STUDIES IN THE SPIRITUALITY OF JESUITS

Jesuits on the Moon

Seeking God in All Things . . . Even Mathematics!

DENNIS C. SMOLARSKI, S.J.

37/1 · SPRING 2005

THE SEMINAR ON JESUIT SPIRITUALITY

The Seminar is composed of a number of Jesuits appointed from their provinces in the United States.

It concerns itself with topics pertaining to the spiritual doctrine and practice of Jesuits, especially United States Jesuits, and communicates the results to the members of the provinces through its publication, STUDIES IN THE SPIRITUALITY OF JESUITS. This is done in the spirit of Vatican II's recommendation that religious institutes recapture the original inspiration of their founders and adapt it to the circumstances of modern times. The Seminar welcomes reactions or comments in regard to the material that it publishes.

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The first word . . .

For such a young man, St. John Berchmans demonstrated extraordinary insight when he reputedly said, "My penance is to live the common life." This is the Catholic Encyclopedia's bland translation of the more pointed version I recall from an earlier life: *"Vita communis, crucifixio maxima."* In other words, the boy-saint from Belgium seemed to imply that the brethren can be a real pain in the nether-lands at times.

Here's one source of the problem. Jesuit communities seem to have been targeted by an unending supply of appliance terrorists, who must have a secret training base somewhere in the Carpathian Mountains near the legendary castle of Count Dracula. Natural talent and serendipity could not explain their astounding success through the years, if not the centuries. Some day I would like to team up with a Scripture scholar who understands the vagaries of the oral tradition and a postulator or "devil's advocate" who can help investigate these stories and track down the fragments of truth that lurk somewhere in the legends of community life. Perhaps we could even begin a new television series: *CSI: Haustus Room.*

Every province has its own anthology of epic incompetence in the aftermath of the industrial revolution. Here are a few that I've gathered from my travels around the Assistancy, some of which may indeed contain more truth than we'd like to imagine. Some involve only limited impact on the community, like the man who was delighted to find a washing machine in the kitchen of his new apartment, and then shredded his clothes into a mass of soggy lint in the dishwasher. Sometimes the effect strikes the group as a whole. For example, one newcomer to the domestic arts once heard the household hint that placing a sneaker in the dryer would help "fluff up" his clothes. Lacking a sneaker, he used a brick doorstop, thereby reducing the drum of the machine to an abstract expressionist sculpture. Sadly, no photographer was present to catch the expression of disbelief on the face of the Maytag repairman, but the others in the residence went several days without a washer.

Haustus rooms or pantries have always been soft targets for surreptitious attacks. Ministers should have a Website to exchange and collect stories, with or without Celtic embellishment. One poor minister bought a "big mouth" toaster to enable his charges to brown a morning bagel without having to risk electrocution by using a fork to dislodge it from a standard-size model. Big mistake. Obviously, according to one man's perception, the device was intended for grilled-cheese sandwiches, which of course melt and flow onto the coils, causing both a rancid fire and a short circuit. I have heard a story about the man who found a new table-top television set on the counter next to the coffee maker. All set to enjoy a newscast with his morning caffeine fix, he punched in the numbers of his favorite station. A light went on, the gadget made a whirring noise and the numbers on the channel selector decreased, one per second until the light went out and the whirring stopped. He tried again. Same result. Of course, he complained that the minister had bought a cheap TV set that didn't work worth a damn. So much for the new microwave oven. And speaking of microwaves, how many communities have had to clean up the mess when someone decided to save time by zapping an egg rather than boiling it?

Coffee makers seem a particularly vulnerable target of opportunity. One despairing villa superior went shopping for yet one more replacement with the determination to find an "Ours-proof" machine. It would have no moving parts, no detachable elements, an automatic turn-off feature, a metal basket and pot, and a large sign in flashing letters warning Sergeant Starbuck, S.J., that the receptacle is intended to take only water for fresh brewing, not yesterday's dregs for recycling. Even if such a device could be found, it would provide only temporary respite. Terrorists traditionally change their tactics in response to new security procedures. Martha Stewart, come to our assistance; Emeril, make haste to help us.

The exploits of Ours in the automotive age outpace the imaginations of Jules Verne and George Lucas combined. Every province seems to have a car that was discovered parked sideways in a garage. One of our veteran drivers, hovering on the edge of being grounded, managed to remove two rear-vision mirrors on two cars on two successive days. Knowing that a preemptive strike might delay the minister's (the rector's, and the provincial's) anticipated move, he invaded the rector's office expressing outrage at the stupidity of superiors for installing garage doors that were too narrow for the cars. Another driver parked a house car on a hill in front of the residence, and watched as it rolled down the slope, through a hedge, across a lawn, and into another building. He explained that the gear shift was stuck and he could not get it into "park." When asked about the parking brake, he expressed amazement, since he had never heard of such a strange device. This could only be matched by the Jesuit who was frustrated at not being able to follow a breaking news story on his radio because he had it set to listen to classical music and was not aware that he could change the station.

Community computers and photocopiers have opened up entirely new horizons of possibility that would clearly strain the space constraints of this column. To borrow the words of an earlier spiritual writer, "If these things were to be described individually, I do not think the whole world would contain the books that would be written" (John 21:25).

Some of these stories may actually be true, at least a little bit. The oral tradition within the Society demands study in itself. We had a wonderful story in the Maryland and New York provinces about an Irish-born brother at Port Kent, the villa for philosophers on Lake Champlain near the Canadian border of New York State. Zealous to protect the reputations of the pious scholastics, he dismissed a deliveryman's comment about the amount of beer he had just unloaded by telling him it was for "a thousand men." Imagine my amazement, sitting at evening seminar in a Midwestern community several years ago and hearing the same story, word-for-word, about a German-born brother at Waupaca, the villa for Wisconsin scholastics. No one should be surprised to hear the same story about an old Italian-born brother at Applegate, the California villa, but there the delivery would probably have been zinfandel or mineral water. The oral tradition has a tendency to take on a life of its own.

The phenomenon raises two intriguing questions. First, why does this caste of dedicated Jesuit appliance terrorists renew itself year after year in such a stunning variety of manifestations and with a seemingly inexhaustible capacity to redirect its energies to ever-newer forms of technology, and second, why do we continue to compile their *acta* and lovingly embroider them with fanciful glosses on the *Urtext?*

The first question seems fairly straightforward. We aren't competent in dealing with worldly matters, because we don't have to be. Clearly, most of us have never negotiated a mortgage, bought insurance, or filled out a tax return, the kinds of routine tasks that generally define responsible adulthood in our contemporary world. This distance from mundane experiences carries over into the trivia of human life. If we had to pay for trashing a washing machine or coffee maker out of our own pockets, or call a repairman, or shop for a replacement, chances are we would be more willing to read the instruction booklets and pay attention to what we were doing. In community living, somebody else takes care of such things.

"Irresponsibility" in both senses of the word is an inevitable result of living in the "total" institution. The concept comes from an Erving Goffman's *Asylums*, a classic fifty-year-old study on social psychology that still provides fascinating insights for those of us trying to understand "the course." Goffman links the common elements in various forms of tightly controlled social structures, like military boot camps, prisons, long-term medical facilities, and—believe it or not—convents, monasteries, and seminaries. For the organization to work, newcomers have to surrender individuality and become totally dependent on "the system," with its clearly established hierarchies and well-defined rituals. In its most extreme forms, in the old novitiates, for example, one novice was a shoe beadle, who alone could take shoes for resoling, and another a sock beadle, who kept the common-stock sock box filled. From an institutional standpoint, it makes perfect sense. It is clearly better to have one man learn how to wash socks than have many learn how to operate the machinery. From a personal standpoint, it's disastrous. Even outside the large houses of formation, a

Jesuit was expected to "put a note in the minister's box" rather than change a light bulb, which he couldn't do anyway, since for years light bulbs were kept in a locked closet.

Why? The institution is slow to change such insane practices, according to Goffman, because a loosening of the rules could jeopardize the social structure by undercutting the control and thus the power of the authorities: the minister, the brother, and now the lay custodian who has to maintain his indispensability to keep his job. Sadly, too, honesty demands the admission that a loosening of long-established restraints could predictably lead to abuses of new-found freedoms and brick-in-the-dryer incidents. In some dark moments, the price we pay for "deinstitutionalization" makes the old days of the "long black line" seem rather attractive. Goffman's study provides the consoling realization that the effects of institutional living are not unique to Jesuits, but that they are risks found in many controlled social structures.

(Younger Jesuits, who have always lived in smaller communities where personal responsibility is presumed, don't know what this is all about. Good. That's a sign of real progress. I invite them to read on in the hope that this reflection might help them understand why some of us older types are so weird.)

Goffman is helpful in addressing the second question: Why do our appliance terrorists assume legendary status in our oral tradition when in fact they should be a source of embarrassment? In his analysis, those who obstruct the system by frustrating its goals and humiliating its hierarchy are perceived as heroes for asserting the role of the individual over the organization. The few give voice and gesture to what is felt by the many. Institutions frequently provide this outlet as one of its condoned rituals. Christmas shows, for example, sanction entertainment that includes unflattering imitations of guards, nurses, boarding-school teachers, and seminary professors. In the military or on shipboard, this outlet takes the form of creative griping about officers. The best impressionists and most incisive critics gain prestige among their peers for their daring defiance of the system. They say what others think.

