Material Piety: Science and Religious Culture in Seventeenth-Century Portugal

NUNO CASTEL-BRANCO, *Max Planck Institute for the History of Science*

In seventeenth-century Lisbon, Jesuit mathematicians taught their students how to build blood-ejecting crucifixes and similar religious devices. Together with the activities of experts in the canonization of Isabel of Portugal and in other contexts, these situations represent rare instances in which religious devotion interacted directly with science. Informed by the histories of science, art, and religion, this essay argues that a piety centered on materiality fostered these scientific practices, which became religious ministries in themselves. This analysis brings new light to lasting debates on science and religion and to the purpose of practicing science in the early modern period.

INTRODUCTION

IN 1617, GIOVANNI Paolo Lembo (1570–1618), the Italian Jesuit famously known for building one of the first copies of Galileo's telescope, taught his mathematics students in Lisbon how to transform small hydraulic devices into crucifixes. These crucifixes ejected red-colored water to look as if blood was coming from the wounds of Christ. Some years later, the Flemish Jesuit Hendrick Uwens (1618–67) also taught in Lisbon how wheels and axles could be used in theaters for representing the Passion of Christ.[1] That Jesuit priests were well versed in early modern mathematics is no novelty. Neither is the fact that seventeenth-century devotions—like those to the Passion of Christ—relied on a sensuous appeal typical of Baroque art. But why would Jesuit mathematicians use religious imagery in a mathematics classroom?

This article benefited much from the advice of many scholars and friends. I am especially thankful to Stephen Campbell, Leonor Castel-Branco, Henrique Leitão, Gianna Pomata, María Portuondo, Lawrence Principe, Erin Rowe (and those at the 2018/19 Iberian seminar at Johns Hopkins University), and Jessica Wolfe, who all read previous versions of this article, sometimes more than once. Research in Portugal and Rome was supported by the Charles Singleton Center for the Study of Premodern Europe.

[1] Given the context, these were most likely school theaters: see Shore, 359–66.

Renaissance Quarterly 74 (2021): 1162–209
doi: 10.1017/rqx.2021.199

What was their intention? In this essay, I argue that answers to these questions can be found in the devotional life of Jesuit mathematicians in seventeenth-century Portugal. The specific classes of Lembo and Uwens, and the institution in which they took place—the Jesuit Royal Academy of Mathematics in Lisbon, also known as the Class of the Sphere—present rare instances where the religious life of Jesuit priests interacted directly with their scientific activities. The careful study of these encounters between science and devotional practice contributes to long-lasting debates about science and religion and, more importantly, to broader inquiries into the very purpose of practicing science in the early modern period.

In the early modern period, although scientific activities such as mathematics, mechanics, or medicine were distinct from the study of theology or the art of painting, they influenced one another in complex ways. My main argument is that early modern religious culture was at the core of the interactions between science, art, and religion because of how piety and its external devotions relied on material things. That there was an institutional demand for scientific knowledge during the Catholic Reformation, for example, is clear: the Gregorian calendrical reform would not have been possible without astronomy; the redevelopment of Renaissance and Baroque Rome was essentially a project of architecture and mechanics; and devotional art required advanced techniques of optics.[2] But, more often than not, historians have taken these encounters as merely institutional. For instance, in his now classic book *The Sun in the Church*, John Heilbron writes that the church's interest in astronomy "was not a love of science but a problem in administration."[3] However, there were deeper motivations for the interest of religious men in science. In this article, I show that in addition to institutional reasons, there were also motivations stemming from the devotional life characteristic of early modern Catholicism.[4]

The consideration of devotional motivations is especially helpful for understanding two kinds of encounters between science and the culture of piety in the Catholic Reformation. First, there are the well-studied cases I have already mentioned, in which religious projects called for scientific expertise. But there were also cases in which religion appears in a scientific context, such as those considered in this article. The relation between devotion and science may be difficult

[2] On the Gregorian calendrical reform, see Coyne et al.; for engineering in Rome, see Long, 2018; for optics in early modern painting, see Kemp. For optics in Jesuit Portuguese art, see Mello and Leitão.

[3] Heilbron, 1999, 3. Feingold, 2003, 7, also writes of a separation between religious and scientific interests.

[4] On the use of terms such as *early modern Catholicism* and *Catholic Reformation*, see O'Malley, 2002, 7–10; Eire, ix–xii.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

to discern in a liturgical problem that is intrinsically related to astronomy, such as the determination of the date of Easter. But it becomes easier in a class of mixed mathematics that uses religious imagery to illustrate examples of mechanics and hydrostatics. By taking the historical actors' devotion seriously, I understand both types of cases as yet another product of early modern Catholic culture, alongside Baroque art and even politics.[5] It might be tempting to argue that the display of religious examples in a mathematics course is not surprising when the teachers were priests lecturing in a Jesuit college in a Catholic monarchy. But this attitude is the flip side of the problem addressed by Lucien Febvre almost eighty years ago in *The Problem of Unbelief in the Sixteenth Century*.[6] Instead of taking ideas outside of their early modern context, which was the anachronism rejected by Febvre, here the context would explain them away, as if religious environment alone were sufficient to explain this phenomenon. Placing early modern science in its own cultural setting, especially within the purview of art and religion, does blur the boundaries between what is properly considered today as religious and scientific. But rather than merely assuming that religion was part of the European cultural mindset, this article explains in exactly what ways religious culture and its devotional aspects shaped different scientific projects.

There has long been a consensus among historians that the seventeenth century was marked by a secularization of theology, in part because more and more laymen, including Galileo Galilei (1564–1642) and Isaac Newton (1643–1727), were writing on the subject.[7] Aligned with this secularization thesis, Mordechai Feingold has argued that there was often a conflict between the interior calling to religious life and the desire to study science.[8] According to Feingold, the nature of a religious vocation for Protestant clerics "was such as to impinge fundamentally on their ability to dedicate themselves to science."[9] But if this was the case for the Protestant clergy, the reform of religious orders in early modern Catholicism opened many doors to the study of science.[10] In fact, the study of the natural world within religious institutions seems to have been particularly fruitful in this period—Dominicans, Minims, Benedictines, Cistercians, Oratorians, non-regular clergy, and, of course, the

[5] I expand on art and religion further in the article. For politics and religion see, for example, Rowe.

[6] Febvre.

[7] Funkenstein, 3–9.

[8] Feingold, 2002.

[9] Feingold, 2002, 80. Feingold deals mostly with English Protestant clergymen.

[10] Even Feingold, who suggested that the clerics' preoccupation with science "was shared by Catholics as well as Protestants," admitted that "the Catholic Church proved to be more hospitable to clerics who pursued secular learning": Feingold, 2002, 113–14.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

Jesuits were all representative of this.[11] As will be seen, what led these religious men to the study of science was not just sheer curiosity, free time in their schedule, or a deeper search for divine truths in nature.[12] Rather, I argue, it was also a kind of piety, which I term *material piety*, that took the material dimension as the very locus for meeting God. This explanation leads to a more robust portrayal of the scientific clergymen, because it places piety at the intersection of their interest in religion and science. The Jesuit mathematicians who held pastoral responsibilities alongside their scientific activities in seventeenth-century Portugal illustrate this approach well. And so too do other clergymen who, even though not practicing science themselves, relied on scientific, and sometimes material and artisanal knowledge, to make religious claims. This aspect of material piety was clearly evident in the 1612 process of canonization of Isabel of Portugal (1271–1336) that took place in the city of Coimbra.

Finally, intellectual historians have also argued that theology had a role to play in the development of early modern science. Catholics and Protestants alike relied on ideas and methods such as biblical scholarship, the doctrine of original sin, and the metaphor of the book of nature when writing on natural philosophy.[13] However, another, and more central, Christian doctrine was also relevant to the early modern religious interest in science. As I briefly explain below, the Christian attention to the material world was a direct consequence of the doctrine of incarnation—the belief that God himself had become incarnate in the person of Jesus Christ. This doctrine of God becoming man and assuming a human, material body resonates with the early modern understanding of mixed mathematics. Unlike pure mathematics, which dealt with abstract numbers and geometrical entities, in mixed mathematics, geometrical entities gained materiality in disciplines such as mechanics and astronomy. While I do not intend to offer lengthy considerations of theology in this article, this shows that the convergence between scientific knowledge and religious devotion should not be detached from the early modern emphasis on incarnational theology, revealed in devotions to Christ's humanity and, more specifically, to Christ's material body.[14]

[11] Some examples are the Dominican Domingo de Soto (1494–1560), the Minim Marin Mersenne (1588–1648), the Benedictine Benedetto Castelli (1578–1643), the Cistercian Paolo Boccone (1633–1704), the Oratorian Nicolas Malebranche (1638–1715), the diocesan Pierre Gassendi (1592–1655), and the Jesuit Christopher Clavius (1538–1612).

[12] For a recent study of spirituality and Jesuit science, see Dupré, 2013.

[13] See Harrison; Portuondo, 2019b; Jorink. For the specific case of Jesuit science, see Feldhay, 2007; Hellyer, 114–37.

[14] Felipe Pereda calls this an emphasis on Christology. See also Pereda, 37.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

This article looks at the role of material piety in the context of the Royal Academy of Mathematics, directed by the Society of Jesus in Lisbon from 1590 to 1759.[15] Before analyzing the primary sources, I explain the concept of material piety with a concise look at the role of material culture in Christianity, from its origins to the early modern period—this comprises the first part of the article. The second and third parts describe how the Jesuits Giovanni Paolo Lembo and Hendrick Uwens used their courses in mathematics to foster a material and sensuous form of devotion among their students, and situate their teaching within a broader culture of artistic piety in seventeenth-century Portugal. The naturalness with which these Jesuits incorporated religious themes into a secular context, such as a class on mathematics, points toward their religious interest in science.[16] Another way to look for these interests is to consider how Jesuit mathematicians balanced their pastoral and scientific activities. Thus, after addressing Lembo and Uwens's religious intent, the fourth part of this article follows other Jesuit mathematicians outside the classroom, into their pastoral ministries, to show how the Jesuits saw their scientific activities as another ministry and, therefore, as religious activities in themselves. Finally, the article turns to João Delgado (ca. 1553–1612), the Jesuit founder of the Class of the Sphere, and his role as a scientific expert in the canonization process of Queen Isabel of Portugal in 1612. This process of canonization relied on the expertise not only of Delgado, but also of physicians, surgeons, masons, and carpenters. It also illustrates material piety at play in another, non-Jesuit context, where science and religion also converged. The material piety of those involved helps make sense of religious engagement with material practices, such as the bodily examination of the queen. In a way perhaps unfamiliar today, but unremarkable to an early modern audience, this article thus brings together the histories of religion, art, and science and medicine.

WHAT IS MATERIAL PIETY?

According to Thomas Aquinas, piety is part of the virtue of religion, which means giving to God that which is due to him.[17] In the sixteenth century, Bartolomeu dos Mártires (1514–90), the bishop who led the reforms demanded by the Council of Trent in Portugal, defined devotion as "the readiness and

[15] Leitão, 2007.

[16] A secular context is not necessarily at odds with a religious context. I use *secular* to distinguish such a context from a class of theology or a liturgical setting. Classes of mathematics largely followed their own rules, for example those of geometrical propositions, and not the rules of theology.

[17] Aquinas, 41:9–12 (*Summa Theologiae* II-II, q. 101, a. 3).

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

fervent inclination of the soul to divine things."[18] Given the similarities between these two definitions, this article takes the words *piety* and *devotion* as synonyms. But it distinguishes piety from devotions in the plural, as the latter stand for specific acts of worship, like praying the rosary or attending Mass. In this plural definition of devotions, I follow Thomas Aquinas, who also defined devotion as "an act of [the virtue of] religion."[19]

Material piety, then, is a form of worship that takes the material world as the main locus for encountering God. *Material* is here understood in the broader metaphysical sense of something distinct from spiritual and abstract realities, as it would also have been understood in the early modern period. Thus, material piety includes the use of material objects in devotional practices or the use of painting and other material activities to portray divine realities. But it is also more than that. In the cases presented here, material piety fostered the assembly of new devotional objects using a rigorous understanding of nature. This was possible only through the study of science and the development of new artisanal practices—secular activities, so to speak, that worked insofar as they did not involve divine causes. In this sense, a second feature of material piety is the transformation of secular activities into religious activities. The emergence of new pastoral ministries as part of the Catholic Reformation led many Christians to engage in activities that shared secular and religious aims, like education, the care for the sick and dying, or, as argued here, science.[20] Besides fulfilling their secular aim, these tasks also became ways for Christians to incline their souls, and the souls of others, to God.[21] However, the main transformation was in these actions' aims rather than in their methods, for these secular enterprises served only insofar as they were successful. And for that, they had to follow their own rules, such as the rules of mathematics or of medicine.

This positive attitude toward the material world is, of course, not surprising. Christianity places matter at the very core of its practices and beliefs, since God is understood to have taken human flesh in the person of Jesus Christ, according to the theological doctrine of incarnation. Because of that, human matter, or the body, played a critical role in a Christian's life and afterlife—"the flesh is the pivot of salvation," as an early Christian writer put it.[22] The centrality of matter in Christianity shaped the way devotional practices developed.[23] In the Middle

[18] Mártires, 276. All translations are the author's except where otherwise noted.

[19] Aquinas, 39:37–39. (*Summa Theologiae* II-II, q. 82, a. 2).

[20] See Bireley, 1999, 25–44, although there is no mention of science.

[21] The Jesuits called this pastoral aim "to help souls": see O'Malley, 1993, 18–19.

[22] "Caro salutis est cardo": see Tertullian, 25 (*De resurrectione mortuorum* 8); see also Bynum, 1995, 43; Brown, 1988.

[23] Brown, 1981; Bynum, 1995.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

Ages, the religious culture of Western Christianity had become so centered on material objects and ritual performances that some described it as a "ceremonial culture" and spoke of a "Christian materiality."[24] Statues, paintings, stained glass, rosaries, and relics all revealed the medieval Christians' "intense awareness of the power of the material," writes Caroline Walker Bynum.[25] More importantly, rather than being at odds with interior devotion, as many Protestants came to argue, this Christian materiality was meant to stimulate piety.[26]

The prominent role of objects and images in Christian piety was highly criticized by Protestant Reformers.[27] In response, however, the Catholic Church emphasized this materiality even more. As Carlos Eire explains, "the liturgical reforms effected after Trent strengthened . . . the substance of medieval Catholic ritual."[28] Eire also stresses, with regard to the material world, that "Catholic reform was as sensual as it was spiritual, for at the core of the Catholic faith lay the claim that all of creation is a gateway to the Creator and that matter and spirit are not antithetically opposed to one another."[29] This sensual aspect was a major feature of Baroque art, which aimed "to stir the spectator's emotions actively," according to Robert Harbison.[30] Artistic sensuousness in itself was not new. The Baroque difference was the involvement of the senses in "creating desirable states of mind and soul," as Wietse de Boer explains.[31] Therefore, religious Baroque art shows the importance of exciting the senses in the life of piety of early modern Catholicism.[32] Meditation practices, for example, were transformed by graphic images especially designed to excite the senses to emotions of piety.[33] These "meditative images," as Walter Melion calls them, helped the faithful to consider the Christian mysteries in more sensuous ways than before.[34] Art and religion also met in the rhetorical and theatrical techniques "of visual illusion . . . [that forged] the semblance of life in art"—as seen not only in painting, but also in sculpture and theater.[35] John O'Malley and others argue that this emphasis on visuality

[24] See Howe; Bynum, 2011.

