuseppe Dardanello, Susan Klaiber, and Henry A. Millon, 404–411. Turin: Allemandi.

Lebreton, M., and L. Fiorani. 1985. *Codices Vaticani Latini: Codices 11266–11326, Inventari di biblioteche religiose italiane alla fine del cinquecento*. Vatican City: Bibliotheca Vaticana.

Levy, Evonne. 2004. Das 'Jesuitische' der jesuitischen Architektur. In *Die Jesuiten in Wien: Zur Kunst- und Kulturgeschichte der österreichischen Ordensprovinz der "Gesellschaft Jesu" im 17. und 18. Jahrhundert*, ed. H. Karner and W. Telesko, 231–241. Vienna: Österreichische Akademie der Wissenschaften.

Lukács, L. (ed.). 1965–1992. *Monumenta paedagogica Societatis Iesu*, 7 vols. Rome: apud "Monumenta Historica Soc. Iesu".

Masetti-Zannini, G.L. 1967. I Teatini, la nuova scienza e la nuova filosofia in Italia. *Regnum Dei* 23(89–90): 3–150.

McQuillan, James. 1992. Antonio Possevino's 'Architectura' and the Baroque. *Scroope: Cambridge Architecture Journal* 4: 45–50.

Mezzanotte, G. 1961. Gli architetti Lorenzo Binago e Giovanni Ambrogio Mazenta. *L'arte* 26: 231–271.

Middleton, W.E. Knowles. 1966. *A history of the thermometer*. Baltimore: Johns Hopkins University Press.

Middleton, W.E. Knowles. 1975. Science in Rome, 1675–1700, and the Accademia Fisicomatematica of Giovanni Giustino Ciampini. *British Journal for the History of Science* 8: 138–154.

Muccillo, Maria. 1993. Francesco Eschinardi. Dizionario Biografico degli Italiani. http://www.treccani.it/biografie.

O'Malley, J.W., G.A. Bailey, S.J. Harris, and T.F. Kennedy (eds.). 1999–2006. *The Jesuits: Cultures, sciences, and the arts 1540–1773*, 2 vols. Toronto: University of Toronto Press.

Oechslin, Werner. 1999. 'Architectura est scientia aedificandi': Reflections on the scope of architectural and architectural-theoretical literature. In *The triumph of the Baroque*, ed. H.A. Millon, 206–217. Milan: Bompiani.

Pachtler, G. 1887–1894. *Ratio Studiorum et Institutiones Scholasticae Societatis Jesu*, 4 vols. Berlin: A. Hofmann.

Payne, Alina A. 1999. Architectural criticism, science, and visual eloquence: Teofilo Gallaccini in seventeenth-century Siena. *Journal of the Society of Architectural Historians* 58(2): 146–169.

Pilo, G.M. 1964. Notizie sull'architetto somasco Francesco Vecelli. *Bollettino del Centro Internazionale di Studi d'Architettura Andrea Palladio* 6(1): 311–314.

Pirri, Pietro. 1955. *Giovanni Tristano e i primordi dell'architettura gesuitica*. Rome: Institutum Historicum S.J.

Pirri, Pietro. 1970. *Giuseppe Valeriano S.I., architetto e pittore 1542–1596*. Rome: Institutum Historicum S.J.

Pirri, Pietro, and Pietro Di Rosa. 1975. Il P. Giovanni de Rosis (1538–1610) e lo sviluppo dell'edilizia gesuitica. *Archivum Historicum Societatis Iesu* 44: 3–104.

Possevino, Antonio. 1593. *Bibliotheca selecta: qua agitur de ratione studiorum in historia, in disciplinis, in salute omnium procuranda. Cum diplomate Clementis VIII. Pont. Max*. Rome: Ex Typographia Apostolica Vaticana.

Pozzo, Andrea. 1693–1700, 2nd ed. 1702–1723. *Perspectiva pictorum et architectorum/Prospettiva de' pittori e architetti*. Rome: Typis Joannis Jacobi Komarek Bohemi apud S. Angelum Custodem.

Pozzo, Andrea. 1707; reprint New York: Dover, 1989. *Rules and examples of perspective proper for painters and architects, etc.* London: J. Senes, etc.

Rabassini, Andrea. 2012. Il lessicografo dell'astrologia. Note biografiche su Girolamo Vitale (1623/24-1698). *Bruniana & Campanelliana* 18(2): 675–681.

Ravaglia, E. 1909. Il portico e la chiesa di S. Bartolomeo in Bologna. *Bollettino d'arte* 3: 110–111.

Redondi, Pietro. 1987. *Galileo Heretic*. Trans. Raymond Rosenthal. Princeton: Princeton University Press.

Repishti, F. 1991. *Formula del offitio del Prefetto delle fabriche apresso delli Chierici Regolari della Congregazione di S. Paolo* secondo Lorenzo Binago. *Arte Lombarda* 96–97: 137–140.

Romano, Antonella. 1999. *La contre-réforme mathématique: constitution et diffusion d'une culture mathématique jésuite à la Renaissance (1540–1640)*. Rome: École Française de Rome.

Romano, Antonella (ed.). 2008. *Rome et la science moderne: entre Renaissance et Lumières*. Rome: École française de Rome.

Sandonnini, T. 1890. Il Padre Guarino Guarini modenese. *Atti e Memorie delle RR. Deputazioni di storia patria per le provincie modenesi e parmensi* ser. 3: 5, part 2: 491–492.

Savarese, Silvana. 1986. *Francesco Grimaldi e l'architettura della Controriforma a Napoli*. Rome: Officina Edizioni.

Schofield, Richard. 2004. Architecture and the assertion of the Cult of Relics in Milan's Public Spaces. *Annali di architettura* 16: 79–120.

Scotti, A. 1985. Tommaso [p. Pietro Paolo] D'Alessandro. *Dizionario biografico degli italiani*. http://www.treccani.it/biografie.

Stabenow, Jörg. 2011. *Die Architektur der Barnabiten: Raumkonzept und Identität in den Kirchenbauten eines Ordens der Gegenreformation 1600–1630*. Munich: Deutscher Kunstverlag.

Tessari, A.S. 1983. Antonio Possevino e l'architettura. *Archivum Historicum Societatis Iesu* 52: 247–261.

Thieme, Ulrich, and Felix Becker (eds.). 1907–50. *Allgemeines Lexikon der bildenden Künstler von der Antike bis zur Gegenwart*. Leipzig: Engelmann.

Trombelli, Giovanni Crisostomo. 1752. *Memorie istoriche concernenti le due canoniche di S. Maria di Reno, e di S. Salvatore insieme unite*. Bologna: per Girolamo Corciolani ed eredi Colli s. Tommaso d'Aquino.

Vallery-Radot, J. 1960. *Le recueil de plans d'édifices de la Compagnie de Jésus conservé à la Bibliothèque nationale de Paris*. Rome: Institutum Historicum S.I.

Vezzosi, A.F. 1780. *I scrittori de' Cherici Regolari detti Teatini*. Rome: Propaganda Fide.

Villoslada, R. Garcia. 1954. *Storia del Collegio Romano dal suo inizio (1551) alla soppressione della Compagnia di Gesù (1773)*. Rome: Apud aedes Universitatis Gregorianae.

Vitale, Girolamo. 1671. *Viaggio al cielo di S. Gaetano Thiene*. Rome: Ignatio de' Lazari.

Vitale, Girolamo. 1690. *Lexicon mathematicum*, 2nd ed. Rome: Vannacci.