Jesuits who wreck coffee makers and computers, despite the inconvenience they cause others, fit into this pattern of admired defiance. Machines are a form of institution; they rule our lives, degrade us, and make us conform to their own priorities, not through their own conscious design, but through the imperious regulations that surround them, like "you have performed an illegal function and will be shut down." In a perverse way, we admire the appliance terrorists for swimming against the tide of history, even though they drive us crazy at times. By telling and retelling their stories, we have it both ways. We enshrine their acts of defiance and make them our own. At the same time, we distance ourselves from the hapless and malicious, and situate ourselves in a somewhat superior position.

Boasting of an inability to add toner to the copier somehow places us above such trivial details, and at the same time we assure ourselves that we are more attuned to modernity than the colleague who tried and did several hundred dollars' worth of damage to the defenseless machine.

It seems hard to believe that this ubiquitous Marching Band of Benevolent Luddites has in fact fallen out of step with the oldest traditions of the Society of Jesus. During the age of exploration, Jesuits were the sixteenth-century equivalent of Silicone Valley techies. They may even have worn plastic pocket protectors inside their soutanes. Their ability to predict eclipses and fashion a more accurate calendar matches the achievement of today's Mars rover. Just like us, early Jesuit scientists and mathematicians probably had to live with people who could break a doorknob by looking at it. These ham-fisted brethren couldn't tell an alembic from an astrolabe, but that didn't stop them from denouncing all these new-fangled gadgets as witchcraft. Despite the fulminations of their less perceptive brethren, Jesuit mathematicians moved ahead in their research and their effort to spread the word that science and technology had a place in the universities, alongside metaphysics and logic.

In this current issue of STUDIES, Dennis Smolarski has assembled a fascinating account of early Jesuits in their more successful encounters with modernity. These men used their mathematics and science as apostolic instruments to enhance the Good News for the intellectual elites of their own world and build bridges to the cultures of Asia. Much of this is a familiar story that needs to be retold. Finally, Dennis offers a reflection for each of us today on the role of the sciences in our ongoing search for God and God's ongoing search for us.

Richard A. Blake, S.J.
Editor

Boasting of an inability to add toner to the copier somehow places us above such trivial details, and at the same time we think ourselves we are more attuned to modernity than the colleagues who tried and did several hundred dollars' worth of damage to the device we now use.

It seems hard to believe that the prosperous, Macintosh Band of Renaissance Luddites has in fact fallen out of step with the oldest traditions of the Society of Jesus. During the age of exploration, Jesuits were the sixteenth-century equivalent of Silicone Valley techies. They may even have worn plastic pocket protectors inside their soutanes. Their ability to predict eclipses and fashion a more accurate calendar matches the excitement of today's Mars rover. Just like us, early Jesuit scientists and mathematicians probably had to live with people who could break a sextant by looking at it. These ham-fisted brethren couldn't tell an alembic from an astrolabe, but that didn't stop them from denouncing all these new-fangled gadgets as witchcraft. Despite the lamentations of their less perceptive brethren, Jesuit mathematicians moved ahead in their research, and their effort to spread the word that science and technology had a place in the universities, alongside metaphysics and logic.

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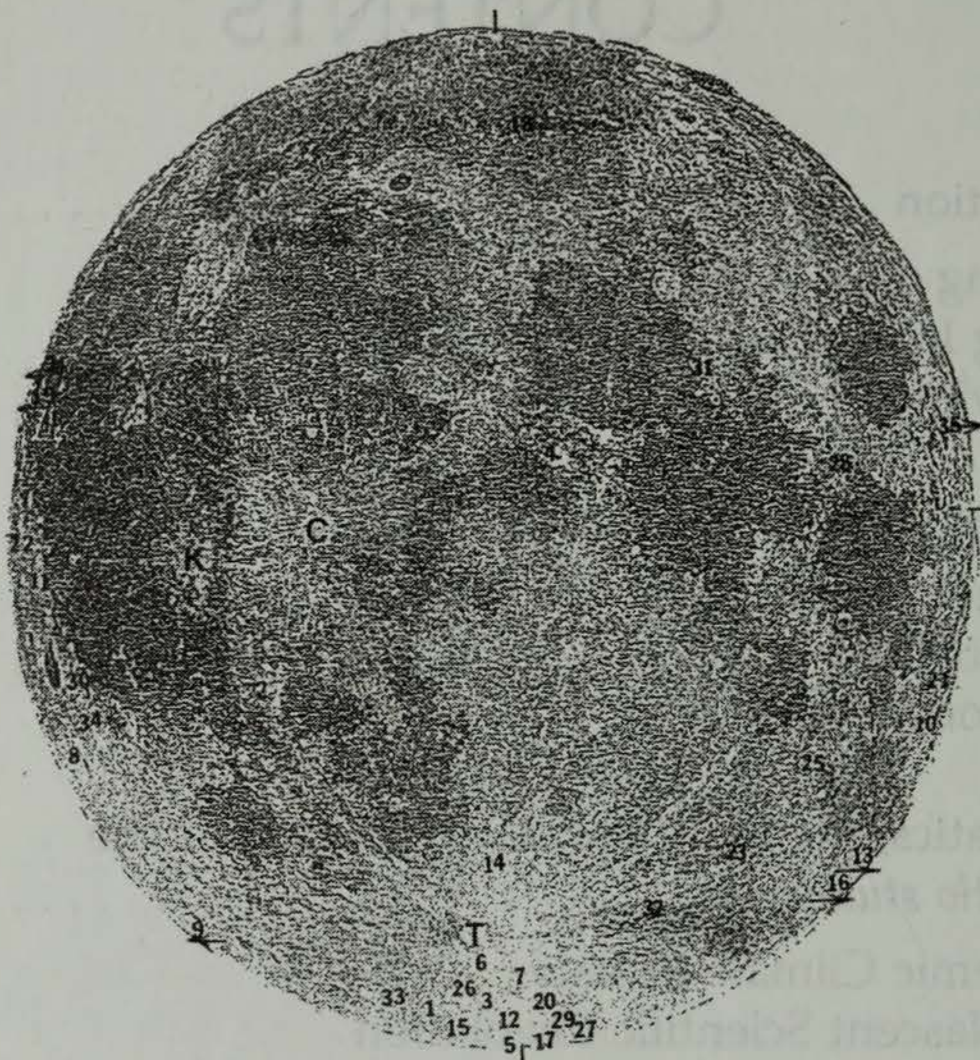

The Moon with Craters Named after Jesuits Indicated
(See Appendix I)

Dennis C. Smolarski, S.J., graduated from Santa Clara University as a math major before entering the California Province in 1969. After ordination, he earned his Ph.D. in computer science at the University of Illinois at Urbana. While teaching mathematics and computer science at Santa Clara, he has been working on a computer model for supernovae for the Department of Education. In addition to his specialized research, he has been involved in liturgy and the Byzantine Catholic parishes around San Francisco. He is the author of the widely known *How Not to Say Mass* (Paulist) and *Q and A: Seasons, Sacraments, and Sacramentals* (Liturgical Press).

JESUITS ON THE MOON

Seeking God in All Things . . . Even Mathematics!

In sixteenth-century Europe several Jesuits pioneered formal studies in mathematics and science and used their research to begin a dialogue with Asian cultures. Their attempt to include mathematics in the university curriculum in Italy was nothing short of revolutionary. The need continues today, as the contemporary world presumes a greater level of technical competence than ever before. In a wider context, mathematics provides a means to contemplate the wonders of God's universe.

I. Introduction

A typical reaction to the title of this issue of STUDIES might well be, "Jesuits on the moon? Surely you jest!" But "jest" I do not! Even though no member of the Society of Jesus has actually stepped foot on the moon (at least as of Christmas 2004), the memory of Jesuit scientists has, nevertheless, become a permanent part of the map of the moon because about thirty-five craters have been named after our brothers in the Society (see frontispiece and Appendix 1). These men studied mathematics, astronomy, and physics (among other sciences), although the modern names given to distinct academic disciplines often do not do justice to the breadth of the scientific interests of these Jesuits. In turn, history has rewarded them for their scientific expertise (and honored the Society through them) by associating their names with the lunar landscape.

The Society has an honored tradition of involvement in mathematics and the natural sciences and this essay is a modest attempt to help readers recall that tradition, and to raise some questions about the future of that tradition. But let me begin by suggesting that a number of early Jesuit scientists devoted themselves enthusiastically to scientific study prompted by two fundamental spiritual principles that are part of our living heritage as Jesuits, namely, (1) striving to seek and find God in all things (yes, even in disciplines as abstract as mathematics!) and (2) using whatever means are appropriate (even using mathematics and natural sciences) to "go in our neighbor's door but come out our own." Let me begin with a brief reflection on these two Ignatian principles to help provide a context for the remainder of this essay.