[25] Bynum, 2011, 18. For relics, see Geary.

[26] Bynum, 2011, 18.

[27] Bartlett, 85–91.

[28] Eire, 398.

[29] Eire, 392.

[30] Harbison viii; see also Sanger and Walker.

[31] De Boer, 253.

[32] Hall; de Boer and Göttler.

[33] For examples in early modern Spain, see Ceballos; Christian; Roe.

[34] Melion, 3–14; Hall, 1–3, 9–11.

[35] Warwick, 9 (quotation), 43–77; Pereda; Norman. For literary rhetoric, see Fumaroli, esp. 354–79.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

could be described as a "theology of the visible."[36] At the center of these developments there was a material piety that promoted a sensuous, or material, engagement with art. This devotional demand for art is seen, for example, in Seville's investments in religious art and devotions to address the city's economic and environmental crises in the seventeenth century.[37]

The role of material piety in the interactions between art and religious culture in the early modern period is, thus, a well-mapped field. But the same cannot be said for the study of natural philosophy, mathematics, and those activities that are today described as scientific. Was it the case that science somehow escaped the influences of its own culture? As this article shows, it did not. Recent studies on the discernment of supernatural phenomena in the early modern period have suggested that the role of miracles in religious devotion promoted a rigorous understanding of the regular order of nature.[38] The only way for religious authorities to make a definite claim about miracles was by making sure they were using the best natural knowledge available to them.[39] Early modern processes of canonization demonstrate this use of natural knowledge well, since the church used medical experts to reach the best natural explanations of phenomena, and thenceforth to make claims about the supernatural when the phenomena did not match such explanations.[40] In the context of the natural sciences, Lorraine Daston calls this "the gradual naturalization of the preternatural."[41] Similar to supernatural miracles, preternatural phenomena were rare, but, unlike miracles, they could be explained by natural causes. According to Mark Waddell, this desire to naturalize the preternatural explains why the Jesuit Athanasius Kircher (1602–80) was so interested in presenting his mastery of natural phenomena as a visible spectacle, either in the museum of the Roman College or in the emblems of his books.[42] It also explains why Niccoló Cabeo (1586–1650), another Jesuit, used iron filings to show for the first time the magnetic field around a magnet.[43] By naturalizing these phenomena, the Jesuits made it easier to discern if something was really a miracle. Thus, Cabeo's work on magnetism was part of a larger Jesuit enterprise of placing boundaries on both the preternatural and the supernatural.[44] Waddell also argues that the Jesuit interest in the visual understanding of hidden qualities

[36] O'Malley, 2013, 43–44.
[37] Wunder, 10–13.
[38] Daston; Dear, 670–80.
[39] Keitt.
[40] Antonelli. See also Siraisi; Pomata, 2016.
[41] Daston, 95.
[42] Waddell, 116–59. For emblems, see also O'Malley, 2013, 43–44.
[43] Waddell, 62–64, 79–80.
[44] Waddell, 22–27.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

manifested the Jesuit practical way of prayer, whose origins can be traced to Ignatius Loyola's *Spiritual Exercises* (1548), a central book in the life of every Jesuit.[45] As the historical events of the Gospel would come alive in the Jesuit's mind through meditation, so invisible natural phenomena would become visible through mathematics and specific experiments.[46] These efforts in making the invisible visible are similar both to the meditative art already mentioned and to the apparently bleeding crucifixes that Jesuit mathematicians introduced to their students in Lisbon.

To sum up, material piety is a way of relating to God by which the material world takes center stage, almost as an agent in itself. *Material piety* was not enunciated as such in the early modern period, but is a useful term for describing the devotion typical of the Catholic Reformation. Thus, this article confirms the centrality of material culture in early modern Catholicism and extends it to the religious interests in science. Here, material piety manifests itself in two ways: in the use and study of nature as a way to reach supernatural realities, and in the transformation of scientific and artisanal activities as religious in themselves. I am not claiming that material piety was the direct cause for the practice of science among the clergy. But I am saying that material piety was a general and positive attitude toward the material world that allowed an interest in science to flourish. That is, material piety influenced the production of science within early modern Catholicism, as much as it influenced Baroque art. But I want to avoid generalizations. As a Catholic monarchy, whether during Habsburg rule (1580–1640) or not, Portugal was a major arena for the cultural transformations of early modern Catholicism, and this is the context in which I explore the role of material piety in science.[47]

BLOOD IN THE MATHEMATICS CLASSROOM

The Jesuits held a mathematics class in their college in Lisbon from 1590 to 1759.[48] The course was known as the Class of the Sphere; it took its name from Johannes de Sacrobosco's textbook of astronomy *De Sphaera* (On the sphere, ca. 1230), widely commented on in the sixteenth century.[49] The class soon became known as the Royal Academy of Mathematics, bearing witness to the Crown's interest in it.[50] The class was taught in Portuguese in order

[45] Loyola.

[46] Waddell, 5–8.

[47] Paiva, 291.

[48] The class ended in 1759 with the expulsion of the Society of Jesus from Portugal; see Leitão, 2003 and 2007.

[49] This textbook became popular in Jesuit schools due to Christoph Clavius's commentaries on it: see Lattis, 30–60.

[50] The first known reference to "Royal Academy" is in the frontispiece of Stafford.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

to target an audience composed of upper-class citizens who barely knew Latin, and who were not necessarily interested in the erudite aspects of ancient mathematics.[51] Their interest in mathematics derived from practical applications in areas such as navigation, astronomy, military arts, and mechanics—all disciplines that were part of early modern mixed mathematics.[52] The teaching of mechanics explicitly illustrates the Jesuit interest in practical applications, according to a professor's description of it as "one of the best and most useful [sciences] of mathematics, for it deals with machines and instruments that are useful for human use."[53] The earliest surviving manuscript entirely dedicated to mechanical topics in the Class of the Sphere is a "Brief Treatise on Hydraulic Machines" by Giovanni Paolo Lembo, who taught in Lisbon from 1615 to 1617.[54] Lembo built the telescopes used by Jesuit astronomers in Rome to confirm Galileo's astronomical observations.[55] His craftsmanship extended to the construction of other devices, as his treatise on pneumatic mechanisms shows.

Lembo's sixty-five chapters on hydraulic machines follow the tradition of Hero of Alexandria's (ca. 10–70 CE) *Pneumatics*, where each chapter corresponds to a single object such as the siphon, pump, or small fountain.[56] Lembo also draws some devices from Vitruvius's (ca. 70–15 BCE) *On Architecture*, such as the Archimedean screw to raise water, and from Giambattista della Porta (1535–1615), who wrote extended commentaries on Hero's devices.[57] However, Lembo does not mention Della Porta explicitly, possibly because of Della Porta's problems with the Inquisition.[58] The main point here is that Lembo was aware of the most important authors on hydraulic machines and introducing these machines to his students was his main focus.

[51] Leitão, 2003, 234–35.

[52] Mathematicians such as Galileo Galilei (1564–1642) and Simon Stevin (1548–1620) also taught private classes to similar audiences. See Chalmers, 28; Valleriani, 72. See also Biagioli, 45–49.

[53] Biblioteca Nacional de Portugal (hereafter BNP), Cod. 4333, fol. 29^{v}: "he comtudo esta sienҫia das milhores e mais proveitosas da mathematica, pois trata de todas as machinas e instromentos que servem para o uzo humano."

[54] Arquivo Nacional da Torre do Tombo (hereafter ANTT), Manuscritos da Livraria (hereafter MS Liv.), 1770.

[55] Baldini, 2014, 131. Lembo also made these observations in Lisbon: see Leitão, 2001, 113.

[56] Lembo also mentions by name Federico Commandino (1509–75), in ANTT, MS Liv. 1770, fol. 103^{v}. See Commandino, who published the most circulated Latin translation of Hero's *Pneumatics*.

[57] Della Porta.

[58] Baldini, 2014, 135. For Della Porta and the Inquisition, see Tarrant.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

Lembo also had further interests, shown by his examples of hydraulic devices. After explaining the theory of siphons, Lembo adds a proposition on how "to make a water faucet that throws pure water into the hands [E] and yet throws colored water upward [A], and some inventions made of this."[59] He says that this water faucet was built "upon the same principles of siphons . . . for the recreation of guests" (fig. 1).[60] He uses "water boiled with brazilwood" to color the water red.[61] After his explanation, which derived from similar devices in Hero's and Della Porta's books, Lembo enumerates small possible changes to the device and their corresponding uses.[62] He says the device could be changed "to make the red water that comes out to seem to the guests like a fountain of wine."[63] Or the device could be made into "a statue of Hercules rigidly gripping two serpents in his hands"; this is done "with such inventiveness that the small pipe that attracts the air goes out through Hercules's mouth and the two ends of pipe H go to the heads of the serpents that Hercules is gripping."[64] The graphic result would be the serpents expelling red water as if it were blood. In the first example, the fountain produces an illusion of wine; in the second, the illusion of blood is apparently caused by the action of Hercules, a symbol of moral virtue in Renaissance art.[65] Thus, the increasing theatricality of Lembo's second example is meant to foster a desire for the virtue of fortitude in the early modern observer.[66] What points to fortitude is the violent element of blood, which becomes more graphic in a third example. Here, Lembo transformed the classical scene of Hercules into a version more familiar to his early modern students by representing "over these pipes a military person, that is a Prince or a Captain . . . in such posture that the Moor over whom he gained victory is

[59] ANTT, MS Liv. 1770, fol. 101^{v}: "Fazer hum lavatório que lance agoa pura para as mãos e contudo lance para cima agoa de cor e algumas invençoins compostas disto."

[60] ANTT, MS Liv. 1770, fol. 101^{v}: "Do mesmo prinçipio da cantimprosa se tirou este lavatorio para recreação dos convidados."

[61] ANTT, MS Liv. 1770, fol. 101^{v}: "água cozida com pao do Brasil."

[62] Commandino, 112 (chap. 53); Della Porta, 23–25 (bk. 2, chap. 2).

[63] ANTT, MS Liv. 1770, fol. 102^{r}: "de maneira que pareça a agoa vermelha que saya da fonte; representa aos convidados huma fonte de vinho."

[64] ANTT, MS Liv. 1770, fol. 102^{r}: "huma statua de Hercoles que esteja apertando rigidamente entre suas maos 2 serpentes e isto com tal artefiçio que o cano pequeno que atrahe o ar saia pella bocca de Hercoles e os dous fins do cano H vao sair aos pescossos das serpentes que Hercoles aperta." This represents the famous episode of the infant Hercules strangling two snakes, as first told by ancient writers such as Pindar, Theocritus, and Apollodorus: see Schmitz, 393.

[65] See Galinsky, 185–230; Martin; Mainz and Stafford.

[66] The other cardinal virtues—prudence, justice, and temperance—do not match as well with this image: see Aquinas, 23:120–23 (*Summa Theologiae* I-II, q. 61, a. 3).

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

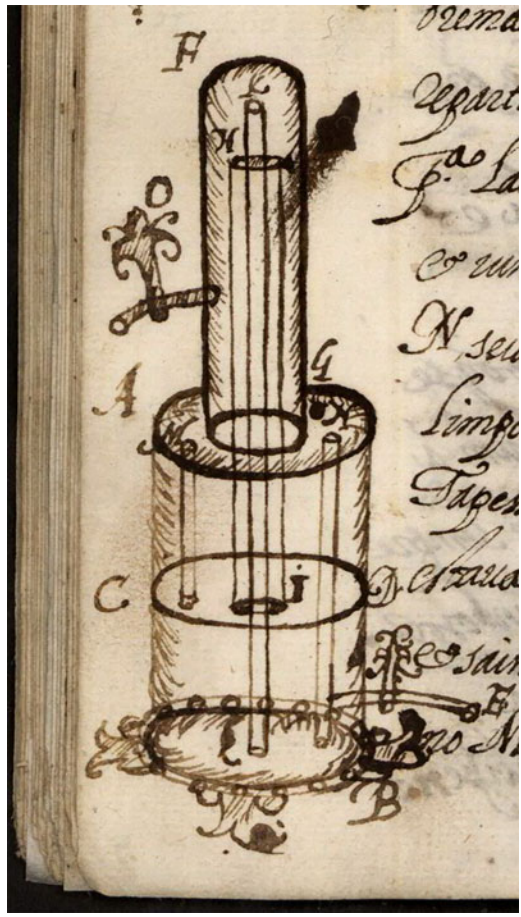

Figure 1. "A water faucet that throws pure water into the hands and throws colored water upward." Giovanni Paolo Lembo. "Brief Treatise on Hydraulic Machines" (1617). Arquivo Nacional da Torre do Tombo, Lisbon, Manuscritos da Livraria 1770, fol. 101^{v}.

held below the feet . . . let [the captain] also have the sword raised, as if he just pierced and gave him a large wound in the head. In this way the hydraulic practitioner will make the red water from the pipe H run from the Moor's wound."[67] Hence, his students learned how to produce different levels of

[67] ANTT, MS Liv. 1770, fol. 102^{r}: "Sobre estes canos se pode mui bem por huma pessoa militar, scilicet hum Principe ou hum Capitão . . . e esteja este capitão em tal postura que lhe fique o mouro de quem alcansou victoria debaixo dos pees . . . tenha tambem a espada levantada, como que o accabou de ferir e lhe deu huma grande ferida na cabeça e assim fará o Hidraulico que a agoa vermelha do cano H corra da ferida da cabeça."

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

illusion with a single hydraulic device. This new example might also evoke in the viewer another feeling associated with the virtue of justice, as it illustrates a righteous Christian prince conquering the infidel. But, as Lembo's final examples show, these devices could become even more expressive and more complex in the feelings they were designed to evoke.

According to Lembo, his two final examples were meant "to incline ourselves to christian piety."[68] Instead of Hercules strangling two serpents, the fourth example was "the Crucified hanging from the Cross and which throws blood from the holy wounds; the pipes will be the Cross and the air shaft will go behind the Cross, the pipe H will be in the arms of the Cross, from which the wounds are made and whence red water will flow, so that it seems blood in order to move and excite the devotion of those present."[69] And Lembo gave yet a fifth example where "Christ Our Lord could be tied to the Column, with blood running from all parts of his body, but it is necessary that the little holes on the body from which the red water flows be very narrow."[70] The narrowness of the holes increased the speed of the ejected water, making it even more dramatic.[71] From Lembo's perspective, the first and second examples used a pagan figure from the classical times of Hero of Alexandria and a secular figure from the Renaissance, respectively, to engage with the audience.[72] But in the latter examples, beyond simply Christianizing them, Lembo changed the theme completely, while maintaining the same mechanism. Previously, the audience was not meant to relate to the dying serpents or the slain Moor, but rather to Hercules and the prince or captain. In the examples with the figure of Christ there is a shift of the image's focus from the attacker to the victim. These devices increase the observer's devotion by creating emotions of horror and then sorrow in witnessing the suffering of the innocent Christ so vividly.[73] With these emotions, Lembo no longer aims for a spectacular

[68] ANTT, MS Liv. 1770, fol. 102[r]: "inclinandonos a piedade christam."