Seeking God in All Things

In the *Constitutions of the Society of Jesus,* St. Ignatius writes that Jesuits should "seek God in all things."[1] Later, in *ConsCN C* 451[v.1], mathematics is mentioned as one of the topics to be taught in the schools of the Society, but reference to mathematics is phrased in such a way, "and also mathematics," that one suspects that its inclusion may have been considered unusual, given the academic climate of sixteenth-century Italy.[2] Yet part of our Jesuit spirituality, an incarnational spirituality, is that God can, indeed, be found in "all things," whether it be in the Christian community gathered at the Eucharist and in the sacramental elements themselves, or in the abstractions developed by our God-given intellectual gifts, whether those abstractions describe moral laws, theological truths, or mathematical structures.

In *Mere Christianity,* C. S. Lewis wrote, "[God] likes matter. He invented it."[3] With a perspective such as this, we should be able to

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[1] The Latin text reads *"ut in omnibus quærant Deum."* This seems to be the base text for the more commonly used expression, "finding God in all things" (*ConsCN C* 288[v.3] [p. 124]). See *The Constitutions of the Society of Jesus and Their Complementary Norms: A Complete English Translation of the Official Latin Texts* (St. Louis: The Institute of Jesuit Sources, 1996). Hereafter this source will be abbreviated to *ConsCN,* followed by C and the boldface marginal number introducing each section and, when useful, the "verse number."

[2] The Latin text reads *"et etiam mathematicæ."* The presence of the *etiam* ("also, even") argues for the unusual nature of including mathematics (mathematical sciences/topics) in a university curriculum. See the discussion on pp. 44 f. by Jeffrey Bloechl in his article, "The Jesuit *Ratio Studiorum* and the Teaching of Mathematics: On the Incursion of Modern Rationality into a Classical Pedagogy," *Fundamental Questions: A Journal of the Liberal Arts* 1, no. 1 (Fall 2004): 41–60.

[3] C. S. Lewis, *Mere Christianity* (New York: Macmillan, 1960), 65.

find God in material creation as well as in the ways human beings have devised to depict or describe that creation, such as abstract art or applied (and abstract) mathematics. Galileo considered that the "book" that is the universe "is written in the language of mathematics,"[4] and many contemporary mathematicians and scientists would agree that mathematics does indeed provide the language for the world of science and technology. That they look at and reflect on the beauty (and interrelatedness) of God's creation (which includes mathematics) is what Ignatius asks of retreatants both in the Principle and Foundation and in the Contemplation to Attain Love.[5] There is a long tradition of Jesuits being actively engaged in mathematical and scientific research as a major means for them to come to a deeper understanding of the creation in which we all continue to seek and find our God. The better human beings come to understand and describe creation, the better we may be able to cooperate with God in building up the Kingdom on earth for the benefit of future generations. Although each Jesuit's description of how he actually "finds God" in mathematics may be as unique as each Jesuit, many (myself included) see in mathematics a glimpse into the order, cohesiveness, and beauty that is of the nature of divine realities.[6]

Going In by Our Neighbor's Door

In explaining St. Paul's words "I became all things to all so as to win some to Christ" (1 Cor. 9:22), Ignatius wrote the following to Alonso Salmerón, S.J., and Paschase Broët, S.J., in 1541 as they were setting off to Ireland as papal legates: "Whenever we wish to win someone over and engage him in the greater service of God our Lord, we should use the same strategy for good which the enemy

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[4] Galileo, *The Assayer* (1623). See Stillman Drake, *Discoveries and Opinions of Galileo* (Garden City: Doubleday Anchor Books, 1957), 237 f.

[5] See *The Spiritual Exercises of St. Ignatius,* trans. with commentary by George E. Ganss, S.J. (St. Louis: The Institute of Jesuit Sources, 1992). Hereafter this source will be abbreviated to *SpEx.* The quotations here are from *SpEx* nos. 23 and 234f. (pp. 32 and 94f.).

[6] Thomas Aquinas's "Fifth Way" for proving the existence of God is related to order found in the universe (*Summ. Theol.,* pt. 1, quest. 2, art. 3). For another contemporary Jesuit's reflections on finding God in science, see "Finding God in Creation," in *Brother Astronomer: Adventures of a Vatican Scientist,* by Guy J. Consolmagno (New York: McGraw-Hill, 2000), pt. 2, pp. 99ff.

employs to draw a good soul to evil. He enters through the other's door and comes out his own."[7] Jerónimo Nadal, summarized these thoughts of Ignatius in the often repeated Jesuit maxim, "Enter by their door so as to come out by our door."[8]

One of the earliest examples of a Jesuit using mathematics as the "other's door" in the hope of drawing someone to Christianity, was Matteo Ricci (1552-1610), the famed Jesuit missionary to China. In his dealings with Qu Rukuei, a Confucian scholar a few years older than he, Ricci was able to wean Qu from his interest in alchemy to mathematics. Ricci's approach was to start with mathematics, however, and only when appropriate speak about religious topics. As Ronald Modras notes,

What I would like to reflect upon in this essay is the tradition and history of mathematical study, research, and use in the Society.

> [Ricci] laid open to Qu the world of Euclidian geometry with its axioms and deductions, and, when the opportunity arose, he related something about Christianity. Qu proved an adept student. He took careful notes and astounded his teacher one day with a series of perceptive questions about the Christian faith, all deriving from a Confucian scholar's perspective. The exchange proved significant for master and disciple alike. Qu eventually became a Christian, and Ricci learned the importance of relating Christianity to someone steeped in Confucian tradition.[9]

[7] *Letters of St. Ignatius of Loyola,* trans. William J. Young (Chicago: Loyola University Press, 1959), 51 f. Also see the discussion on "Going In by His Door," in *The Conversational Word of God,* by Thomas H. Clancy, S.J. (St. Louis: The Institute of Jesuit Sources, 1978), 26–28.

[8] In "Jerónimo Nadal's Sixth Exhortation (chap. 4, par. 26), we read: "But in these exchanges one should watch carefully for an occasion to give the conversation a religious turn. Father Ignatius used to speak of this method as 'entering by their door so as to come out by our door.' He was not in favor of launching forth immediately on virtues and vices, the life of Christ, and the last things, because in this way our hearers never really get interested in what we are saying, but are rendered inattentive by our untimely zeal" (English translation in Clancy, *Conversational Word of God,* 54).

[9] Ronald Modras, *Ignatian Humanism* (Chicago: Loyola Press, 2004), 105.

Overview

What I would like to reflect upon in this essay is the tradition and history of mathematical study, research, and use in the Society and, by extension, the pursuit, by Jesuits, of other forms of scientific and technical knowledge. My reflection is influenced by my own "seeking God in all things," particularly in mathematics and computer science, since those are the disciplines I have studied and they are what I teach. It goes without saying that the contemporary society in which we live is one in which science and technology play ever-greater roles. At the same time, I, for one, notice an ever-increasing gap between those comfortable with modern technology (aside from surfing the "Net" and using e-mail or word-processing programs) and those (Jesuits included) who seem to feel that the farther they stay from mathematics and other technical fields, the better! One hope of mine is that in the future, more Jesuits may be able to help close the technological "gap" evident in our society, since Jesuits have had a long and distinguished history of scholarship in mathematics and scientific disciplines.

I will first offer brief vignettes of three Jesuits who were actively engaged in mathematics and science to remind the reader of early Jesuit scientific history, particularly in light of the two principles just mentioned. Then I will turn my attention to the place of mathematics in the early Society, by looking at the curriculum of Jesuit schools as incarnated in the *Ratio studiorum,* the first guidelines for a "core curriculum" for Jesuit schools as well as a handbook for faculty and administration. Finally, I will offer some personal reflections and concluding thoughts on mathematics and technical disciplines today.

II. Three Vignettes

To help the reader recall part of our Jesuit tradition regarding mathematics and related sciences, let me present brief vignettes of three Jesuit scientists: **Christopher Clavius,** whose enthusiasm in seeing mathematics in every human discipline is reminiscent of Ignatius's maxim to seek God in all things; **Matteo Ricci,** who is a prime example of someone who entered through his neighbor's door to attempt to bring the neighbor out our own; and **François d'Aguilon,** who brought to fruition the dream of Clavius to have a Jesuit "academy" of mathematics that would attempt to carry on the newly established scientific tradition of the Society.[10]

Christopher Clavius

Christopher Clavius was born in Bamberg (Germany) in 1538. In 1555 he traveled to Rome to join the Society and in 1564 was ordained a priest while finishing theology at the Roman College. He began teaching mathematical subjects at the Roman College around 1564 and continued for about forty-five years, until his death in 1612 (except for two years around 1596 when he was in Naples and Spain).[11] Documents from the Roman College indicate that Clavius was the sole teacher of mathematics for at least twenty-two years between 1564 and 1595.[12]

One of Clavius's major accomplishments was his influence on the revision of the calendar. In 325 the Council of Nicea had set the date of Easter as the first Sunday after the first full moon after the vernal equinox, which marks the start of spring. The full moon corresponds to the middle day (fourteenth day) of a Hebrew (lunar) month of twenty-nine days (which always begins with a new moon). Thus, the seemingly odd rule for computing Easter is an attempt to situate Easter as the first Sunday after the beginning of Passover, which should always occur on the fourteenth day of Nisan (Exod. 12:6), the first spring month of the Hebrew calendar.

Since the actual length of an astronomical earth year is slightly less than 365.25 days, the Julian calendar in use in the Roman empire, with its unvarying rule of inserting a leap day every four years, overcompensated in trying to adjust calendar dates to match astronomical dates (in particular, in trying to synchronize the first

[10] Sections 2–4 are based on what is presented in "The Jesuit *Ratio Studiorum*, Christopher Clavius, and the Study of Mathematical Sciences in University," by Dennis C. Smolarski, *Science in Context* 15, no. 3 (2002): 447–57. Also see Dennis C. Smolarski, "Teaching Mathematics in the Seventeenth and Twenty-First Centuries," *Mathematics Magazine* 75, no. 4 (Oct. 2002): 256–62.

[11] An in-depth look at the life of Christopher Clavius, S.J., may be found in *Between Copernicus and Galileo: Christoph Clavius and the Collapse of Ptolemaic Cosmology*, by James M. Lattis (Chicago: The University of Chicago Press, 1994). On p. 23 Lattis suggests that Clavius may have left Rome because of health problems.

[12] William A. Wallace, *Galileo and His Sources: The Heritage of the Collegio Romano in Galileo's Science* (Princeton: Princeton University Press, 1984), 7.

Christopher Clavius, S.J. (1538 - 1612)

day of spring always as March 21). By the beginning of the sixteenth century, the calendar date was ten days later than the astronomical date, that is, the beginning of spring was celebrated on what we would now consider to be March 31 rather than March 21.[13] Astronomers who determined the beginning of spring by the height of the sun in the sky (and thus the length of shadows) raised concerns that, without some sort of calendar correction, the official beginning of spring (on the calendar) might eventually move so that Easter (around the middle of the first month of spring) would be celebrated in summer.[14]

Proposals for correcting the calendar had been submitted to Pope Paul III (1534–49) and were discussed at the Council of Trent,

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[13] The current difference between the Julian calendar and the revised Gregorian calendar is thirteen days. That difference results in Christmas's being celebrated on January 7 (thirteen days after December 25, both dates according to the Gregorian calendar) by those still using the Julian calendar; for example, many in Orthodox countries, such as Russia. In actuality, what is January 7 on the Gregorian calendar is December 25 according to the Julian calendar.

[14] An example of a solarium that marks the seasons by the sun's shadow has been built at the University of Illinois at Urbana-Champaign, situated before the Beckman Institute. The shadow cast by the modern obelisk (gnomon) of the solarium hits specific fountain markers on the ground at solar noon on each solstice and equinox. See also the description of the Solarium/Horologium Augusti project at the University of Oregon (Eugene) at http://darkwing.uoregon.edu/~klio/solarium/solarium_project.htm (URL accurate as of December 2004).

but only after Pope Gregory XIII was elected in 1572 was a commission established to propose a definitive solution after reviewing the various proposals.[15] This commission included Clavius, who built on the work of Luigi Lilio (d. 1576). As a result of the work of this commission, Gregory XIII issued the bull *Inter gravissimas* in 1582, which reformed the calendar.[16] Since the reformed calendar was not universally accepted (particularly in Protestant and Orthodox countries), Clavius attempted to justify the computations that formed the basis for the papal bull against detractors in his tome *Novi calendarii Romani apologia* [Defense of the New Roman Calendar], published in 1588 and totaling over eight hundred pages.[17]

Other documents authored or influenced by Clavius show someone who saw in mathematics a foundational body of knowledge that was a key to understanding most other disciplines. In contrast to the prevailing academic climate in Italian universities in the sixteenth century (more on this below), Clavius wrote, "Since . . . the mathematical disciplines in fact require, delight in, and honor truth . . . there can be no doubt that they must be conceded the first place among all the other sciences."[18] This praise is similar to the well-known statement of famed German mathematician Carl Friedrich Gauss (1777–1855) that "mathematics is the queen of the sciences," but Clavius lived two centuries earlier.

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[15] Discussion about reforming the calendar had been active for several centuries. Roger Bacon (1214–92) submitted his treatise *De reformatione calendaris* to Pope Clement IV in 1267.

[16] The reform consisted of (1) omitting ten days in October 1582, so that October 4 was followed by October 15, and (2) modifying the "leap-year rule" so that century years not divisible by four hundred were not to be leap years (e.g., 1900, 2100).

[17] Details about the reform of the calendar and the role of Clavius may be found in *Gregorian Reform of the Calendar: Proceedings of the Vatican Conference to Commemorate Its 400th Anniversary, 1582–1982,* ed. George V. Coyne, M. A. Hoskin, and O. Pedersen (Vatican City: Pontificia Academia Scientiarum, Specola Vaticana, 1983).

[18] Peter R. Dear, *Discipline and Experience: The Mathematical Way in the Scientific Revolution* (Chicago: The University of Chicago Press, 1995), 38, quoting from "In disciplinas mathematicas prolegomena" as follows: "Cum . . . disciplinæ mathematicæ veritatem adeo expetant, adament, excolantque, . . . quin eis primus locus inter alias scientias omnes sit concedendus" (Christopher Clavius, *Opera mathematica* [Mainz, 1611–12], 1:5).

In two documents, most probably written for the Jesuit commission charged with composing the *Ratio studiorum,* Clavius describes mathematics as being a *magnum ornamentum* ("great ornament" [or "jewel"] in the sense of being an object of honor, pride, and distinction rather than meaning an unnecessary embellishment) for the Society.[19] He then also argues that all Jesuits should study mathematics and that special academies ought to be established where scientifically gifted Jesuits could be trained in more depth in the mathematical sciences.

A major contribution of Clavius to the mathematical community of later generations was his set of texts. One example was his 1574 *Elements of Euclid,* which was not simply a translation, but a text containing Euclid's work as well as a commentary. Some comments were taken from earlier authors, but the book also included Clavius's own criticisms and elucidations of Euclid's axioms. This text has been held up as a model and led to Clavius's being called the "Euclid of the Sixteenth Century."[20]

Matteo Ricci

Perhaps of all the Jesuits who have studied various mathematical sciences and have made use of their scientific expertise to help spread the Gospel message, the early Chinese missionary Matteo Ricci (1552–1610), along with his successors, Johann Adam Schall von Bell and Ferdinand Verbiest, deserves special mention.

Ricci entered the Society in Rome in 1571 and studied mathematics under Clavius until 1577, when he asked to be sent on mission to Asia. Ricci's life is a wonderful example of someone eager to learn from the culture in which he found himself, sensitive to that culture, and willing to adapt his European mind-set to Chinese customs to gain credibility. Ricci (or Li Ma Tau in Chinese) was esteemed by the Chinese for his scientific skills as well as his mem-

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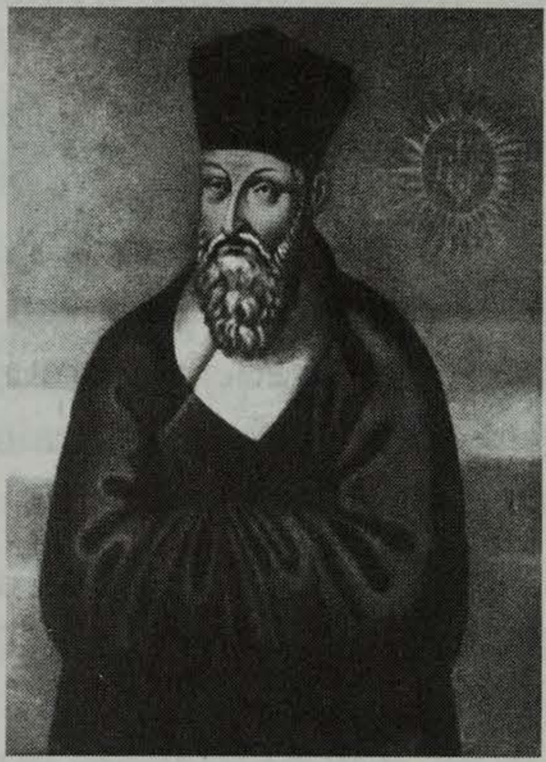
[19] The Institute of Jesuit Sources is about to publish a bilingual edition (Latin and English) of the *Ratio studiorum,* the first translation into English of the entire *Official Ratio* of 1599.—Ed.

[20] Charles C. Gillispie, ed., *Dictionary of Scientific Biography* (New York: Scribner, 1970–90), 311.



Matteo Ricci, S.J. (1552 - 1610)

ory and his grave in Beijing is still a place of pilgrimage.[21] As is widely known, he eventually adapted his manner of dress to that of the mandarin class, and his modus operandi of discussing mathematical and scientific matters first and only afterwards raising issues of religion (as noted earlier) shows a very concrete way of following Ignatius's counsel of "entering by their door."