[69] ANTT, MS Liv. 1770, fol. 102[r]: "faremos hum Crucifixo que este pendurado na Crus, e lance sangue das sagradas chagas; os canos seguirão da Crus e o respiradouro sobirá para o traseiro da Crus, o cano H ficara nos bracos da Crus, dos quaes se dirivarão as chagas e correrá a agoa vermelha que pareçerá sangue, para mover e excitar a devoção aos que estiverem presents."

[70] ANTT, MS Liv. 1770, fol. 102[r]: "podesse poer Cristo senhor nosso attado á Columna correndolhe o sangue de todas as partes do corpo, mas os buraquinhos do corpo por onde há de sair a agoa vermelha he necessario que seião mui estreitos."

[71] The precise formulation that speed is inversely proportional to the cross-sectional area was first described in 1628, in Castelli, 53–54, but the idea has been familiar since antiquity.

[72] For Hero's use of Hercules, see Commandino, 93–95 (*Pneumatics* chap. 40).

[73] On Christ's innocence see, for example, 1 Peter 2:22–23; and the section "The Dignity of the Sufferer" in McHugh and Callan, 56 (*Catechism of the Council of Trent* part 1, article 4).

demonstration of fortitude, but rather to stimulate piety. The intentional higher pressure of the blood coming out of several holes made the sensory impact much stronger. Moreover, if Christ underwent all these sufferings because of the sins of every person, as Christians believe, then these two vivid images of Christ's Passion also represent the consequences for Jesus of the observer's personal sins.[74] Thus, the bleeding is apparently caused not just by the crucifixion or the flagellation, but also by the spectator himself, which adds yet another layer of both theatricality and religious reflection to these devotional devices.

The copious representation of blood in these two images deserves a final comment. In its declaration on the Eucharist, the Council of Trent affirmed that the soul and divinity of Christ were always present in each part of Christ's body and blood.[75] This declaration gave strength to the medieval devotion to the precious blood, whereby vivid representations of the blood of Christ carried important meanings such as the union of Christ's divine and human natures, or the salvific nature of Christ's blood.[76] A famous example of this devotion in early modern art is Gian Lorenzo Bernini's (1598–1680) *Sangue di Cristo* (Blood of Christ, 1670), in which Christ hangs on the cross, blood pouring from his wounds into an ocean of blood (fig. 2).[77] Yet, unlike Lembo's images—but characteristic of Italian artists—Bernini's Christ was not himself, apart from the bleeding wounds, covered with blood. And when the friar Innocenzo da Petralia (d. 1648) sculpted a crucifix covered in blood in Assisi, he was called by the Inquisition on account of an exaggerated representation of Christ's wounds.[78] Such wooden polychrome crucifixes covered with blood are known by art historians as dolorous crucifixes.[79] If these crucifixes were rare in Italy, to the point of disturbing the Inquisition, they were quite common in Iberia.[80] Even crucifixes that represented only the five wounds of Christ often showed the blood running down the body of Christ, as seen in Philippe de Vries's 1551 crucifix in the Jeronimos monastery in Lisbon

[74] See, for example, Loyola, 64 (3rd week, 1st day).

[75] Waterworth, 77–78 (*Council of Trent* session 13, chap. 3); Sollier.

[76] See Bynum, 2007. This idea has biblical roots as seen, for example, in 1 John 1:7.

[77] Lavin, 159–71.

[78] See the third page of Chiara Franceschini's March 2014 research proposal, "The Flesh of Images: Art, Techniques of Emotion and the Limits of Expression after Trent," Project FMSH Bourse Braudel, Labex HASTEC: https://labexhastec.ephe.psl.eu/files/projet-de-recherche-chiarafranceschini-fernandbraudel-april2014.pdf; Pereda, 219–22.

[79] See Pereda, 219–24.

[80] Pereda, 222–24.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

Figure 2. Gian Lorenzo Bernini. *Sangue di Cristo*, frontispiece of Francesco Marchese, *Unica speranza del peccatore* (Rome, 1670). Courtesy of Philadelphia Museum of Art.

(fig. 3).[81] In fact, Fra Petralia was from Southern Italy, a region ruled by Spain since the late Middle Ages and thus influenced by Iberian culture. As Lembo

[81] See also the earlier painting *Fons Vitae* (1515–17) by the Flemish Colijn de Coter (ca. 1445–ca. 1532), in the Misericórdia Museum, Porto, Portugal. See http://www.mmipo.pt/en-gb/obras/fons-vitae. For later examples, see Saldanha and Carvalho.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

Figure 3. Philippe de Vries. Crucifix, 1551. Jeronimos Monastery, Lisbon. © Nuno Cera / Mosteiro dos Jerónimos e Torre de Belém, 2020.

was from Naples, he was probably familiar with the tradition of dolorous crucifixes and knew that such crucifixes would be well received by his Iberian audience. These sensuous images, produced by artists and, in the case of Lembo, by a mathematician, illustrated Christ's suffering in a powerfully material dimension. Ultimately, it can be said that this form of material piety helped the audience to engage with Christ as an embodied entity.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

MATHEMATICS IN THE RELIGIOUS THEATER

A similar case can be seen in the work of the Flemish Jesuit Hendrick Uwens, who authored the "Treatise on Statics" (1645) and whose two manuscript copies comprise the first known Portuguese textbook on early modern mechanics.[82] One of the copies is signed by João Nunes Tinoco (ca. 1610–89), a famous Portuguese architect who attended Uwens's classes while already working on building projects such as the Monastery of St. Vincent Outside the Walls (Mosteiro de São Vicente de Fora).[83] The treatise is split into five major parts: the calculus of centers of gravity, mechanics, hydrostatics, aerostatics, and military arts. The part on mechanics, by far the largest (eighty-four folios), is divided into five chapters—the balance, lever, pulley, wheel and axle, and wedge and screw—following Guidobaldo dal Monte's *Mechanicorum Liber* (Book of mechanics, 1577), one of the most important books on mechanics in the first half of the seventeenth century.[84] Uwens also knew well some of the late Renaissance writers on mechanics, since he describes Simon Stevin's (1548–1620) explanation of the inclined plane, a correct version of the problem unlike the inaccurate one presented by Dal Monte.[85] More importantly, with this textbook, Uwens became one of the earliest Jesuits to teach ideas associated with Galileo and Descartes.[86]

Uwens's course, like Lembo's, was primarily focused on mathematics and not religion. Yet his examples also give a glimpse into Jesuit devotional practices in early modern Lisbon. When explaining the wheel and axle, for example, Uwens mentions four uses for them (fig. 4).[87] Then he introduces "some curiosities [which can be] deduced from the same axle," to be used in theatrical scenery.[88] The wheel should have some images "in the circumference either painted or made of cardboard or other material."[89] Only one part of the wheel was to be shown, which would then rotate and give the audience a sense of action (fig. 5). In a first example, Uwens mentions a sequential order of "beasts, dogs, and hunters following one another."[90] But then he

[82] Two copies are known: BNP, Cod. 4333; and Biblioteca Pública de Évora, CXXVI/2-7.

[83] Sousa Viterbo, 3:112–16.

[84] Respectively, BNP, Cod. 4333, fols. 30^{r}, 50^{v}, 68^{v}, 83^{v}, 100^{r}. See also Dal Monte, fols. 112^{r}–130^{v}; Bertoloni Meli, 19.

[85] BNP, Cod. 4333, fol. 104^{v}. For Stevin's demonstration, see Dugas, 123–27.

[86] Castel-Branco, 6–16.

[87] BNP, Cod. 4333, fols. 89^{r}–90^{r}. Uwens follows Dal Monte again.

[88] BNP, Cod. 4333, fol. 90^{r}: "são algumas curiozidades deduzidas do mesmo Timpano."

[89] BNP, Cod. 4333, fol. 90^{v}: "pintados ou feitos de papelão ou de outra materia na circumferençia."

[90] BNP, Cod. 4333, fol. 90^{v}: "as feras, caens, cassadores, perseguindo huns aos outros."

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

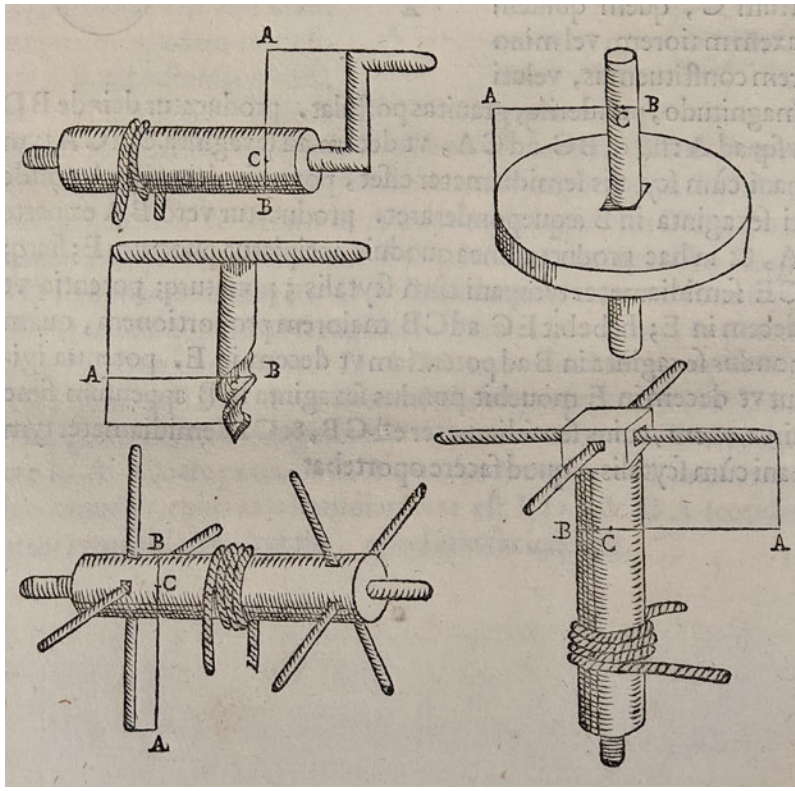

Figure 4. The different uses of the wheel and axle. Guidobaldo Dal Monte. *Mechanicorum Liber* (Pisa, 1577), fol. 111^{v}. Biblioteca Nacional de Portugal, Lisbon. Author's photograph.

adds that "with a similar wheel one can represent the steps of the passion of Our Lord . . . and all the steps . . . appear one after another."[91] Like Lembo, Uwens showed how these devices could be used to create devotional images that fostered emotions of piety among his audience. The rotating scenery of the Passion, which added an extra layer of motion to the theater, illustrates the appeal to the excitation of the senses in Jesuit piety and the use of the sciences behind it. It also shows an explicit use of mechanics in religious theater—probably school dramas, given the context, but Uwens does not specify.[92] Uwens's sensuous scenery and Lembo's dolorous devices show how

[91] BNP, Cod. 4333, fol. 90^{v}: "Com semelhante roda pode se representar os passos da paixão de Nosso Senhor . . . ande passar todos os passos . . . hum depois do outro."

[92] For Jesuits and theater, see Zampelli; Sempilius, 94–95. For science and theater, see Santo-Tomás.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

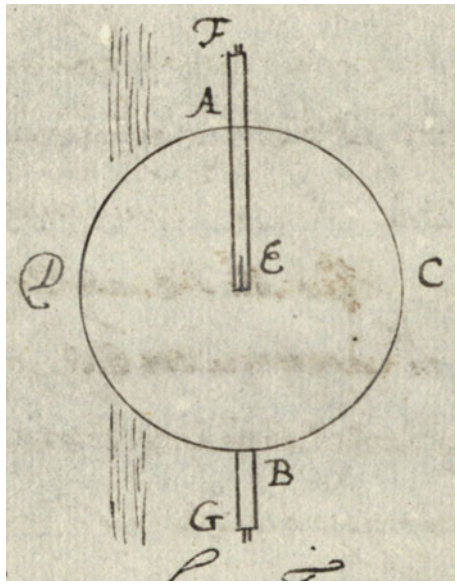

Figure 5. A wheel to use in the theater, with the cover on the left. Hendrick Uwens. "Treatise on Statics" (1645). Biblioteca Nacional de Portugal, Lisbon, Cod. 4333, fol. 90[r].

religious devotion relied on materiality in new and sophisticated ways, with mixed mathematics playing a critical role in early modern Portuguese devotional practices. It also shows how material piety easily adopted specific local features, such as the specifically Iberian representations of Christ's blood.

JESUIT SCIENCE AS RELIGIOUS MINISTRY

The Catechism of the Council of Trent, a manual for Catholic priests in the early modern period, taught that a pastor should be assiduous in instilling piety in his flock, by "stirring up in the minds of the faithful the frequent recollection of our Lord's Passion . . . in order that the faithful . . . may give themselves entirely to the contemplation of the goodness and love of God toward us."[93] Years before the council, Ignatius Loyola (1491–1556), the founder of the Jesuits, dedicated one of the four weeks in the *Spiritual Exercises* (1548) to the contemplation of the Passion. Thus, it is not surprising that the religious examples chosen by Lembo and Uwens also focus on the Passion of Christ.

[93] McHugh and Callan, 50 (*Catechism of the Council of Trent* part 1, article 4).

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

The feelings of piety that Lembo and Uwens created with their mathematical devices were seen as an efficacious way of improving their audience's spiritual lives, and thus as not distinct from the Jesuit goal of helping souls. Helping souls entailed a broad range of actions, from providing for people's material needs in hospitals or prisons, to improving their spiritual lives through practices of prayer and the sacraments, all traditional Catholic practices.[94] For the Jesuits in Lisbon, helping souls also included mathematics. Lembo's explicit use of the expression "to move and excite" devotion connects his dolorous devices with a type of religious art made to assist in meditative practices.[95] Through this extremely graphic version of meditative art, the observer was supposed to contemplate the sufferings of Christ in a more sensuous way.[96]

These pious uses of mathematical devices expand the ordinary understanding of practical applications in science. Lembo was teaching mathematics not only to build mechanical devices per se, but also to teach his students how to grow in devotion by means of a visually engaging crucifix. This duality of goals blurred whatever lines separated the Jesuit as priest from the Jesuit as mathematician. But the coexistence of these goals was not problematic for Jesuits, since their piety relied a great deal on material objects and secular practices. The beginning of the *Spiritual Exercises*, a book that all Jesuits used regularly in their prayer lives and preaching, illustrates it well: "Man is created to praise, reverence, and serve God our Lord, and by this means to save his soul. The other things on the face of the earth are created for man to help him in attaining the end for which he is created. Hence, man is to make use of them in as far as they help him in the attainment of his end, and he must rid himself of them in as far as they prove a hindrance to him."[97]

This idea becomes explicit in a mathematics textbook in which the German Jesuit Paul Guldin (1577–1643) laid out his scheme of mathematical disciplines, writing in a large font, "his itur ad astra" (fig. 6).[98] This is an altered version of the quotation "sic itur ad astra" ("thus one journeys to the stars") from Virgil's *Aeneid* (9.641), which in the Jesuit context could easily be translated as "by these things one goes to Heaven." This quotation is clearly highlighted within the page, suggesting that by "these things," Guldin meant mathematics. However, the quotation plays with the double meaning of "ad astra," because on the textbook page the line is adjacent to the list of astrological disciplines.