Ricci continued an active correspondence with his former teacher, Clavius, and after receiving Clavius's *Elements of Euclid,* translated the work into Chinese, giving China its first exposure to Western mathematics and its basis on fundamental principles. Ricci acknowledged his intellectual dependence on Clavius and presented Clavius as the intellectual heir of Euclid. He also presented his scientific tradition (from his small Western country) as one based on rigor and reason in which there is no unsubstantiated opinion and therefore no doubt. This contrasted with the state of science in China at that time, where the methodology did not have a good basis.[22]

In commenting on the work of the early Jesuit missionary effort in China, Gilbert Highet writes as follows:

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[21] Ricci's memory skills are the subject of Jonathan D. Spence's book *The Memory Palace of Matteo Ricci* (New York: Viking Penguin, 1984). Also see Vincent Cronin's *The Wise Man from the West* (Garden City: Image Books, 1957).

[22] Cf. Spence, ibid., 143–46.

> The Jesuits went to unparalleled lengths and showed unbelievable patience in adapting themselves to the people they had determined to teach. . . . The Jesuits therefore spent several years learning Chinese philosophy, art, and literature, making ready to meet the Chinese on their own level. . . . Instead of being rejected as foreign barbarians, they were accepted as intelligent and cultivated men. . . . The next stage, which they approached very, very delicately, was to make the mandarins willing to learn from them. They did this by discussing astronomy with the Chinese scientists, constructing maps of the world with the place-names shown in Chinese characters and the Chinese empire at the center, presenting sundials and astronomical instruments to the high officials whom they met, and ultimately by assisting the Imperial Board of Rites to correct its calendar so as to forecast eclipses and calculate celestial phenomena more accurately than any Chinese had ever been able to do.[23]

Nine years after Ricci's death in 1610, Johann Adam Schall arrived in China to continue the work Ricci had begun, and his skill in predicting a lunar eclipse led to his being named the director of the Chinese Bureau of Astronomy.[24] Unfortunately, at the death of the Emperor, Schall was accused of sorcery by rival Chinese astronomers, but was exonerated of the accusations after his death. While being investigated, he had a stroke which left him paralyzed. Schall was succeeded by Ferdinand Verbiest, who also succeeded Schall as head of the calendar office. Modras notes:

> Verbiest tutored the new emperor in mathematics, introduced the thermometer into China, built new astronomical instruments, and in the course of the above became the emperor's friend. Thanks to the trust and admiration Verbiest inspired, the emperor issued an edict in 1692 comparable to the Emperor Constantine's fourth-century edict of Milan, which legitimized Christianity for the Roman Empire. The Kangxi emperor declared that Christians, no less than Buddhists, had a rightful place in Chinese society and culture. (120)

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[23] Gilbert Highet, *The Art of Teaching* (New York: Knopf, 1954), 222 f., as quoted in *Jesuit Geometers,* by Joseph MacDonnell, S.J. (St. Louis: The Institute of Jesuit Sources, 1989), 63.

[24] Modras, *Ignatian Humanism,* 118.

François d'Aguilon

Clavius's vision of a special "academy" to train Jesuit mathematicians became realized near the end of his life through the efforts of François d'Aguilon (1567–1617). D'Aguilon was born in Brussels, entered the Society in 1586, and was ordained in 1596. In 1611 he founded a school for mathematics in Antwerp and around 1616 was joined by Gregory St. Vincent (1584–1667), who had studied under Clavius in Rome. During their lives, d'Aguilon focused on geometrical optics, publishing in 1613 his major work, *Six Books of Optics, Useful for Philosophers and Mathematicians Alike,* and St. Vincent researched mathematical concepts we would now see as precursors to the infinitesimal calculus. Although d'Aguilon's contributions in no way compare to the impact of Clavius or Ricci, his role in establishing a special school for mathematics shows the commitment of the early Society to training Jesuits during a time of rapid developments in scientific fields.

III. Mathematics, the Early Society of Jesus, and the *Ratio studiorum*

The *Constitutions* gives a general norm about what should be taught in Jesuit universities: "Since the end of the learning which is acquired in this Society is with God's favor to help the souls of its own members and those of their neighbors, it is by this norm that the decision will be made . . . as to what subjects [Jesuits] ought to learn" (*ConsCN C* $351^{v.2}$). Elsewhere, we find this advice: "Since the arts or natural sciences . . . are useful for the perfect understanding and use of [theology], and also by their own nature help toward the same ends, they should be treated with fitting diligence" (*C* $450^{v.1}$).

When the *Constitutions* list specific subjects taught in universities, it says, "Logic, physics, metaphysics, and moral philosophy should be treated, and also mathematics, with the moderation appropriate to secure the end which is being sought" (*C* $451^{v.1}$). The Latin reads *"et etiam mathematicæ"* and, as noted earlier (see n. 2 above), the presence of the *etiam* (translated either as "also" or "even" in English) seems to give an added emphasis, as if one would not normally expect mathematics to be taught at the university level (and, in fact, in most places it was not taught—see below).

The thrust of Ignatius's thought seems obvious: Any discipline, including mathematics and other scientific and technical disciplines, which "help[s] souls" is worthy of study in a Jesuit university. This is particularly true of those disciplines that "by their own nature help toward the . . . ends" envisioned in the *Constitutions.*[25]

Part IV of the *Constitutions* also refers to a "separate treatise" to be written regarding schools (*C* $455^{v.1}$), and the *Ratio studiorum* was that document. From a modern perspective, the *Ratio* was a combination of core curriculum guidelines, faculty handbook, and pedagogical manual. As such it is about as exciting to read as are some modern curriculum guidelines and faculty handbooks. The *Ratio* expanded upon the relatively brief notes in the *Constitutions* about subjects to be taught and the pedagogical methods to be used in Jesuit schools.

Here the proposed rules for provincials included an exhortation to make sure that the college administrators took care that the instructors of philosophy not disparage the dignity of mathematics. This rule concludes with this astute observation: "[F]or it often happens, that the less one knows about such things, the more he disparages them."

In actuality, several different versions of the *Ratio* were published by the Curia of the Society: two preliminary (and published) drafts in 1586 and in 1591, and the definitive version of 1599. In addition, a slightly revised version of the 1586 text was drafted but never published.[26] Neither of the 1586 documents was a first draft; both had had several predecessors, the best known of which was the *Ratio* of Francis Borgia, compiled between 1565 and 1572. After the preliminary drafts of the *Ratio* were distributed and discussed, on January 8, 1599, fifty-nine years after the papal approbation of the

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[25] Dennis C. Smolarski, S.J., "GC 34, Higher Education, and Computer Science," in *Promise Renewed: Jesuit Higher Education for a New Millennium,* ed. Martin R. Tripole, S.J. (Chicago: Loyola Press, 1999), 109 f.

[26] The second 1586 version was recently found in the Jesuit archives. See Frederick A. Homann, S.J., *Church, Culture, and Curriculum: Theology and Mathematics in the Jesuit "Ratio Studiorum"* (Philadelphia: St. Joseph's University Press, 1999), 34.

Society of Jesus and forty-three years after the death of St. Ignatius, the definitive version of the *Ratio studiorum* was approved.[27]

The *Ratio* was influenced by various dynamics in the late-sixteenth century, including the academic climate in Italy, the nascent scientific revolution, and the practices of the Roman College along with the experiences of its faculty, including Clavius (and his experiences in helping to revise the calendar). Reviewing these three dynamics, in particular, may help the reader better understand some of the guidelines contained in the definitive *Ratio,* and better appreciate the evolution of the text that culminated in the 1599 *Ratio.*

Academic Climate in Italy

To appreciate more fully what the *Ratio* says about mathematics, it is important to read the various drafts of the *Ratio* in light of the lack of prestige given in the sixteenth century to mathematics and to what we would now call scientific and technical disciplines. At that time, a number of Italian philosophers, including some Jesuits, denied to pure mathematics the status of *scientia,* true scientific knowledge in Aristotle's sense, because it did not demonstrate its conclusions through causes and it dealt with abstractions in the intellect, rather than real objects.[28] Thus, mathematics was not considered by many to be worthy of study in a university. Mathematics was presented via the subjects of the quadrivium, namely, arithmetic, geometry, music (taught as applied arithmetic), and astronomy

He saw the intrinsic and apostolic value of mathematics and, as noted above, did not share the opinion of some of his university colleagues who gave it a relatively low place in the hierarchy of academic disciplines.

[27] This definitive 1599 *Ratio* appeared at a crucial time in the growth of Jesuit schools, for in 1556, at the death of Ignatius, Jesuit schools numbered about 35, but forty years later, in 1596, they numbered around 245. Then, nineteen years later, in 1615, three years after the death of Clavius and sixteen years after the promulgation of the *Ratio,* they numbered around 372 (see Martin P. Harney, S.J. *The Jesuits in History: The Society of Jesus through Four Centuries* [New York: America Press, 1941], 201).

[28] Dear, *Discipline and Experience,* 36 f.; Homann, *Church, Culture and Curriculum,* 5; Wallace, *Galileo and His Sources,* 136.