[94] O'Malley, 1993, 18–19.
[95] ANTT, MS Liv. 1770, fol. 102^{r}: "para mover e excitar a devoção."
[96] Melion, 3–14.
[97] Loyola, 12.
[98] Guldin, 21.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

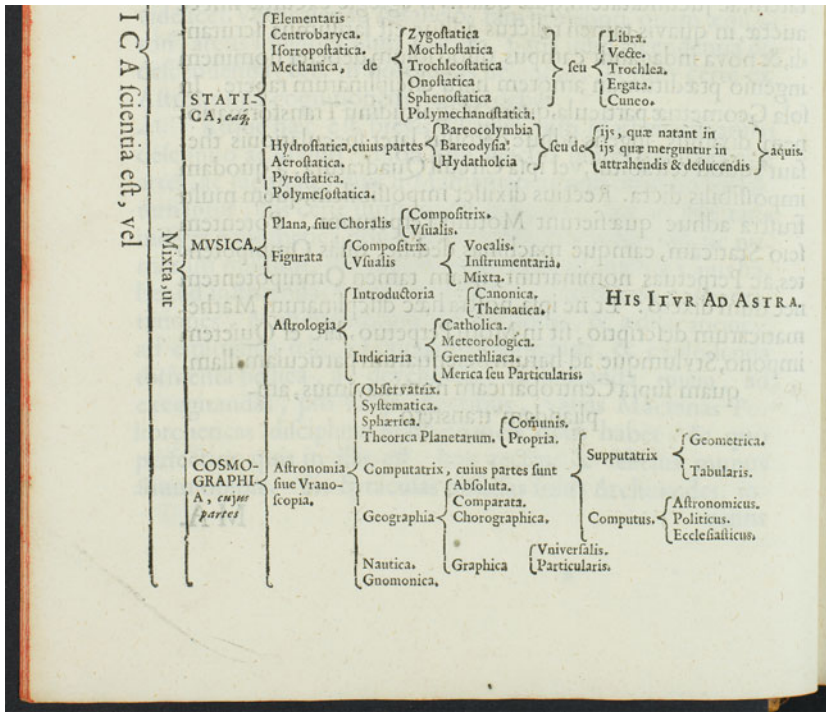

Figure 6. Table of mathematical disciplines. Paul Guldin. *De Centro Gravitatis* (Vienna, 1635), page 21. Max Planck Institute for the History of Science, Berlin.

Mathematics was useful for helping the souls of the students, but also for helping the soul of the Jesuit who taught it. Lembo himself used the first-person plural when he said that these examples were meant "to incline ourselves to christian piety."[99] It was said that Bernini drew the *Sangue di Cristo* to foster his own personal piety; so, too, did Lembo and Uwens conceive of their mathematical devices as expressions of their piety.[100] In a way, these mathematical devices were instruments of the interior senses. Just as the recently invented telescope extended human vision to the heavens, so these devotional devices aimed to extend interior life to God. Studying artistic efforts to portray divine realms, Felipe Pereda recently claimed that works of art in seventeenth-century Iberia should be "treated not as representations of a collective [religious] mentality but as arguments, as forms that lead to belief."[101] But, by definition,

[99] ANTT, MS Liv. 1770, fol. 102[r]: "inclinandonos a piedade christam."
[100] Montanari, 136–42; Lavin, 164.
[101] Pereda, 30.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

material realities always fall short of divine realities. So, to create a visual argument of belief in the supernatural, the artist has to use various levels of illusion. In his representations of the suffering Christ, Lembo used such material illusions to demonstrate religious truths because the graphic representation of blood recalled "a violence that, paradoxically, enhances the redemptive power of Christ's sacrifice."[102]

Perhaps clearer is Uwens's other religious example, in which he uses water technology to represent the famous miracle of the transformation of water into wine.[103] In the second chapter of the aerostatics section of his textbook, Uwens writes on how "to raise waters by the expulsion of air."[104] In this chapter, Uwens introduces a mechanism by which two containers (A and E) are filled with water and another (B) is filled with air (fig. 7). If a small valve (G) below the first container is opened, water from the first container (A) falls in the second container (B), pushing the air upward through a tube (CD) connected to the final container (E). As the air enters this container (E), the water is expelled through another pipe (EF), if the pipe (EF) is not too high. As a first corollary, Uwens says that this is "how an artificial fountain can be made. We only have to look at the vessels A, B, C, D as parts of the same fountain, and the pipes GB, CD, EF are covered with the body of the same fountain, as one can see in the figure" (fig. 8).[105] Then Uwens explains "the way in which, by dropping water in a fountain or vessel, the result will be wine or another liquor instead of water."[106] This is straightforward if in the second container (E) (fig. 7) there is wine instead of water. If successful, Uwens says, "one can represent gallantly the miracle in which Christ Our Lord changed water into wine."[107] Of course, the goal was not to trick the observer into thinking that the miracle was happening. On the contrary, while acknowledging the theatrical illusion, the observers were still able to experience the surprise of seeing the water become wine, thus placing themselves in the role of guests at the wedding feast at Cana, witnessing Jesus perform a miracle.

[102] Pereda, 222. See also Kimmel.

[103] John 2:1–11.

[104] BNP, Cod. 4333, fol. 169^{r}: "por meyo da expulção do ar levantar as agoas."

[105] BNP, Cod. 4333, fols. 169^{v}–170^{r}: "como se poderá fazer huma fonte artefiçial. Não temos mais que fazer que os vazos A, B, C, D seja pedaços da mesma fonte, e que os canos GB, CD, EF se emcobrem com o corpo da mesma fonte, como se vé na figura."

[106] BNP, Cod. 4333, fol. 170^{v}: "o modo com que botando agoa em huma fonte ou em hum vazo sahirá no lugar dagoa vinho, ou outro licor."

[107] BNP, Cod. 4333, fols. 170^{v}–171^{r}: "e desta sorte se poderá reprozentar galantemente o milagre em que Christo Senhor Nosso mudasse a agoa em vinho."

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

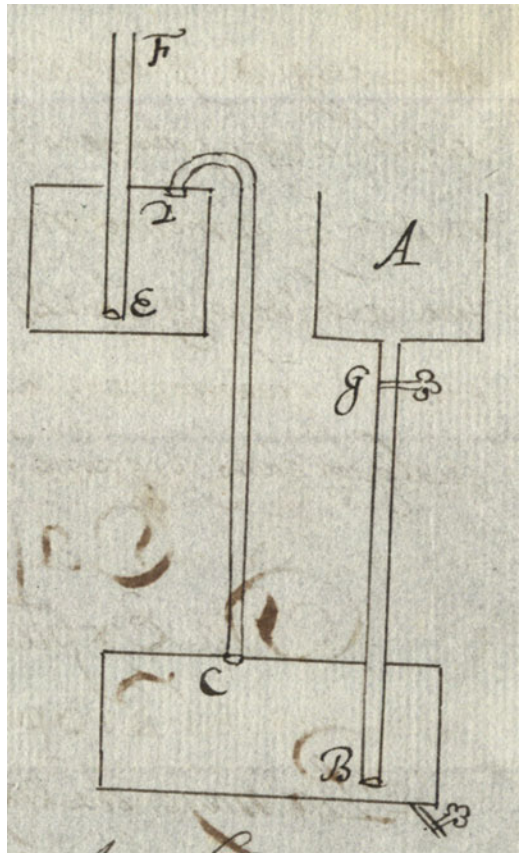

Figure 7. Illustration of the device to raise water by means of air. Hendrick Uwens. "Treatise on Statics" (1645). Biblioteca Nacional de Portugal, Lisbon, Cod. 4333, fol. 169^{v}.

This example appeared in Uwens's textbook as a corollary to the proposition that explained the original device. In Euclid's *Elements*, a book that all early modern mathematicians knew, corollaries were logical applications of a proposition. Thus, it seems that Uwens saw the representation of this miracle as a logical consequence of such a device. This example of the miracle was only one among many. Others include the assembly of an ordinary fountain, the "way in which one can make fictional birds sing," "a way to refrigerate houses in the summer," and "the way to give sound to the organ."[108] Religious imagery was just another possibility in Uwens's repertoire of useful things and thus, once

[108] BNP, Cod. 4333, fols. 169^{v}; 171^{r}: "o modo com que se poderão fazer cantar passaros fitissios"; 173^{v}: "hum modo de refrigerar as cazas no tempo de verão"; 175^{r}: "o modo de fazer o som ao órgão."

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

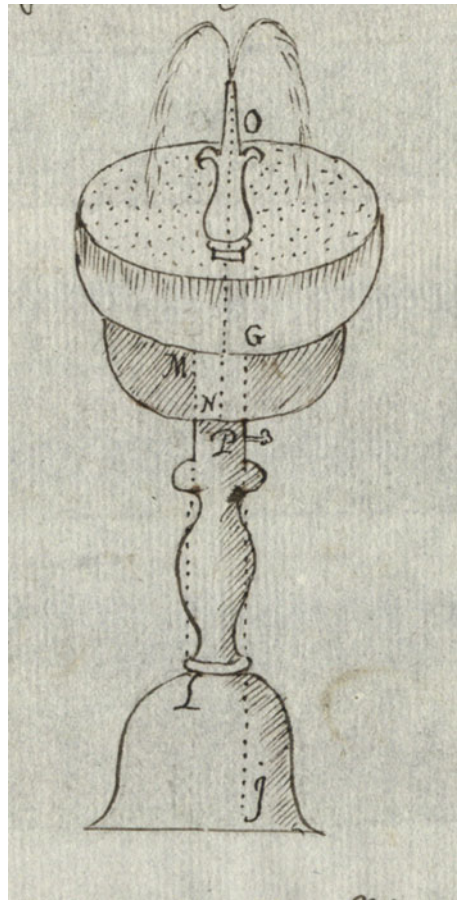

Figure 8. Illustration of an artificial fountain with the pipes drawn inside. Hendrick Uwens. "Treatise on Statics" (1645). Biblioteca Nacional de Portugal, Lisbon, Cod. 4333, fol. 170^{r}.

again, it shows how a sophisticated mechanical device could enhance his and his students' piety. In fact, to achieve the desired level of piety, artistic skills were not enough. Lembo, Uwens, and their respective students had to master hydrostatics and mechanics, something only possible with many hours of mathematical training.

The Jesuit interest in early modern mechanics contained yet another connection to religion besides pious applications. In the Renaissance, mechanics was seen as the means to do things that seemed humanly impossible to achieve, such as the lifting of extremely heavy objects or the mastery of mechanisms hidden inside machines. In 1623, the German Jesuit Johann Chrysostomus Gall (1586–1648) taught a brief course on mechanics in Lisbon following the

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

pseudo-Aristotelian *Mechanical Problems*.[109] Gall writes that "among the mixed sciences of mathematics, there is also mechanics, whose objects [of study] are diverse instruments, machines and inventions of preternatural motions."[110] By preternatural motions, Gall means the kinds of motion beyond the more common, natural motions, in which "by means of art we overcome the obstacles that we cannot overcome in a natural way."[111] Unlike Lembo and Uwens, Gall does not include any religious examples in his classes. And his interest in what he terms the *preternatural* does not necessarily imply a religious motivation, as that term (in Greek *para physis*, or *πάρα φύσιν*) is also used by the author of the pseudo-Aristotelian text.[112] But the Latin rendering of the term as *praeternatura* in the Renaissance linked it to the definition used by Thomas Aquinas to categorize the marvelous, non-miraculous operations of nature whose causes were natural but unseen.[113] Moreover, according to Pamela Long, the discipline of mechanics developed in the Renaissance precisely alongside efforts to make hidden causes visible.[114] Therefore, even if Gall made no explicit mention of religion, the use of the term *preternatural* in his classes connected the science of mechanics to the same intellectual problems that theologians were grappling with, because mechanics made some preternatural phenomena visible and understandable. Gall was one of the first Jesuits to write on mechanics.[115] But later generations of Jesuit authors, such as Athanasius Kircher and Gaspar Schott (1608–66), made the connection between mechanics and the religious preternatural more explicit.[116]

Besides teaching mathematics, what other religious ministries did these Jesuit mathematicians have? How involved were they with the traditional activities of Jesuits as preachers, confessors, and so on? Three other Jesuits who taught mathematics in Portugal help answer these questions. Ignace Stafford (1599–1642) was an Englishman who entered the Society of Jesus in Spain in 1618. In 1625 he was sent to Lisbon to act mainly as a confessor to the court, but in 1630 he started teaching mathematics in the Class of the

[109] ANTT, MS Liv. 2340, "Tratado da Mechanica."

[110] ANTT, MS Liv. 2340, fol. 150^{r}: "Entre as ciencias mixtas da Mathematica, contamos tambem a Mechanica; cuio objecto são diversos instrumentos machinas, e invenções de movimentos preternaturaes."

[111] ANTT, MS Liv. 2340, fol. 150^{r}: "con que vençemos por arte as dificuldades de que pela natureza estamos vencidos."

[112] Aristotle, 330 (*Mechanical Problems* 847a).

[113] On the Latin rendering of Aristotle, see Van Leeuwen, 161. On Thomas Aquinas's usage of preternatural, see Daston, 97–99.

[114] Long, 2004, 14–15, 172, 245–47.

[115] The first Jesuit textbooks on mechanics were only printed after 1650: see Feldhay, 2006.

[116] Waddell, 22–27, 87–117, 161–86.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

Sphere while also acting as confessor.[117] In 1634, Stafford published a selection of Euclid's *Elements* in Lisbon. This book, despite being written in Spanish, was "consecrated to the name of the most illustrious Lusitanian [i.e., Portuguese] nobility, and it [the book] originated from the powerful command of its requests."[118] The frontispiece shows a fortification in the center bottom and two angels wearing military helmets and holding the coat of arms of Portugal and the United Kingdom in the top left and right (fig. 9). In 1640, Stafford traveled to Brazil as confessor to the viceroy, where he also gave his opinion as a mathematician on a number of fortifications.[119] The three different contexts in which Stafford exercised his activities as confessor and mathematician—the court, the college, and Brazil—suggest that Stafford easily integrated them wherever he was. Thus, listening to confessions and teaching mathematics, although different activities, both seemed to be ways "to help souls"—the main goal of the Jesuits.[120] The religious motif in the frontispiece, which seems almost to crown the Euclidean elements with thorns—an unambiguous reference to the Passion—reinforces the intertwining of religious interests with the practice of mathematics in Portugal. As was common among Jesuits, Stafford finished his work with a brief prayer to offer his work "for the greater glory of God" (fig. 10).[121] This conclusion, alongside the Laus Deo (Praise God) that typically ended Jesuit mathematical manuscripts from Lisbon, is not merely a formality, but rather represents the completion of their work as both a religious and a secular task.[122]

Outside of Lisbon, two other Jesuits also taught and worked on mixed mathematics while performing other religious ministries in Portugal. The first was the English Jesuit Richard Gibbons (d. 1632), who taught mathematics in the Jesuit college of Coimbra between 1590 and 1593. In these years, he also taught classes of theology and contributed to the final edition of the first volume (published 1591, on natural philosophy) of the *Conimbricenses* (Coimbra commentaries), one of the most important commentaries on Aristotle's philosophy in the early modern period.[123] Gibbons later taught mathematics in Leuven,

[117] Baldini, 2000, 65n46; Rodrigues, 190–91.

[118] See, in the preface to Stafford, n.p.: "la illustrissima nobleza lusitana; a cuyo nombre consagro el presente trabajo, originado del poderoso imperio de sus ruegos."

[119] L. Costa, 16–17, drawing on Arquivo Histórico Ultramarino, Bahia, Luis. Fons., cx. 9, doc. 1053, letter "Sobre a fortificação da cidade de Bahia," 7 May 1644. See also Magalhães, 120–25.

[120] For a gloss on the phrase "to help souls," see O'Malley, 1993, 18–19.

[121] Stafford, 188.

[122] ANTT, MS Liv. 2340, fol. 165^{v}; BNP, Cod. 4333, fol. 211^{r}. For a similar conclusion, see Drake, 2001, v.

[123] Baldini, 2000, 59n24.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

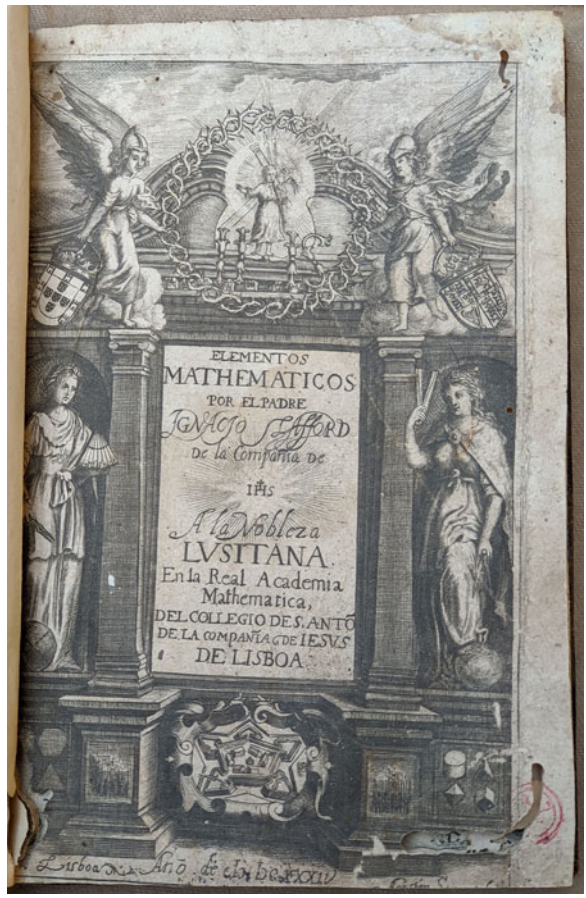

Figure 9. Ignace Stafford. *Elementos Mathematicos* (Lisbon, 1634), frontispiece. Biblioteca Nacional de Portugal, Lisbon, Res. 760 P.

and throughout his life wrote and translated several theological and devotional books.[124] The other Jesuit was Johann König (1639–91), who arrived in Portugal from Germany in 1681 while on his way to East Asia to become a missionary.[125] The apostolic uses of mathematics in the Jesuit mission in China are well known.[126] However, König never boarded a ship to Asia. Before departing he was asked to teach mathematics in the Coimbra college

[124] Backer et al., 1:2118–19.
[125] Rodrigues, 216; Baldini, 2004, 394n173.
[126] Brockey, 2007, 15–16; Hsia, 30–36.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

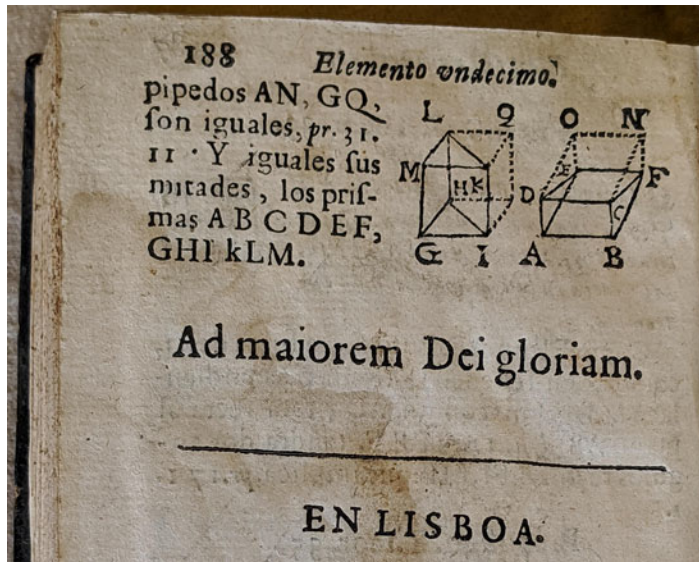

Figure 10. Ignace Stafford. *Elementos Mathematicos*, final page. Biblioteca Nacional de Portugal, Lisbon, Res. 760 P.

from 1682 to 1686.[127] And, when the time of his departure came, the Portuguese King Pedro II (1648–1706) asked him to do a geographic survey of the kingdom, across "the provinces, the towns and fortifications, as well as the seaports."[128] Geography was one of the subdisciplines of mixed mathematics.[129] König carried out the assignment until his death in 1691.[130] But even though he never traveled to East Asia, he channeled his presumed missionary zeal into his ministry to local populations across the lands of Portugal.[131] Thus, a trip that was primarily a scientific expedition became, too, an opportunity for evangelization.

MATERIAL PIETY BEYOND JESUIT SCIENCE

But how ingrained was material piety in the broader religious culture of Portugal? Jesuit mathematicians integrated religious devotions into their scientific work, both in and out of the classroom. But if material piety was central to

[127] Baldini, 2004, 394n173, drawing from Archivum Romanum Societatis Iesu (hereafter ARSI), Lusitania 34, fol. 77^{r}.

[128] Braga, 2:824–25, as quoted in Rodrigues, 214.

[129] See Guldin, 21.

[130] The survey was included in A. Costa, 10.

[131] ARSI, Lusitania 57, fols. 2^{r}–8^{r}.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

early modern Catholicism, it should also be discernible in other contexts. This section looks at the process of canonization of Queen Isabel of Portugal as a way to explore such a context. Since most experts involved in this process were not Jesuits, this case illustrates the interaction between science and devotion in non-Jesuit contexts. Moreover, unlike the Jesuit classes of mathematics, this canonization was primarily a religious project. And yet, practices such as medicine and artisanal culture burst their way in. The canonization process was led by non-scientist clergymen who were interested in scientific insights and artisanal know-how, and in how these could help support religious claims as to whether something was a miracle or not.

It is beyond the scope of this article to analyze Queen Isabel's canonization in detail. And, as mentioned above, historians of medicine have already dealt at length with the uses of medical expertise in the confirmation of miracles, a common practice since at least the late Middle Ages.[132] However, by analyzing this canonization process with an eye toward material culture, the role of material piety becomes much clearer. In these cases, material things, such as relics or holy bodies, carry strong religious meanings in large part because of their materiality, and not in spite of it. This makes sense, because, as I have been arguing, early modern Catholicism fostered an engagement between the material world and the divine in its devotional practices. Therefore, having material piety undergird these devotional enterprises can help historians see beyond the mere institutional need for experts.

Queen Isabel of Portugal, also known as the Holy Queen (Rainha Santa), was the wife of the Portuguese king Dinis I (1261–1325). She gained a reputation for holiness due to her charity toward the poor and her devout life. When she died in 1336, her body was buried at a monastery of Poor Clare nuns that she founded in Coimbra.[133] Originally from Aragon, Queen Isabel was an ideal candidate for sainthood in a period of union of the Portuguese and Spanish Crowns, which explains why Philip III of Spain (Philip II of Portugal, r. 1598–1621) and his wife provided the financial support for the canonization cause.[134] The canonization of Isabel of Portugal was, therefore, a project of the church of Coimbra and of the Iberian Crown. And yet, perhaps surprisingly, some Jesuits also played an important role in this project.

In 1612, João Delgado (ca. 1553–1612), the Jesuit mathematician who founded the Class of the Sphere in Lisbon, was called to Coimbra to oversee the opening of the tomb of Queen Isabel. The postmortem examination of

[132] Ziegler.

[133] For the queen's life and death, see Janninck et al., 173–97 (*Acta Sanctorum* July 4).

[134] See Vasconcellos, 2:106, drawing from BNP, Cod. 8446, "Traslado da comissão dos tres auditores da Rota" (8 June 1611).

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

candidates for sainthood by secular experts was common practice in early modern canonization causes.[135] Until the late seventeenth century, if the body showed few or no signs of decomposition, the church considered it a miracle.[136] Queen Isabel's body was deemed incorrupt and thus, when she was canonized in 1625, this finding counted as one of the officially approved miracles for her process. On 26 March 1612, the Vatican-appointed judges of the cause went to the Poor Clare monastery in Coimbra to examine the queen's body, accompanied by a select group of people: Balthazar d'Azeredo, the chief physician of the king; Antonio Sebastião, another physician from Coimbra; Gonçallo Dias, chief surgeon of the king; João Coutinho, rector of the University of Coimbra; Manuel de Lima, rector of the Jesuit college in Coimbra; the Jesuits André Palmeiro (a theologian) and João Delgado; Gaspar Borges de Azevedo, the main inquisitor of Coimbra; and some others.[137] The presence of these illustrious individuals added a certain solemnity to the day. In fact, the sequence of events that led to the actual examination of the queen's body manifested a theatricality that emphasized the devotional value of the incorruption of the queen's body.

The tomb was covered by a single stone with a sculpted image of Queen Isabel (fig. 11). To open the tomb, the Vatican judges "asked for an architect and official masons who detached, moved away, and raised the said stone that covered the said tomb, with the instruments they brought for that end."[138] It is unclear who these "official masons" were. But the architect was the Jesuit mathematician João Delgado, the only architect among the witnesses. Looking inside the tomb for the first time, the masons found a "coffin [made of] wooden boards covered by a cloth painted in red, already worn out in the outer part and attached with nails all around. And beneath it another cover of ox leather with hair, which also covered and surrounded the coffin."[139] Then, the judges "ordered a religious priest of the Society of Jesus to open the said coffin."[140] Although stated as a simple order, the opening of the coffin implied the careful

[135] See Bouley.

[136] This practice changed in 1712: see Pomata, 2007.

[137] Vasconcellos, 1:397–400.

[138] Vasconcellos, 2:116: "mandarão vir hum architecto, e officiais pedreiros que com os engenhos que para isso trouxerão, desunirão, e apartarão e levantarão a dita pedra que cobria o dito sepulcro."

[139] Vasconcelos, 2:116: "acharão e foi logo visto hum ataude de taboas de madeira, cuberto pella parte decima de hum pano pintado de cor vermelha, ya gastado pella parte de fora e pregado todo ao redor, e por baixo delle outro forro de hum couro de boi com cabello, que tambem cobria e encourava o ditto ataude."

[140] Vasconcelos, 2:116: "e logo mandarão abrir a dita caxa por um religioso sacerdote da companhia de Jesus."

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

Figure 11. Master Pero. Original tomb of Queen Isabel, 1330. Sculpted in two blocks of limestone (the ark and cover). Santa Clara-a-Nova Monastery, Coimbra. Courtesy of Confraria da Rainha Santa Isabel.

removal of all the nails and of the covers because, in the end, "the coffin was immediately nailed" again.[141] This twofold process, of which the masons and the mathematician were the protagonists, reveals the critical role of artisanal knowledge in an event the main goal of which was to determine whether the body was miraculously incorrupt or not—a purely religious question.

When they opened the tomb, the masons found a small purse and a staff with "Santiago shells," which the Bishop of Santiago had reportedly given to Queen Isabel when she visited the Compostela shrine.[142] This staff was given "to the Mother Abbess to save everything as relics," who then "sent [parts of it] to the king of Castile."[143] As material and devotional objects, relics involved a rigorous process of authentication, which developed new forms in the early modern period in the face of Protestant critiques such as those in John

[141] Vasconcelos, 2:126: "O caixão se pregou logo."

[142] Vasconcellos, 2:116.

[143] Vasconcellos, 2:116: "entregarão a madre Abba dessa . . . para que tudo guardasse como reliquias"; Vasconcellos, 2:126: "enviarão a ElRei de Castela hum pedaço."

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

Calvin's *Treatise on Relics* (1543).[144] In this particular case, the authentication of the relics was reinforced by the fact that "official masons" found them in the coffin that had, until their intervention, always been sealed. Besides their spiritual powers as relics, the staff and purse also granted reliability to older accounts of the queen's life, in which these artifacts were mentioned. This was also an important element of authentication because the longevity and accuracy of historical accounts were important banners of the Catholic Reformation.[145]

After the careful examination of the queen's body, the masons placed new covers on top of the body—the old ones were saved as relics—and the large stone at the top was moved back to close the tomb.[146] Ultimately, since most historical accounts tend to focus on the postmortem examinations by medical experts, it might be tempting to think that the masons led by the Jesuit João Delgado, and their opening of the tomb, were not as relevant as the bodily examination. However, Delgado was the only person who traveled from outside of Coimbra to participate in this event. That Delgado, already in his late fifties, came from Lisbon to oversee the opening of Queen Isabel's tomb shows how important this initial process was to the commission judges. Delgado's architectural knowledge and the artisanal skills of the masons, both purely material, lent extra credibility to claims of the incorruption of the queen's body and the integrity of the whole tomb. Moreover, Delgado's status as a mathematician and priest placed him at the intersection of piety and artisanal expertise, and thus he was not only involved in opening the exterior tomb, but also personally opened the interior coffin. By testifying that the tomb had never been opened, Delgado and the masons contributed to the belief in the body's supernatural preservation. What is paradoxical is that, according to Catholic theology, the body of the queen was just "a lifeless object" ("rem insensibilem"), with no soul attached to it.[147] At the same time, the bodies of saints were thought to be "temples and instruments of the Holy Spirit," and thus, in the words of Thomas Aquinas, "God himself grants honor to their relics [by] performing miracles when they are present."[148] So, although purely material, the bodies of saints were associated with supernatural powers. Yet, in the examination of Queen Isabel's body, the material realities that surrounded

[144] For medieval authentications, see Bartlett, 324–32; for early modern, see Lazure; Brockey, 2015.

[145] See Ditchfield, 1995.

[146] Vasconcellos, 2:117.

[147] Aquinas, 50:202 (*Summa Theologiae* III, q. 25, a. 6). See also Brown, 1981, 2; Bynum, 1995, 13–14. Death was understood as the temporary separation between body and soul, even in the case of Christ: see Aquinas, 54:126–27 (*Summa Theologiae* III, q. 50, a. 3).

[148] Aquinas, 50:203 (*Summa Theologiae* III, q. 25, a. 6).

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

the body seemed to be almost as important as the bodily examination itself. That is, the careful opening of the tomb also mattered to the piety of those involved.

Already excited by the careful opening of the tomb and the discovery of the relics inside, the judges proceeded to examine the central piece of evidence—the body of the queen. While the masons and architect dealt with the tomb, the bodily examination was conducted by medical doctors and the surgeon, who were the corresponding experts in their fields. They found the body "very healthy, whole and without corruption; rather, [it] was very white and odoriferous, and covered in flesh, so that the head had unbroken and blond hair, and pulling it [showed that] it was fixed to the forehead."[149] The physical examinations, such as the pulling of the hair, were undertaken by the three medical experts individually, since each of them mention it. For example, the physician Balthazar d'Azeredo said that he saw "hair in the forehead (where they begin to disappear first)," which he "pulled, and they were attached and very soft, thin, and well colored."[150] The original report continued, reading that "all her face was covered in the same flesh . . . with nose, ears, eyes, and mouth without corruption; the head attached to the body with the neck, very white and intact. Then one could see the breasts with the nipples raised up also very white and clean."[151] Finally, the chief physician "strongly pressed [the queen's chest] with the hand," noticing that "it was firm, without breaking or being destroyed."[152] They could also "see the veins and the nerves in the hand, which had its fingers and nails very intact and consolidated."[153] The judges thereupon said there was no need to continue examining the queen's body, since they wanted to maintain "honesty and reverence toward the said blessed Queen and because it seemed to the doctors that, from what

[149] Vasconcellos, 2:117: "mui são, inteiro, e sem corrupção, antes muito alvo e cheiroso e cuberto de carne, de maneira que a cabeça estava com os cabellos inteiros louros e sãos que pegando por elles estavam fixos à testa." The testimonies were written by the commission's notary.