(taught as applied geometry), and also, in some degree, via logic (one subject of the trivium). But at that time the trivium and quadrivium were considered preparatory arts studied before one pursued the higher disciplines of theology, medicine, or law, which were usually the only accepted disciplines for university study, particularly in Italy.[29]

We should also note that the "mathematical sciences" in the sixteenth century included applied topics now considered separately as part of astronomy, physics, and engineering and that "physics" usually meant the philosophy of nature.[30]

The tension between those who saw value in mathematics being taught in a university and those who did not is evident in the 1591 draft of the *Ratio.* Here the proposed rules for provincials included an exhortation to make sure that the college administrators took care that the instructors of philosophy not disparage the dignity of mathematics. This rule concludes with this astute observation: "[F]or it often happens, that the less one knows about such things, the more he disparages them."[31] People waxing eloquent about subjects they know little about is not a new phenomenon in human history. The tension also is seen in an earlier document written by Clavius (noted below) which recommends that instructors of mathematics be invited to solemn academic assemblies (when decrees are conferred) and be involved in public disputations. The document then comments, "[S]ince up to now the students seem almost to have despised these [mathematical] sciences for the simple reason

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[29] Homann, ibid., 81; cf. Dear, ibid., 35. The arts and humanities were only beginning to make their way into the universities, to be followed by the sciences as we think of them today.

[30] See the introduction by Edward C. Phillips, S.J., to the translations of Documents 34 and 35 (of Clavius): "For a better understanding of some portions of these documents, it should be remembered that at that period 'Mathematics' was a term including astronomy and much of what would now be taught in physics" (*Bulletin of the American Association of Jesuit Scientists* [Eastern Section]) 18, no. 4 [May 1941]: 203). Also, see Homann, *Church, Culture and Curriculum:* "Mathematics courses comprised not only arithmetic, geometry, and algebra, but also diverse use of mensuration and calculus in astronomy and astrology, computation of time (calendar and sundial), surveying, theory of music, optics (perspective), and mechanics" (81).

[31] "Fit enim sæpe, ut qui minus ista novit, his magis detrahat" ("Regulæ Præpositi Provincialis: 'De mathematicis,'" in the 1591 *Ratio studiorum,* no. 44; see Homann, ibid., 79n69.

that they think that they are not considered of value and are even useless, since the person who teaches them is never summoned to public events with the other professors."[32]

The Nascent Scientific Revolution

It seems also important to situate the 1599 *Ratio* among the significant events in the history of science. In 1543 Nicholas Copernicus published *De revolutionibus orbium cœlestium* [On the Revolutions of the Heavenly Spheres], and in 1582 Pope Gregory XIII ordered the shift to the Gregorian calendar. Later, in 1633, Galileo's thesis was condemned;[33] and in 1687, Sir Isaac Newton published his *Philosophia naturalis principia mathematica* [Mathematical Principles of Natural Philosophy]. The *Ratio* appeared about the same time as the beginnings of the scientific revolution, and although references to mathematics and sciences are relatively few, what it did contain did influence the teaching of mathematics and science in Jesuit schools for generations at an important moment in the history of science.

Clavius bemoaned the poverty of mathematical interest and instruction, and argued that the lack of well-trained mathematics teachers and the absence of Jesuits studying mathematics harmed the Society.

The Influence of Clavius on the *Ratio studiorum*

Clavius realized the important role mathematics played in revising the calendar (1582) and, through his correspondence with Ricci in China (after Ricci left Rome in 1577), also knew that mathematics could be the doorway through which Western culture and science as well as faith in Christ could be brought to other peoples and cultures. He saw the intrinsic and apostolic value of mathematics and, as noted above, did not share the opinion of some of his

[32] For the complete text, see Christopher Clavius, S.J., "Historical Documents, Part II: Two Documents on Mathematics," *Science in Context* 15, no. 3 (Sept 2002): 465–70.

[33] In *Galileo and His Sources,* Wallace shows an exchange of idea between Galileo and Clavius at the Roman College (pp. 91, 269).

university colleagues who gave it a relatively low place in the hierarchy of academic disciplines.

Although not officially a member of any commission involved with the *Ratio,* Clavius's influence on the *Ratio*'s sections on mathematics cannot be denied.[34] Around 1580, Clavius authored two documents, probably written for the commission charged with composing the first version of the 1586 *Ratio.*[35] Similarities between the sentiments expressed in these documents and in the 1586 and 1591 drafts of the *Ratio* along with the inclusion of Clavius's name in these drafts attest to their influence (see Appendix 2 for excerpts from the 1586 *Ratio*).

He wanted to make sure that Jesuit schools placed proper emphasis on mathematics by recruiting and training qualified instructors of mathematics as well as by requiring that mathematics be studied by all.

The first document, *Modus quo disciplinæ mathematicæ in scholis Societatis possint promoveri* [A Method of Promoting the Mathematical Disciplines in the Schools of the Society],[36] blamed philosophy instructors, in part, for the low opinion held by many about mathematics because some "teach that mathematical sciences are not sciences" and that they do not have proofs.[37] Clavius bemoaned the poverty of mathematical interest and instruction, and argued that the lack of well-trained mathematics teachers and the absence of Jesuits studying mathematics harmed the Society.[38] The document also notes that without mathematics one

[34] In an article by Gabriel Codina, S.J., Clavius's name does not appear among the members of any commission charged with writing or revising various drafts of the *Ratio.* Cf. Gabriel Codina, S.J., "'Our Way of Proceeding' in Education: The *Ratio Studiorum," Educatio S.J.,* no. 1 (May 1999): 8 f.

[35] Homann, *Church, Culture, and Curriculum,* 61, 64.

[36] This is Document 34 in the 1901 *Monumenta Pædagogica S.I.,* found as well in vol. 7 of the 1992 *Monumenta Pædagogica S.I.,* "Collectanea de Ratione Studiorum Societatis Iesu," 109–22. A translation of this document and of Document 35 is found in *Science in Context* 15, no. 3 (2002): 465–70.

[37] Homann, *Church, Culture, and Curriculum,* 61 f.; Dear, *Discipline and Experience,* 35; Clavius, "A Method . . . ," (Doc. 34; 1901 Latin text): "præceptores philosophicæ . . . in quibus docent scientias mathematicas non esse scientias" (p. 473).

[38] Homann, ibid., 61 f.

cannot understand most physical phenomena.[39] He then proposes establishing a special "private academy" for Jesuits to study mathematics.

> Now in order that the Society may be able always to have capable professors of these [mathematical] sciences, some men apt and capable of undertaking this task ought to be chosen who may be instructed in a private academy in various mathematical topics; otherwise it does not seem possible that these studies will last long in the Society, let alone be promoted; since, however, they are a great ornament to the Society, and quite frequently a discussion about them will occur in conversations and meetings of leading men, where they might understand that Ours are not ignorant of mathematical topics.

Clavius's other brief note, *De re mathematica instructio* [On Teaching Mathematics], dealt with faculty problems and the need to have well-trained, mature instructors.[40] Its sentiments influenced the 1586 *Ratio,* which prescribes teachers of mathematics in gymnasia and at least two mathematics instructors at the Roman College, naming Clavius as a possibility for one of these positions.

Some modern scholars view the 1586 Ratio as a radical document for raising mathematics to be on a par with other university-level disciplines and for giving it a prominence unheard of in Italian universities.

From his work with the calendar-revision commission, Clavius's influence may also be seen in the statement in the 1586 *Ratio* that if one or two people leave the Roman College, there may not be anyone left who can "be at hand for the Apostolic See, when there is a discussion about ecclesiastical times" (1586 *Ratio,* "De mathematicis," no. 1). His knowledge about Ricci's missionary efforts may have given rise to the suggestion of

[39] Homann, ibid., 62; Clavius, ibid., (Doc. 34; 1901 Latin text): "cum tamen apud peritos constet physicam sine illis recte percipi non posse" (p. 472). Some of the thrust of this apologia for mathematics seems to have influenced the content of the 1586 *Ratio* if not the exact wording as well.

[40] This is Document 35 in the 1901 *Monumenta Pædagogica S.I.* A translation of this document and of Document 34 is found in *Science in Context* 15, no. 3 (2002): 465–70. See Homann, *Church, Culture and Curriculum,* 63.

establishing an academy of eight to ten Jesuits to study specialized mathematics, and the comment, "Afterwards, the excellent mathematicians of this academy will go forth, who will disseminate this discipline into all provinces to which they will return, and they will uphold the reputation of Ours, if at any time it behooves them to speak about mathematics" (1586 *Ratio,* "De mathematicis," no. 3).[41]

The impact Clavius had on the 1586 *Ratio* cannot be overestimated. He was someone who had done significant scientific and mathematical work; his effort in revising the Julian calendar noted earlier was just one example.[42] And he proclaimed the importance of mathematics in the face of an academic culture in Italy and professorial colleagues at the Roman College who apparently demeaned mathematics whenever possible. Clavius saw new uses for mathematics in ways that were only beginning to be discovered in the last decades of the sixteenth century. He wanted to make sure that Jesuit schools placed proper emphasis on mathematics by recruiting and training qualified instructors of mathematics as well as by requiring that mathematics be studied by all. Clavius's daring proposals are now viewed by some as revolutionary. He did not want partial remedies but a complete and complex strategy to obtain a radical change in attitude and structures.[43] It was probably due to Clavius's influence that the 1586 *Ratio* included a lengthy apologia about mathematics and its connection to various disciplines and professions, including poetry, history, politics, metaphysics, theology, law, farming, and medicine. More concretely, the 1586 *Ratio* required all students to take mathematics for at least a year and a half (1586 *Ratio,* "De mathematicis," no. 2).