[150] Vasconcellos, 2:121: "Cabellos na Cabeça, é parte dianteira (onde mais cedo faltão) pellos quaes eu puxei, e estavão pegados, e mui brandos, delgados, e bem corados." The chief surgeon Gonçallo Dias also said a similar thing, in Vasconcellos, 2:124, drawing from BNP, Cod. 8446, 1454.

[151] Vasconcelos, 2:117: "e todo o rosto cuberto da mesma carne . . . com naris, orelhas, olhos, e boca sem corrupção[,] pegada a dita da cabeça ao corpo com seu pescoço, muito alvo e inteiro, e dahi seuiam os peitos com as tetas levantadas tambem muito alvos e enxutos."

[152] Vasconcelos, 2:117: "e pondolhe a mão com muita força, estava firme sem se quebrar nem desfazer.

[153] Vasconcelos, 2:117: "descobrindose as veas, e os nervos na mão, a qual estava com seus dedos e unhas mui inteira e consolidade."

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

they saw, everything else would be equally preserved."[154] This decision to stop the examination out of "honesty and reverence" shows that the examination of the queen's breasts did not "come across as suggestively sexual," as recently proposed.[155] On the contrary, the queen's uncorrupted breast pointed to common miracles associated with her cult, that of helping women who struggled with breastfeeding. In the end, the surgeon Gonçallo Dias, almost repeating what the physicians said, wrote that it was "beyond nature and out of [natural] order that a body could remain so many years without corruption, which cannot happen but miraculously."[156]

Upon the medical confirmation of incorruption, all those present erupted in praise. The nuns of the convent, who were able to see the examination only from afar and with the help of a mirror, immediately started singing psalms of thanksgiving.[157] And the count-bishop of Coimbra—himself one of the Vatican-appointed judges—exploded with enthusiasm, saying that "in good theology" Queen Isabel was second in holiness only to the Virgin Mary and Saint John the Baptist.[158] That is, the material examination of the queen's body—a material object from a theological point of view—triggered the devotion of those present. The report of three medical experts confirmed that the body could not have become incorrupt by natural means. Thus, if in Lisbon the Jesuits used mathematics to portray supernatural realities by means of illusions and mechanical devices, the opposite happened in this postmortem examination in Coimbra, where medical and artisanal expertise were used to confirm what the actors understood as a supernatural reality. Yet, both cases relied on natural knowledge—medicine or mixed mathematics—in order to excite the piety of those present. The joyous cries of piety from those present also served as an illustration of existing devotion to the potential saint, something that a process of canonization also had to demonstrate. Ideally, those who would read the process in the Vatican would be convinced not just of the body's

[154] Vasconcelos, 2:117: "por reverencia e honestidade da dita beata Rainha e parecer aos medicos que pello que vião estaria tudo o mais na mesma conformidade e inteireza."

[155] Bouley, 124. Bouley's conclusion derives from the Latin word *erectis*, in the Vatican archives' report. However, the original Portuguese report uses the more neutral word *levantadas* (raised).

[156] See Vasconcellos, 2:124, drawing from BNP, Cod. 8446, 1455: "he fora do natural e fora de ordem, estar hum Corpo tantos annos sem Corrupsão, o que não pode ser senão miraculosamente."

[157] Vasconcellos, 2:126. This contrasts with the case of Saint Catherine of Bologna, also in a Poor Clare monastery, where the nuns had exclusive access to the Catherine's body: see Pomata, 2007, 573.

[158] Vasconcellos, 2:120: "em boa theologia."

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

incorruption, but also of its miraculous nature and of the devotion it triggered, hence the graphic descriptions of the queen's body and of the subsequent exultation.

Many other miracles were attributed to the intercession of Queen Isabel, although only a handful were considered authentic miracles by the Vatican. For instance, the Jesuit André Palmeiro (1569–1635), professor of theology at the Jesuit college in Coimbra, was the first of more than a hundred persons to be interviewed in spring 1612 for this process of canonization.[159] He said that the queen was known still to operate miracles, such as helping mothers whose milk had dried up and who still needed it to breastfeed their children; or the specific case of another Jesuit, Luís Pinheiro (1550–1620), who had a tumor in his head: after the doctors' recommendations for Pinheiro did not work, a priest said Mass at the queen's tomb for him and brought some of the oil from a candle used during Mass. After dipping the oil on the Jesuit's head, he was healed. Palmeiro concluded this was a miracle because oil lacked the "natural forces" to produce such a rapid effect.[160] However, even though Palmeiro was a well-educated Jesuit, this miracle, like many others, did not pass the scrutiny of the Roman judges.[161]

Queen Isabel was canonized in 1625. But what criteria did the Vatican judges use to make a decision on the supernatural character of miracles? For miracles of that period, and particularly those that immediately preceded the canonization process, the most important factor was the testimony of expert eyewitnesses. The best experts for healing miracles were medical practitioners like physicians and surgeons. Of all the 120 witnesses interrogated in Coimbra, four were trained in medicine: Balthazar d'Azeredo (1552–1631), the king's chief physician in Portugal; Antonio Sebastião, a physician; João de Goerres, a physician from Leuven who lived in Coimbra; and Miguel Luiz, a surgeon. The latter two are particularly important because they had witnessed miracles happening in their households that ended up making the final cut of approved miracles. For instance, in the miracle testified to by João de Goerres, the healed person was his wife, who was unable to nurse their newborn child because of a throat disease. De Goerres said that "as the doctor that he was, [he] tried to heal her in diverse ways, but the disease continued to grow nonetheless."[162] However, one night, de Goerres woke up and "prayed much to the

[159] Vasconcellos, 1:366.

[160] BNP, Cod. 8446, 164: "forças naturais." This is also quoted in Brockey, 2014, 70.

[161] The list of all approved miracles in Rome can be found in Janninck et al., 208–10 (*Acta Sanctorum* July 4).

[162] Vasconcellos, 1:432n1: "de maneira que a curara elle testemunha como medico que é, com diversas mezinhas, e que com tudo isso o mal fora por diante."

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

Holy Queen for his wife, so that she would give her health and would help her in this need."[163] Immediately after this request, de Goerres was certain that the favor had been granted. Thus, the next morning he saw his wife "with her breasts filled with milk . . . and nursing the said child with great abundance, healthy and with no disease."[164] A total of five people testified to this miracle. All of them were members of the de Goerres household, and all concurred in the essential points—that the disease had not been possible to heal by natural means, that the healing took place instantaneously at night, and that the wife was healed by the intercession of Queen Isabel.[165]

Another approved miracle was that of a fifty-year-old woman who, due to personal circumstances, had to take care of her newborn grandson.[166] Due to old age, she was not able to nurse the baby. It was only upon a pilgrimage to Queen Isabel's tomb that she was able to produce the milk needed to breastfeed her grandson. There were only two witnesses for this miracle, the grandmother herself and her husband, the surgeon Miguel Luiz. Luiz's testimony was more complete than that of his wife. He mentioned that his grandson had measles, which disappeared only upon his wife's prayers to the Holy Queen. Moreover, he added that twenty-two years before, when his wife had to nurse their daughter, she had some difficulty, because one of her breasts did not produce milk. Yet, after the miracle she not only was able to produce milk from both breasts, but the one that had failed before was now the more productive.[167] These accounts indicated two main things: that the healings could not have happened in a natural way and that the healing happened after invoking the help of Queen Isabel. These were significant details for the judges in Rome. But perhaps more revealing of material evidence in this canonization process is the centrality of breastfeeding in the miracles, since they indicated what seemed to be the Holy Queen's particular interest in this very human and material condition.[168] According to the account of the Jesuit André Palmeiro, this was a common miracle attributed to Queen Isabel at the time. Breastfeeding was indeed a typical symbol of the virtue of charity in the early modern period; the lactation of the Virgin Mary was a popular theme in late medieval and early modern Catholic art.[169] Considering that the postmortem account also mentioned her

[163] Vasconcellos, 1:432n1: "encomendara sua mulher muito à Rainha Santa, que lhe desse saúde e lhe acudisse aquella necessidade."

[164] Vasconcellos, 1:433, "com os peitos cheios de leite e . . . criando o ditto menino com muita abastança, sãm e sem enfermidade alguma."

[165] Vasconcellos, 1:431–35.

[166] Vasconcellos, 1:428–30.

[167] Full account in Vasconcellos, 1:430n1.

[168] For a similar phenomenon, see Pomata, 2001.

[169] See Sperling, 2013 and 2018; Lyon.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

uncorrupted breasts, it was as if the queen's virtue of charity continued to work even after her death.

The role of material evidence in validating supernatural realities becomes especially clear in a miracle attributed to the intercession of Queen Isabel, to which all the witnesses were carpenters. Domingos Machado, the "carpentry official" of the Poor Clare monastery, was fixing the roof of one of the monastery's buildings early in 1612.[170] At some point, eight of the beams of the ceiling where he was standing fell, taking him with them: "As he was falling, [Domingos] prayed to the Holy Queen and the beams, being already distanced from their place more than four spans, returned to their place, and he was safe from harm. . . . And himself, as the witness, and all those who were with him understood the fact that he did not fall and that those beams moved upward, back to the place where they originally were, as a miracle of the Holy Queen."[171] The report added that Machado "knew according to his craft and the art of carpentry that those logs could not return upward, since they were already falling with their weight."[172] This testimony was confirmed by two other carpenters who also witnessed the event.[173] Their role in showing how this phenomenon "could not have happened naturally," as one of the carpenters said, is crucial for attesting the miracle.[174] By having recourse to carpenter eyewitnesses, the canonization commission and officials in Rome were assured that there was no other way for this phenomenon to have happened, except by miraculous means. Thus, it was not natural knowledge per se but rather familiarity with the natural order of the material world that was the main requirement to define the miracles. This familiarity was also patent in the two previous healing miracles, in which the witnesses were all members of the cured patients' households. However, the role of materiality is particularly strong in the breastfeeding element of the healing miracles and in the less common artisanal context of the carpentry miracle.

[170] Vasconcellos, 1:427n1: "official de carpintaria."

[171] Vasconcellos, 1:427n1: "e indo ya caindo chamara pella rainha santa e as ditas asnas estando ja apartadas do Canto em que dantes estavão seguras, mais de quatro palmos, se tornarão a endereitar pera cima, e elle ficara salvo do perigo. . . . e elle testemunha e todos os mais que estavão com elle tiverão por milagre da Rainha Santa, o não cair elle, e tornarem se aquelles paos a levantar ao seu mesmo lugar donde estavão dantes."

[172] Vasconcellos, 1:427n1: "elle testemunha intendia, conforme a seu officio e arte de carpentaria que sabia, que nao podião aquelles paos tornar acima, indo ya pendendo com opeso."

[173] Vasconcellos 1:427–28.

[174] Vasconcellos, 1:427n2: "o que não podia ser naturalmente."

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

CONCLUSION

From Lembo's dolorous crucifixes to Uwens's fountain of wine, and from Stafford's scientific ministries to the role of material knowledge—both medical and artisanal—in the canonization of Queen Isabel, this essay has introduced a variety of cases in which science and religion supported each other in new and powerful ways. These cases illustrate an intentional, and even mechanical, use of the material world to promote religious devotion. Natural knowledge was used to portray supernatural truth by means of sensuous representations in paintings or, as shown here, in mechanical devices. This disposition toward material things, which characterized much of the Catholic Reformation, manifested itself not only in art, but also in the science practiced and taught in religious environments. In some cases, this affinity for material displays of piety reached levels of intensity that could be achieved only through a deep mastery of nature, exemplified in the knowledge of mechanics and hydrostatics. It thus becomes clear that, in many cases, the church's interest in early modern science originated not just in an institutional demand for scientific expertise, as John Heilbron and others rightly suggest, but also in a material piety that lent spiritual support to practitioners' actions. Perhaps it was not a "love of science," to use Heilbron's words, but rather a love of the material world (as a conduit to the divine) that moved priests to study nature.[175]

There is also a surprising silence in all these cases: namely, the absence of any obstacles to the practice of science among religious men. As Mordechai Feingold argues, the religious vocation could in fact be an obstacle to the scientific vocation, not just among Protestant clergy, but sometimes even among the Jesuits, especially after Galileo's condemnation.[176] But in the case of seventeenth-century Portugal, at least, this was barely felt. On the contrary, scientific projects often delayed, and sometimes canceled, religious ministries that were planned well in advance. Hendrick Uwens had his departure to Goa delayed in order to teach mathematics in the Class of the Sphere, and Johann König never became a missionary in East Asia because he was asked to do a geographic survey of Portugal.[177] Nonetheless, although this article's cases span from Lisbon to Coimbra, and even beyond the Jesuit realm, it might be tempting to consider these cases uncommon in the history of science. But perhaps what is uncommon are not these cases themselves but rather a method of analysis that takes the actors' religion and devotion seriously. As I demonstrate, the boundaries between religious and scientific activities were substantially blurred: for the actors studied here, the engagement with science was

[175] Heilbron, 1999, 3.
[176] See Feingold, 2003, 29–32.
[177] For Uwens, see Castel-Branco.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

not necessarily detached from an ardent desire to reach for God, which it may be assumed these mathematicians had. Material piety played an important part in this as a form of early modern Catholic piety that had at its center an engagement with the material world.

It is beyond the scope of this article to study the situation outside of seventeenth-century Portugal, but a look at similar cases suggests that material piety might play a broader role in explaining the interaction of science and religious culture elsewhere. For instance, Orazio Grassi (1583–1654), the Italian Jesuit who became Galileo's main adversary in the controversy on comets, wrote an essay associating the Virgin Mary's invocation as Stella Maris (Star of the Sea) with salvation and navigational mathematics.[178] Like Uwens, Grassi also used machines in theatrical scenery, especially in the theater celebrating the canonization of the first two Jesuit saints—Ignatius Loyola and Francis Xavier.[179] And, as Delgado worked as an architect in Portugal, Grassi also led after 1627 the construction of the Church of St. Ignatius, attached to the Jesuit Roman College.[180] Finally, in 1633, Grassi left his post as mathematician at the Roman College to become a confessor in Genoa, as Ignace Stafford also did in Lisbon and Brazil.[181] But the organic interaction between early modern science and devotion was not confined to the Jesuits. The Oratorian Antonio Gallonio (1556–1605), for example, in his writings on canonizations, medicine, and engineering, "endeavored to claim for the priesthood aspects . . . that at first sight seemed to be the preserve of worldly experts."[182] One thing is certain: material piety could vary considerably in the world of early modern Catholicism. As the many foreign Jesuit mathematicians arrived in seventeenth-century Lisbon, they adapted their teaching to local forms of material piety. Only thus is it possible to understand Lembo's focus on bleeding crucifixes or the frontispiece of Stafford's *Elements of Euclid*, with its crown of thorns flanked on one side by the Portuguese coat of arms.

The usefulness of the concept of material piety for the history of science and religion leads to two final observations. The first has to do with the development of science in Southern Europe in the seventeenth and early eighteenth centuries. As I have shown, important features of early modern science, such as the mechanical manipulation of nature or the interest in mathematics, were integral to Baroque culture and, therefore, to early modern Catholicism.[183] In the

[178] Heilbron, 2010, 234.
[179] Heilbron, 2010, 234.
[180] Preti and Ercolino.
[181] Preti and Ercolino.
[182] Touber, 2.
[183] For science in Iberian, non-religious Baroque art, see Marcaida and Pimentel, 101.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

canonization of Queen Isabel, the selection of miracles whose witnesses were familiar with both medicine and the healed person is part of a larger history in which, according to Peter Dear, "like experimental claims, miracles appealed to ideas and assumptions about the 'ordinary course of nature.'"[184] Dear goes so far as to claim that the cultural belief in modern miracles supported the mathematical sciences in early modern Catholic France (and that their rejection promoted the experimental sciences in Protestant England), an idea previously suggested by Thomas Kuhn.[185] More interestingly, "medical expertise," and in this Portuguese case artisanal expertise too, "played a decisive role in the process that turned miracles from objects of faith into objects of knowledge," as Gianna Pomata states.[186] Thus, if material piety tended to foster an openness toward the study of the natural world, sources associated primarily with religious culture may help improve our understanding of the history of science in seventeenth- and eighteenth-century Iberia and elsewhere.[187]

A second and final comment has to do with the relation between material piety and theology. A common feature of Lembo's and Uwens's mathematical devices is their focus on the Passion of Christ, a theme also present in Stafford's frontispiece. Devotion to the Passion implied a meditation on Christ's sufferings and, consequently, on Christ's materiality as a human being. Incarnational theology acquired a new emphasis in the early modern period, especially due to the devotional practices of the Catholic Reformation. The Tridentine reform of the liturgy, for example, added a common final reading to the Roman rite of the Mass.[188] This reading—the first fourteen verses of the Gospel of John—was always the same throughout the year and the rubrics of the missal required the celebrant to kneel at the words "et verbum caro factum est," to further emphasize that "the Word was made flesh."[189] Lembo, Uwens, and all the priests mentioned in this essay performed this liturgy every day. John O'Malley and others have argued that the devotional life of the *Spiritual Exercises* was itself a manifestation of this theological trend that emphasized the doctrine of incarnation.[190] The emphasis on the sacraments, the increase in the number of canonizations after Trent, and the specific role of

[184] Dear, 674.

[185] Dear, 682–83; Kuhn. Both historians allowed for several exceptions.

[186] Pomata, 2007, 569.

[187] For recent studies and similar conclusions, see Giurgevich; Macuglia; Portuondo, 2019a.

[188] Fortescue; Wandel, 10–11, 250–51; Jungmann, 2:447–51.

[189] BNP, Res. 2442 V., page 18: "Cum dicitur 'Et verbum caro factum est,' genuflectit, et surgens progreditur."

[190] O'Malley, 2013, 39–40; Melion, 13–15.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

breastfeeding in devotion to Queen Isabel can all be read as a testimony to the early modern interest in the incarnation and humanity of Christ.[191]

The question, however, is how much this incarnational theology influenced the scientific work of Jesuit mathematicians. Part of the answer can be found in the kind of theology that the Jesuits studied, since most of them had to defend a thesis at the end of their studies. For example, André Palmeiro, one of the Jesuit theologians who witnessed the examination of Queen Isabel's body, sat as discussant in several theological theses, of which the only extant one is on "whether the incarnation of the Divine Word would have happened if Adam had not sinned."[192] There are not many sources on the theological preferences of most Jesuit mathematicians in Portugal. But Luíz Gonzaga (1666–1747), a Jesuit who taught in the Lisbon class of mathematics from 1700 to 1706, defended his theology dissertation in 1697 precisely "on the mystery of incarnation."[193] And Richard Gibbons, the Jesuit who taught mathematics in Coimbra, and in other places throughout Europe, included among his theological writings a book *De Praecipuis Incarnati Verbi Mysteriis* (On the special mysteries of the incarnation of the Word).[194] More importantly, incarnational theology might also shed light on the early modern Jesuit interest in mixed mathematics as opposed to pure mathematics. Instead of bringing mathematics into natural philosophy, the Jesuits were using mixed mathematics to bring the natural world and its causes into their mathematics classrooms. The role of Jesuit mathematicians in this naturalization or physicalization of mathematics might usefully be explored in this light.[195] One may also ask to what extent material piety was behind this move from pure to mixed mathematics, since the theology of incarnation represents a similar move of making the divine, often hidden in more theoretical discussions, human.

[191] Bireley, 2008, 149, 157–58; Ditchfield, 2008, 205–06.
[192] BNP, R. 6512/1 A. See also Brockey, 2014, 66.
[193] Biblioteca da Ajuda, 46-VIII-23, doc. 1. On Gonzaga, see Baldini, 2004, 404n206.
[194] Gibbons.
[195] See Heeffer; Dupré, 2014.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

BIBLIOGRAPHY

Archival and Manuscript Sources

Archivum Romanum Societatis Iesu (ARSI), Rome, Lusitania 57.

Arquivo Nacional da Torre do Tombo (ANTT), Lisbon, Manuscritos da Livraria 1770, fols. 95^{r}–120^{v}. Giovanni Paolo Lembo. "Tratado Breve das Máquinas Hidráulicas." 1617.

ANTT, Manuscritos da Livraria 2340 (4), fols. 150^{r}–165^{v}. Johann Chrysostomus Gall. "Tratado da Mechanica." 1623.

Biblioteca da Ajuda, Lisbon, 46-VIII-23, doc. 1. Luíz Gonzaga. *Conclusiones Theologicas pro Mysterio Incarnationis . . . Defendet Aloisius Gonzaga.* Coimbra, 1697.

Biblioteca Nacional de Portugal (BNP), Lisbon, Cod. 4333. Hendrick Uwens. "Tratado da Estática." 1645.

BNP, Cod. 8446. "Auto do processo . . . na causa de canonização da Beata dona Isabel." 1612.

BNP, R. 6512/1 A. João Rocha and André Palmeiro. *Conclusiones ex Tertia Theologiae Parte . . . Utrum Adamo non Peccante Futura Esset Divini Verbi Incarnatio.* Coimbra, 1614.

BNP, Res. 2442 V. *Missale Romanvum ex Decreto . . . Tridentini . . .* Coimbra, 1583.

Biblioteca Pública de Évora, Évora, CXXVI/2-7. Hendrick Uwens. "Tratado Mathematico da Estatica." 1645.

Printed Sources

Antonelli, Francesco. *De Inquisitione Medico-Legali super Miraculis in Causis Beatificationis et Canonizationis*. Rome: Pontificium Athenaeum Antonianum, 1962.

Aquinas, Thomas. *Summa Theologiae*. Ed. Thomas Gilby, OP. 61 vols. London: Eyre and Spottiswoode, 1964–76.

Aristotle. *Minor Works*. Trans. Walter S. Hett. Loeb Classical Library. Cambridge, MA: Harvard University Press, 1955.

The Ashgate Research Companion to the Counter-Reformation. Ed. Alexandra Bamji, Geert Janssen, and Mary Laven. Farnham: Ashgate, 2013.

Backer, Augustin de, Alois de Backer, and Carlos Sommervogel, eds. *Bibliothèque des Écrivains de la Compagnie de Jésus*. 3 vols. Paris, 1869–76.

Baldini, Ugo. "The Portuguese Assistancy of the Society of Jesus and Scientific Activities in Its Asian Missions until 1640." In *History of Mathematical Sciences: Portugal and East Asia, I–História das Ciências Matemáticas: Portugal e o Oriente*, ed. Luís Saraiva, 49–104. Lisbon: Fundação Oriente, 2000.

Baldini, Ugo. "The Teaching of Mathematics in the Jesuit Colleges of Portugal from 1640 to Pombal." In *The Practice of Mathematics in Portugal*, ed. Luís Saraiva and Henrique Leitão, 293–721. Coimbra: Imprensa da Universidade de Coimbra, 2004.

Baldini, Ugo. "Giovanni Paolo Lembo's Lessons in Lisbon: A Partial Content Analysis." In *Proceedings of the International Conference "History of Astronomy in Portugal": Institutions, Theories, Practices*, ed. Luís Saraiva, 123–81. Porto: Sociedade Portuguesa de Astronomia, 2014.

Bartlett, Robert. *Why Can the Dead Do Such Great Things? Saints and Worshippers from the Martyrs to the Reformation*. Princeton, NJ: Princeton University Press, 2015.

Bertoloni Meli, Domenico. *Thinking with Objects: The Transformation of Mechanics in the Seventeenth Century*. Baltimore, MD: Johns Hopkins University Press, 2006.

Biagioli, Mario. "The Social Status of Italian Mathematicians." *History of Science* 27 (1989): 41–95.

Bireley, Robert. *The Refashioning of Catholicism, 1450–1700: A Reassessment of the Counter Reformation*. Washington, DC: Catholic University of America Press, 1999.

Bireley, Robert. "Redefining Catholicism: Trent and Beyond." In *The Cambridge History of Christianity: Vol. 6* (2008), 145–61.

Bouley, Bradford. *Pious Postmortems: Anatomy, Sanctity, and the Catholic Church in Early Modern Europe*. Philadelphia: University of Pennsylvania Press, 2017.

Braga, Teófilo. *Historia da Universidade de Coimbra nas Suas Relações com a Instrucção Publica Portugueza*. 4 vols. Lisbon: Academia das Ciências de Lisboa, 1892–1902.

Brockey, Liam. *Journey to the East: The Jesuit Mission to China, 1579–1724*. Cambridge, MA: Harvard University Press, 2007

Brockey, Liam. *The Visitor: André Palmeiro and the Jesuits in Asia*. Cambridge, MA: Harvard University Press, 2014.

Brockey, Liam. "The Cruelest Honor: The Relics of Francis Xavier in Early-Modern Asia." *Catholic Historical Review* 101 (2015): 41–64.

Brown, Peter. *The Cult of the Saints: Its Rise and Function in Latin Christianity*. Chicago: University of Chicago Press, 1981.

Brown, Peter. *The Body and Society: Men, Women, and Sexual Renunciation in Early Christianity*. New York: Columbia University Press, 1988.

Bynum, Caroline Walker. *The Resurrection of the Body in Western Christianity, 200–1336*. New York: Columbia University Press, 1995.

Bynum, Caroline Walker. *Wonderful Blood: Theology and Practice in Late Medieval Northern Germany and Beyond*. Philadelphia: University of Pennsylvania Press, 2007.

Bynum, Caroline Walker. *Christian Materiality: An Essay on Religion in Late Medieval Europe*. New York: Zone Books, 2011.

The Cambridge History of Christianity: Vol. 6, Reform and Expansion, 1500–1660. Ed. R. Po-Chia Hsia. Cambridge: Cambridge University Press, 2008.

Castel-Branco, Nuno. "From Flanders to Lisbon to the Mughal Empire: Hendrick Uwens and the Mathematical Backstage of a Jesuit Missionary's Life." *Early Science and Medicine* 25.3 (2020): 1–26.

Castelli, Benedetto. *Della Misura dell'Acque Correnti*. Rome, 1628.

Ceballos, Alfonso Rodríguez. "Image and Counter-Reformation in Spain and Spanish America." In *Sacred Spain: Art and Belief in the Spanish World* (2010), 15–35.

Chalmers, Alan. *One Hundred Years of Pressure: Hydrostatics from Stevin to Newton*. Cham: Springer, 2017.

Christian, William, Jr. "Images as Beings in Early Modern Spain." In *Sacred Spain: Art and Belief in the Spanish World* (2010), 75–100.

Commandino, Federico. *Heronis Alexandrinis Spiritalium Liber*. Cambrai, 1583.

Costa, Antonio Carvalho da. *Corografia Portugeza*. Lisbon, 1706.

Costa, Luiz Monteiro da. *O Engenheiro Jesuíta Stafford, Confessor do Marquês de Montalvão: Apontamentos para a História do Primeiro Vice-Rei do Brasil*. Salvador: Centro de Estudos Bahianos, 1954.

Coyne, George, Michael A. Hoskin, and Olaf Pedersen, eds. *Gregorian Reform of the Calendar*. Vatican City: Specola Vaticana, 1983.

Dal Monte, Guidobaldo. *Mechanicorum Liber*. Pisa, 1577.
Daston, Lorraine. "Marvelous Facts and Miraculous Evidence in Early Modern Europe." *Critical Inquiry* 18.1 (1991): 93–124.
Dear, Peter. "Miracles, Experiments, and the Ordinary Course of Nature." *Isis* 81.4 (1990): 663–83.
de Boer, Wietse. "The Counter-Reformation of the Senses." In *The Ashgate Research Companion* (2013), 243–60.
de Boer, Wietse, and Christine Göttler. "Introduction: The Sacred and the Sense in an Age of Reform." In *Religion and the Senses in Early Modern Europe* (2013), 1–13.
Della Porta, Giovanni Battista. *Pnevmaticorvm Libri Tres*. Naples, 1601.
Ditchfield, Simon. *Liturgy, Sanctity and History in Tridentine Italy: Pietro Maria Campi and the Preservation of the Particular*. Cambridge: Cambridge University Press, 1995.
Ditchfield, Simon. "Tridentine Worship and the Cult of Saints." In *The Cambridge History of Christianity: Vol. 6* (2008), 201–24.
Drake, Stillman. *Galileo: A Very Short Introduction*. Oxford: Oxford University Press, 2001.
Dugas, René. *A History of Mechanics*. New York: Dover Publications, 1988.
Dupré, Sven. "Jesuit Responses to Kepler's New Theory of Images." In *Religion and the Senses in Early Modern Europe* (2013), 473–87.
Dupré, Sven. Review of *Baroque Science*, by Ofer Gal and Raz Chen-Morris. *Early Science and Medicine* 19.4 (2014): 373–75.
Eire, Carlos. *Reformations: The Early Modern World, 1450–1650*. New Haven, CT: Yale University Press, 2017.
Febvre, Lucien. *The Problem of Unbelief in the Sixteenth Century: The Religion of Rabelais*. Trans. Beatrice Gottlieb. Cambridge, MA: Harvard University Press, 1982.
Feingold, Mordechai. "Science as Calling? The Early Modern Dilemma." *Science in Context* 15.1 (2002): 79–119.
Feingold, Mordechai. "Jesuits: Savants." In *Jesuit Science and the Republic of Letters*, ed. Mordechai Feingold, 1–45. Cambridge, MA: MIT Press, 2003.
Feldhay, Rivka. "On Wonderful Machines: The Transmission of Mechanical Knowledge by Jesuits." *Science and Education* 15 (2006): 151–72.
Feldhay, Rivka. "Thomist Epistemology of Faith: The Road from 'Scientia' to Science." *Science in Context* 20.3 (2007): 401–21.
Fortescue, Adrian. "Gospel in the Liturgy." In *The Catholic Encyclopedia*, 6:659–63. New York: Robert Appleton Company, 1909.
Fumaroli, Marc. *L'Age de L'Eloquence: Rhétorique et "res literaria" de la Renaissance au seuil de l'époque Classique*. Geneva: Droz, 1980.
Funkenstein, Amos. *Theology and the Scientific Imagination: From the Middle Ages to the Seventeenth Century*. Princeton, NJ: Princeton University Press, 1986.
Galinsky, Karl. *The Herakles Theme: The Adaptations of the Hero in Literature from Homer to the Twentieth Century*. Totowa, NJ: Rowman and Littlefield, 1972.
Geary, Patrick J. *Furta Sacra: Thefts of Relics in the Central Middle Ages*. Princeton, NJ: Princeton University Press, 1978.
Gibbons, Richard. *Historiae Admirandae . . . de Praecipuis Incarnati Verbi Mysteriis*. Douay, 1616.