Some modern scholars view the 1586 *Ratio* as a radical document for raising mathematics to be on a par with other university-

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[41] Cf. Rivka Feldhay, *Galileo and the Church: Political Inquisition or Critical Dialogue?* (Cambridge: Cambridge University Press, 1995), 221 f.

[42] We should also note some of Clavius's other contributions to mathematics, such as the use of *x* as an indeterminate unknown quantity (Florian Cajori, *A History of Mathematical Notations,* vol. 1, *Notations in Elementary Mathematics* [LaSalle, Ill.: The Open Court Publ. Co., 1928], 154, §161 and MacDonnell, *Jesuit Geometers,* 29; the decimal point (Cajori, ibid., 322, §280; MacDonnell, ibid., 18); parentheses in algebraic expressions (Cajori, ibid., 151, §161, 392, §351; MacDonnell, ibid., App. 1, p. 5 [p. 5 of the appendix section is toward the rear of the book]). He seems to be one of the first in Italy to make use of the square-root sign (Cajori, ibid., 369, §327).

[43] Homann, *Church, Culture, and Curriculum,* 64; Feldhay, *Galileo and the Church,* 221.

level disciplines and for giving it a prominence unheard of in Italian universities.[44] Clavius's insight about the importance of the mathematical sciences, especially as incarnated in the 1586 *Ratio,* provides us with a vision about mathematical (and other contemporary technical) disciplines, their importance for understanding our world, and their usefulness in our ongoing quest to find God in all things and to proclaim God's presence in a world still searching for him. Unfortunately, the culture and the times of the sixteenth century were not appropriately receptive to this insight.

The Evolving *Ratio studiorum*

In the early 1580s, the creation of the *Ratio studiorum* was authorized by Father General Claude Aquaviva in order to provide common guidelines for the curriculum, pedagogy, and organization of the increasing number of Jesuit schools in Europe and elsewhere. In 1584 six Jesuit university instructors, elected from different European Jesuit provinces, gathered in Rome and reviewed the various local education documents in use at Jesuit schools. In August 1585 this commission submitted a report to Aquaviva, who, in turn, submitted the draft to the faculty of the Roman College, where Clavius had been teaching for some twenty years.[45] After revision, the first draft of the *Ratio* appeared in 1586 and was sent to Jesuit schools throughout Europe with a request for comments. As noted earlier, a second draft ("1586B") also was written in 1586 but was not published or circulated. The collected comments on the original 1586 *Ratio* were again studied by the faculty of the Roman College (including, presumably, Clavius) and a revised *Ratio* was published in 1591 to be circulated for review. After more study in Rome, both by Father General Aquaviva and the

The 1586 first draft of the Ratio seemed too radical for some individuals. In response, this draft was submitted by a Spanish Jesuit, Father Enrique Enriquez, to the Spanish Inquisition.

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[44] Feldhay, ibid., 221 f.; Dear, *Discipline and Experience,* 35.

[45] E. Fitzpatrick, ed., *St. Ignatius and the "Ratio Studiorum"* (New York: McGraw-Hill Book Co., Inc., 1933), 28–30.

faculty of the Roman College, a definitive version was promulgated in 1599.[46] (Also see the introductory letter promulgating the 1599 *Ratio.*)[47]

The 1586 first draft of the *Ratio* seemed too radical for some individuals. In response, this draft was submitted by a Spanish Jesuit, Father Enrique Enriquez, to the Spanish Inquisition. His contention was that the *Ratio* was at variance with the teachings of St. Thomas Aquinas, much of whose outlook was Aristotelian.[48] Changes were introduced into the *Ratio,* and some of the differences between the 1586 draft and the definitive 1599 *Ratio* are noteworthy in light of analyses by contemporary scholars.[49] One striking difference pertains to the amount of text devoted to mathematics. In the 1599 *Ratio,* the references to mathematics are only about a quarter of the length of what is found in the first 1586 draft.[50]

> ***One could rightly wonder whether the 1599* Ratio *represents a retreat from the intense interest in mathematics evident in the 1586 draft.***

The never-published 1586 second draft kept the apologia for mathematics found in the first draft, but revised the practical advice. This new draft added a public presentation of mathematical problems before an assembly of students once or twice a month, and monthly repetitions of the principal topics in an interactive format. In contrast, the number of students mentioned for special tutoring is reduced from eight or ten to only four or five. (Maybe the revisors of the *Ratio* felt that Clavius was too optimistic in gauging the number of Jesuits competent to study advanced mathematics.)

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46 Fitzpatrick, *St. Ignatius and the "Ratio Studiorum,"* 31–33.

47 Ibid., 119 f., and Farrell's translation of the *Ratio studiorum,* xii-xiii, available at www.bc.edu_org/avp/ulib/digi/ratio/ratiohome.html

48 Farrell, ibid., 231; Feldhay, *Galileo and the Church,* 222.

49 Cf. Feldhay, ibid., 223ff.

50 In the first 1586 version, the section dealing with mathematics runs to about fifty-four lines in a recent edition of the Latin text. In the 1599 version, the section dealing with mathematics is only ten lines in the same edition, with four additional lines about studying mathematics in a different section.

The 1591 draft did not include any rationale as to why various disciplines were to be taught. So the general apologia for mathematics disappeared. In addition, the study of mathematics by all is reduced to one year. A second year is only recommended for students of metaphysics, and the length of time for private tutoring is reduced from three years to six months.[51]

The definitive 1599 *Ratio* (see excerpts in Appendix 3) makes no direct mention of how long students should study mathematics, but only says that mathematics should be taught to the students of physics and those in the second year of philosophy. It also reduced the public presentations of mathematical problems from once or twice a month to each month or every other month.

One could rightly wonder whether the 1599 *Ratio* represents a retreat from the intense interest in mathematics evident in the 1586 draft. In a sense, it does, yet one should not overlook the fact that the definitive text is overall a much leaner document than the earlier drafts (hence the absence of anything like the 1586 apologia). In addition, mathematics is still required in Jesuit schools (unlike in most other Italian universities of the period), along with regularly scheduled public presentations of mathematical problems. This commitment to mathematics is still noteworthy in the history of higher education.

IV. The Definitive 1599 *Ratio studiorum* and the Revised *Ratio* of 1832

The 1599 *Ratio* served newly established Jesuit schools well. Over the years, mathematicians and other scientists, Jesuit and non-Jesuit, well known and obscure, all benefited from the approach taken toward mathematics and science in Jesuit institutions. Over the approximately two centuries between the publication of the *Ratio* and the suppression and restoration of the Society, however, the world changed significantly. And even though the *Ratio* was adapted in various ways, based on the Ignatian principle

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[51] The philosophy curriculum at the Roman College in the late-sixteenth century consisted of a three-year cycle, with logic taught the first year, natural philosophy and mathematics the second, and metaphysics the third. See Wallace, *Galileo and His Sources*, 6–8, 59–61.

of adapting to persons and places as found in the *Constitutions* and the *Spiritual Exercises,* for various reasons[52] (the primarily ones being the suppression of the Society, the rapid development in the sciences, and the political upheavals in various parts of the world in the late 1700s and early 1800s) the impact of the original *Ratio* regarding mathematics and science generally seems to have dissipated over two centuries.

Father General Luigi Fortis (the second general after the restoration of the Society), with a mandate from the general congregation that elected him, started a revision of the *Ratio studiorum.* He appointed a commission and solicited opinions about educational needs in a post–French Revolution world. As William Bangert, S.J., notes, "Many reports indicated new trends: greater attention to vernacular languages; wider stress on mathematics, history, and geography; a more alert appreciation in logic and metaphysics of modern philosophical currents; a comprehensiveness in projecting a program for the natural sciences."[53] After Fortis's death in 1829, Father General Jan Roothaan, with a new mandate from the next general congregation, issued in 1832 a revised *Ratio* on a trial basis, but this version never received the approbation of any general congregation. The 1832 *Ratio* was not an extensive revision; it did, however, explicitly permit the study of vernacular literature, and one of the new rules for the professor of physics notes the obligation of the instructor to keep up to date because of the new

Over the years, mathematicians and other scientists, Jesuit and non-Jesuit, well known and obscure, all benefited from the approach taken toward mathematics and science in Jesuit institutions.

[52] For example, we find the following in the *Constitutions:* "[The separate treatise on schools] ought to be adapted to places, times, and persons" (*C* 455$^{v.3}$); "that which is found to be more suitable may be done" (*C* 477); "These details and those which follow below are appropriate and should be observed when possible, but they are not necessary" (C 526$^{v.1}$). In the *Spiritual Exercises* we also read, "The Spiritual Exercises must be adapted to the condition of the one who is to engage in them, that is, to his age, education, and talent" (18$^{v.1}$ [pp. 26 f.]).