Giurgevich, Luana. "Visiting Old Libraries: Scientific Books in the Religious Institutions of Early Modern Portugal." *Early Science and Medicine* 21 (2016): 252–72.

Guldin, Paul. *De Centro Gravitatis Trium Specierum Quantitatis Continuae*. Vienna, 1635.

Hall, Marcia. "Introduction." In *The Sensuous in the Counter-Reformation Church* (2013), 1–20.

Harbison, Robert. *Reflections on Baroque*. London: Reaktion Books, 2000.

Harrison, Peter. *The Fall of Man and the Foundations of Science*. Cambridge: Cambridge University Press, 2008.

Heeffer, Albrecht. "Identifying Adequate Models in Physico-Mathematics: Descartes' Analysis of the Rainbow." In *Model-Based Reasoning in Science and Technology: Theoretical and Cognitive Issues*, ed. Magnani Lorenzo, 431–48. Berlin: Springer, 2013.

Heilbron, John. *The Sun in the Church: Cathedrals as Solar Observatories*. Cambridge, MA: Harvard University Press, 1999.

Heilbron, John. *Galileo*. Oxford: Oxford University Press, 2010.

Hellyer, Marcus. *Catholic Physics: Jesuit Natural Philosophy in Early Modern Germany*. Notre Dame, IN: University of Notre Dame Press, 2005.

Howe, Nicholas, ed. *Ceremonial Culture in Pre-Modern Europe*. Notre Dame, IN: University of Notre Dame Press, 2007.

Hsia, Florence. *Sojourners in a Strange Land: Jesuits and Their Scientific Missions in Late Imperial China*. Chicago: University of Chicago Press, 2009.

Janninck, Conrad, Jean-Baptiste du Sollier, and Joannes Pinnius. *Acta Sanctorum Julii . . . Tomus II*. Antwerp, 1721.

Jorink, Eric. *Reading the Book of Nature in the Dutch Golden Age, 1575–1715*. Trans. Peter Mason. Leiden: Brill, 2010.

Jungmann, Joseph. *The Mass of the Roman Rite: Its Origin and Development*. 2 vols. New York: Benziger, 1951–55.

Keitt, Andrew. "Religious Enthusiasm, the Spanish Inquisition, and the Disenchantment of the World." *Journal of the History of Ideas* 65.2 (2004): 231–50.

Kemp, Martin. *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat*. New Haven, CT: Yale University Press, 1990.

Kimmel, Seth. "Automatons and the Early Modern Drama of Skepticism." In *Science on Stage in Early Modern Spain* (2019), 210–30.

Kuhn, Thomas. "Mathematical versus Experimental Traditions in the Development of Physical Science." In *The Essential Tension: Selected Studies in Scientific Tradition and Change*, 31–65. Chicago: University of Chicago Press, 1977.

Lattis, James. *Between Copernicus and Galileo: Christoph Clavius and the Collapse of Ptolemaic Cosmology*. Chicago: University of Chicago Press, 1994.

Lavin, Irving. "Bernini's Death." *Art Bulletin* 54.2 (1972): 159–86.

Lazure, Guy. "Possessing the Sacred: Monarchy and Identity in Philip II's Relic Collection at the Escorial." *Renaissance Quarterly* 60.1 (2007): 58–93.

Leitão, Henrique. "The First Telescopes in Portugal." In *Actas do 1° Congresso Luso-Brasileiro de História da Ciência e da Técnica*, 107–18. Évora: Universidade de Évora, 2001.

Leitão, Henrique. "Jesuit Mathematical Practice in Portugal, 1540–1759." In *The New Science and Jesuit Science: Seventeenth Century Perspectives*, ed. Mordechai Feingold, 229–47. Dordrecht: Kluwer Academic Publishers, 2003.

Leitão, Henrique. *A Ciência na Aula da Esfera no Colégio de Santo Antão, 1590–1759*. Lisbon: Comissariado Geral das Comemorações do V Centenário do Nascimento de São Francisco Xavier, 2007.

Long, Pamela. *Openness, Secrecy, Authorship: Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance*. Baltimore, MD: Johns Hopkins University Press, 2004.

Long, Pamela. *Engineering the Eternal City: Infrastructure, Topography, and the Culture of Knowledge in Late Sixteenth-Century Rome*. Chicago: University of Chicago Press, 2018.

Loyola, Ignatius. *The Spiritual Exercises of St. Ignatius*. Trans. Louis Puhl. New York: Vintage Books, 2000.

Lyon, J. Vanessa. "Full of Grace: Lactation, Expression and 'Colorito' Painting in Some Early Works by Rubens." In *Medieval and Renaissance Lactations* (2013), 255–77.

Macuglia, Daniele. "Newtonianism and Information Control in Rome at the Wake of the Eighteenth Century." *Annals of Science* 77.1 (2020): 108–26.

Magalhães, Pablo Antonio. "Equus Rusus: A Igreja Católica e as Guerras Neerlandesas na Bahia (1624–1654)." PhD diss., Universidade Federal da Bahia, 2010.

Mainz, Valerie, and Emma Stafford. "Introduction: The Transmission of a Classical Tradition in Theory and Practice." In *The Exemplary Hercules from the Renaissance to the Enlightenment and Beyond*, ed. Valerie Mainz and Emma Stafford, 1–21. Leiden: Brill, 2020

Marcaida, Jose, and Juan Pimentel. "Dead Natures or Still Life? Science, Art and Collecting in the Spanish Baroque." In *Collecting across Cultures: Material Exchanges in the Early Modern Atlantic World*, ed. Daniela Bleichmar and Peter C. Mancall, 99–115, 304–07. Philadelphia: University of Pennsylvania Press, 2011.

Martin, John. "Immagini della Virtù: The Paintings of the Camerino Farnese." *Art Bulletin* 38. 2 (1956): 91–112.

Mártires, Bartolomeu dos. *Catecismo ou Doutrina Cristã e Práticas Espirituais*. Ed. Arlindo Ribeiro da Cunha. Porto: Ed. do Movimento Bartolomeano, 1962.

McHugh, John A., and Charles J. Callan, trans. *Catechism of the Council of Trent for Parish Priests: Issued by Order of Pope Pius V*. Rockford, IL: Tan Books, 1982.

Medieval and Renaissance Lactations: Images, Rhetorics, Practices. Ed. Jutta Gisela Sperling. Farnham: Ashgate, 2013.

Melion, Walter. *The Meditative Art: Studies in the Northern Devotional Print, 1550–1625*. Philadelphia, PA: St. Joseph's University Press, 2009.

Mello, Magno, and Henrique Leitão. "A Pintura Barroca e a Cultura Matemática dos Jesuítas: O *Tratado de Prospectiva* de Inácio Vieira, S.J. (1715)." *Revista de História da Arte* 1 (2005): 95–142.

Montanari, Tomaso. *La Libertà di Bernini: La sovranità dell'artista e le regole del potere*. Turin: Giulio Einaudi Editore, 2016.

Norman, Larry, ed. *The Theatrical Baroque*. Chicago: David and Alfred Smart Museum of Art; University of Chicago Press, 2001.

O'Malley, John W. *The First Jesuits*. Cambridge, MA: Harvard University Press, 1993.

O'Malley, John W. *Trent and All That: Renaming Catholicism in the Early Modern Era*. Cambridge, MA: Harvard University Press, 2002.

O'Malley, John W. "Trent, Sacred Images, and Catholics' Senses of the Sensuous." In *The Sensuous in the Counter-Reformation Church* (2013), 28–48.

https://doi.org/10.1017/rqx.2021.199 Published online by Cambridge University Press

Paiva, José Pedro. "Spain and Portugal." In *A Companion to the Reformation World*, ed. R. Po-Chia Hsia, 291–310. Oxford: Blackwell, 2004.

Pereda, Felipe. *Crime and Illusion: The Art of Truth in the Spanish Golden Age*. Turnhout: Harvey Miller, 2018.

Pomata, Gianna. "A Christian Utopia of the Renaissance: Elena Duglioli's Spiritual and Physical Motherhood (ca. 1510–1520)." In *Von der dargestellten Person zum erinnerten Ich: Europäische Selbstzeugnisse als historische Quellen (1500–1850)*, ed. Kaspar von Greyerz, Hans Medick, and Patrice Veit, 323–53. Cologne: Böhlau Verlag, 2001.

Pomata, Gianna. "Malpighi and the Holy Body: Medical Experts and Miraculous Evidence in Seventeenth-Century Italy." *Rennaissance Studies* 21.4 (2007): 568–86.

Pomata, Gianna. "The Devil's Advocate among the Physicians: What Prospero Lambertini Learned from Medical Sources." In *Benedict XIV and the Enlightenment: Art, Science and Spirituality*, ed. Rebecca Messbarger, Christopher M. S. Johns, and Philip Gavitt, 120–50. Toronto: University of Toronto Press, 2016.

Portuondo, María. "Conclusion: Looking Behind the Curtain; Clues of Early Modern Spanish Science." In *Science on Stage in Early Modern Spain* (2019a), 250–73.

Portuondo, María. *The Spanish Disquiet: The Biblical Natural Philosophy of Benito Arias Montano*. Chicago: University of Chicago Press, 2019b.

Preti, Cesare, and Maria G. Ercolino. *Dizionario Biografico degli Italiani*, s.v. "Grassi, Orazio." 2002. http://www.treccani.it/enciclopedia/.

Religion and the Senses in Early Modern Europe. Ed. Wietse de Boer and Christine Göttler. Leiden: Brill, 2013.

Rodrigues, Francisco. *História da Companhia de Jesus na Assistência de Portugal.* Tome 3, *A Província Portuguesa no Século XVII 1615–1700,* vol. 1, *Nos Colégios—Nas Ciências e Letras—Na Côrte*. Porto: Apostolado da Imprensa, 1944.

Roe, Jeremy. "Nature and Beauty in Velázquez's Representations of Christ." In *Imagery, Spirituality and Ideology in Baroque Spain and Latin America*, ed. Jeremy Roe and Marta Bustillo, 85–96. Newcastle: Cambridge Scholars Publishing, 2010.

Rowe, Erin. *Saint and Nation: Santiago, Teresa of Avila, and Plural Identities in Early Modern Spain*. University Park: Pennsylvania State University Press, 2011.

Sacred Spain: Art and Belief in the Spanish World. Ed. Ronda Kasl. Indianapolis, IN: Indianapolis Museum of Art, 2010.

Saldanha, Sandra, and Maria João V. de Carvalho. *"O pai dos Cristos": Esculturas de Manuel Dias (1688–1755)*. Lisbon: Museu Nacional de Arte Antiga, 2018.

Sanger, Alice, and Siv Tove Walker, eds. *Sense and the Senses in Early Modern Art and Cultural Practice*. Farnham: Ashgate, 2012.

Santo-Tomás, Enrique García. "Introduction: Great Theaters of the World." *Science on Stage in Early Modern Spain* (2019), 3–21.

Schmitz, Leonhard. "Heracles (Ἡρακλής), and in Latin Hercules." In *A Dictionary of Greek and Roman Biography and Mythology*, ed. William Smith, 2:393–401. London, 1880.

Science on Stage in Early Modern Spain. Ed. Enrique García Santo-Tomás. Toronto: University of Toronto Press, 2019.

Sempilius, Hugo. *De Mathematicis Disciplinis Libri Duodecim*. Antwerp, 1635.

The Sensuous in the Counter-Reformation Church. Ed. Marcia Hall and Tracy Cooper. Cambridge: Cambridge University Press, 2013.

Shore, Paul. "Counter-Reformation Drama." In *The Ashgate Research Companion* (2013), 355–72.

Siraisi, Nancy. "Signs and Evidence: Autopsy and Sanctity in Late Sixteenth-Century Italy." In *Medicine and the Italian Universities, 1250–1600*, ed. Nancy Siraisi, 356–80. Leiden: Brill, 2001.

Sollier, Joseph. "Precious Blood." In *The Catholic Encyclopedia*, 12:372–73. New York: Robert Appleton Company, 1911.

Sousa Viterbo, Francisco. *Diccionario Historico e Documental dos Architectos, Engenheiros e Constructores Portugueses*. 3 vols. Lisbon: Imprensa Nacional, 1899–1922.

Sperling, Jutta Gisela. "Introduction." In *Medieval and Renaissance Lactations* (2013), 1–20.

Sperling, Jutta Gisela. "Squeezing, Squirting, Spilling Milk: The Lactation of Saint Bernard and the Flemish *Madonna Lactans* (ca. 1430–1530)." *Renaissance Quarterly* 71.3 (2018): 868–918.

Stafford, Ignace. *Elementos Mathematicos por el Padre Ignacio Stafford de la Compañia de IHS*. Lisbon, 1634.

Tarrant, Neil. "Giambattista Della Porta and the Roman Inquisition: Censorship and the Definition of Nature's Limits in Sixteenth-Century Italy." *British Journal for the History of Science* 46.4 (2013): 601–25.

Tertullian. *De resurrectione mortuorum*. Trans Ernest Evans. London: SPCK, 1960.

Touber, Jetze. *Law, Medicine and Engineering in the Cult of the Saints in Counter-Reformation Rome: The Hagiographical Works of Antonio Gallonio, 1556–1605*. Leiden: Brill, 2014.

Valleriani, Matteo. *Galileo Engineer*. Dordrecht: Springer, 2010.

Van Leeuwen, Joyce. *The Aristotelian "Mechanics": Text and Diagrams*. London: Springer, 2016.

Vasconcelos, Antonio de. *Evolução do Culto de Dona Isabel de Aragão*. 2 vols. Coimbra, 1894.

Waddell, Mark. *Jesuit Science and the End of Nature's Secrets*. Farnham: Ashgate, 2015.

Wandel, Lee. *The Eucharist in the Reformation: Incarnation and Liturgy*. Cambridge: Cambridge University Press, 2006.

Warwick, Genevieve. *Bernini: Art as Theater*. New Haven, CT: Yale University Press, 2012.

Waterworth, James, trans. *Canons and Decrees of the Sacred and Ecumenical Council of Trent*. London, 1848.

Wunder, Amanda. *Baroque Seville: Sacred Art in a Century of Crisis*. University Park: Pennsylvania State University Press, 2017.

Zampelli, Michael. "'*Lascivi Spettacoli*': Jesuits and Theater (from the Underside)." In *The Jesuits II: Cultures, Sciences, and the Arts, 1540–1773*, ed. John O'Malley, Gauvin A. Bailey, Steven J. Harris, et al., 550–71. Toronto: University of Toronto Press, 2006.

Ziegler, Joseph. "Practitioners and Saints: Medical Men in Canonization Processes in the Thirteenth to Fifteenth Centuries" *Social History of Medicine* 12.2 (1999): 191–225.