[53] William V. Bangert, S.J., *A History of the Society of Jesus,* 2nd ed. (St. Louis: The Institute of Jesuit Sources, 1986), 435–37.

advances in science every day. Yet the political realities of that era (revolutions in the United States [1776], France [1790], Paraguay [1811], Spain [1820], Mexico [1810–1820], Austria, Hungary, and Germany [1848], among others) impacted the possibility of ever having a unified, worldwide *Ratio.* The new governments often made education one of their specialized interests, superseding anything a revised *Ratio* would contain. In addition, the 1832 *Ratio* contained only a few accommodations to the rapidly changing educational landscape, not taking the contemporary educational currents sufficiently into account. Compared to its 1599 ancestor, the 1832 *Ratio* was a case of "too little, too late," and the attempt to reclaim the glory of the earlier *Ratio* ended more with a whimper than a bang.[54]

V. Reflections

The world is a significantly different place now than it was when Clavius was defending the new calendar, Ricci was translating Clavius's text on Euclid into Chinese, and the 1599 *Ratio* was promulgated. Since that time, entire areas of mathematics and science have been developed and have even been taken for granted. When I began my undergraduate studies as a mathematics major in 1965, I was worried that I would not get the correct type of slide rule. Today, most incoming college freshmen arrive on campus with their own computers (occasionally several) and have spent several years using e-mail and looking up information via Google on the Internet. But one can rightly wonder how well the avalanche of information, both technical and nontechnical, available via computers has drawn students closer to God or, at the least, raised questions about the use of science and technology for the benefit of human society. In an often quoted passage, T. S. Eliot, in his choruses from *The Rock,* poses some crucial questions about the purpose of knowledge:

> The endless cycle of idea and action,
> Endless invention, endless experiment,
> Brings knowledge of motion, but not of stillness;

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[54] Codina, "'Our Way of Proceeding' in Education," 15; John W. Donohue, S.J., *Jesuit Education: An Essay on the Foundations of Its Idea* (New York: Fordham University Press, 1963), 53.

Knowledge of speech, but not of silence;
Knowledge of words, and ignorance of the Word.

All our knowledge brings us nearer to our ignorance,
All our ignorance brings us nearer to death,
But nearness to death no nearer to God.
Where is the Life we have lost in living?
Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in information?[55]

To my mind, one special charism of the Society of Jesus and its scholarly tradition has been the ability of Jesuits to start with information of various sorts and let that information draw them nearer to the knowledge of God, as the Society pursues "what will seem expedient for the glory of God and the common good."[56]

Having reviewed the history of the Society's involvement in mathematics (and other scientific and technical fields) in the earlier sections, I would now like to offer some personal reflections on how mathematical information has, in fact, drawn me "nearer to God. " I would also like to raise some questions about what the Society's past involvement in the mathematical sciences might suggest about our future. I admit that it is very easy to raise questions and identify problems, but much more difficult to provide answers and solutions. Yet often it is more important to ask the question than to provide any immediate answer.

Seeking and Finding God

Students of literature, music, or art, lacking the ability to interview authors, composers, or artists of previous centuries, often come to know the "mind" of the artist by examining the various artistic creations produced, whether those creations be plays, novels, operas, symphonies, paintings, or sculptures. In a similar way, I feel I am drawn into ever-deeper insights into the "mind" of God through mathematics, in particular when I reflect on the coherence, pervasiveness, order, and beauty of my field. In "reading" the book of the universe, "written in the language of mathematics" (quoting Galileo once again), I am drawn into a deeper awe of the Creator as

[55] T. S. Eliot, *The Complete Poems and Plays, 1909–1950* (New York: Harcourt, Brace and World, 1952).

[56] "Formula of the Institute," in *ConsCN* 1$^{v.3}$ (p. 4).

I marvel at the wonders of creation. And then, standing in awe before my loving God, I also feel drawn more into my academic discipline, to come to a deeper understanding of the works of creation. I think my feelings are shared by other scientists who are also individuals of faith. I remember reading an article, years ago, by someone who was reflecting on the wonders of computers (then just becoming more and more widespread), and how a combination of silicon chips, disk drives, and connecting wires could do so much. The author then paused, as it were, and reflected that, even though the personal computer was amazing, even more amazing were the human minds that created the computer. For me, it is when I look at the mathematical "laws" that are used in so many ways to describe, albeit often imperfectly, the motion of the planets, the growth of population, the power of earthquakes, and so on, that I continue to stand in awe of my God, whose love brought such order out of the chaos of the primordial sea.

I do not see myself so much as bringing order out of chaos as attempting to see the order and patterns that exist in God's creation and then describing and interrelating these patterns using the symbols of mathematics. Over the years, I have been struck by the mathematical patterns that recur throughout nature, sensing a Divine Plan in what at times seems like the chaotic nature of the universe. My feelings often mirror statements by minds much greater than mine, such as the statement "God exists because mathematics is consistent, and the Devil exists because we can't prove it."[57]

Mathematics can help train individuals to think abstractly and in disciplined, structured ways, thereby offering them ways to describe so many aspects of God's creation.

Timothy Toohig, S.J., in his essay "Physics Research, a Search for God," concluded with a reflection on how his physics research was related to his search for God and to an appreciation of the sense

[57] This statement has been attributed both to Hermann Weyl (1885–1955) and to Andre Weil (1906–98) (in *Mathematical Circles Adieu*, by Howard W. Eves [Boston: Prindle, Weber & Schmidt, 1977]).

of mystery, both of creation and of redemption.[58] In a similar way, mathematics draws me to reflect on the wonders of creation, seeing connections that are so often overlooked. But since mathematics is the "language" of science and technology, I also rejoice at those ways that mathematics has assisted other scientists to improve our human condition in so many ways, whether by helping meteorologists better predict the weather, or helping engineers design stronger earthquake-resistant buildings and bridges.

In recent months I, as possibly many others, found myself to be in awe at photos taken by NASA's Hubble Space Telescope of galaxies and nebulae at the end of the known universe.[59] While looking at the Hubble pictures, I reflected on the ways that computers and mathematics have aided other scientists to obtain such images and also whether the beauty seen in these patterns can be described via mathematical equations. My reflections, in a sense, mirrored the first section of "De mathematicis" in the 1586 draft of the *Ratio* that spoke about the interrelation between mathematics and other human disciplines (see Appendix 2).

Mathematics is an abstraction, sometimes even called the "science of patterns." For example, what is the numeral "3" other than an abstraction that describes the common pattern found in 3 oranges, 3 dogs, 3 squares, or 3 houses? Or what is the Pythagorean Theorem but an abstraction that describes the pattern found between the hypotenuse and the other two sides of a right triangle? Mathematics can help train individuals to think abstractly and in disciplined, structured ways, thereby offering them ways to describe so many aspects of God's creation. Although many people today, Jesuits included, may exhibit a benign tolerance toward mathematics and other related scientific and technical fields (and some may even claim to have "math anxiety"), most would also acknowledge the underlying importance of mathematics and other technical human disciplines.

Speaking about "beauty" in relationship to mathematics, as I did earlier, may seem novel to some readers. I must admit that I, too, was surprised when, years ago, as an undergraduate, I read the

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[58] Timothy E. Toohig, S.J., "Physics Research, A Search for God," STUDIES IN THE SPIRITUALITY OF JESUITS 31, no. 2 (March 1999): 25 f.

[59] See hubblesite.org or hubble.nasa.gov for some recent pictures.

following in one of my mathematics texts: "It works! Isn't that lovely? Such a delightful display of symmetry should make shivers of joy run up and down the spine of anyone with any mathematical sensitivity."[60] Yet, even taking into account a bit of poetic hyperbole in this statement, it does capture some of the joy and enthusiasm that mathematicians feel when doing mathematics. For many mathematicians, the focus is on the process of doing mathematics, rather than on the end product. In addition, for theoretical mathematicians, the focus is on the abstract theory as one form of basic scientific research, rather than any immediate practical application (although often mathematical questions arise from problems raised in some other scientific field, like physics, for example. There is an excitement in the pursuit of trying to find connections between what may, at first glance, seem very disconnected; there is an exhilarated feeling when one goes from a hunch that some proposition may be true to a detailed, rigorous proof. Often significant mathematical results are described as being "deep" and a particularly well-crafted proof is described as "elegant." Such modifying descriptors are more similar to words used in the fields of art or music than those used in other academic disciplines.

Bertrand Russell also addressed the beauty of mathematics when he wrote, "Mathematics, rightly viewed, possesses not only truth, but supreme beauty—a beauty cold and austere, like that of sculpture, without appeal to any part of our weaker nature, without the gorgeous trappings of painting or music, yet sublimely pure, and capable of a stern perfection such as only the greatest art can show."[61]

I suggest that it is due to the inner beauty of mathematics, albeit not always obvious to many people, as well as due to the usefulness of mathematics in so many other human disciplines, that the Society has had a long and distinguished history of involvement in mathematics and, in the case of Ricci and others, used mathematics as a vehicle through which the Gospel message might be spread.

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[60] J. B. Fraleigh, *A First Course in Abstract Algebra* (Reading: Addison Wesley Co., 1967), 92.

[61] Bertrand Russell (1872–1970), *The Study of Mathematics: Philosophical Essays* (London: Longmans, Green & Co, 1910), 73.

The "Desires" and Insights of Clavius

In both the *Constitutions* and the *Spiritual Exercises,* Ignatius speaks about desires (*ConstSJ, Gen. Exam.* [101, 102], in speaking about a candidate's "desires"; *SpEx* [48], in recommending focus for the second or third prelude for a meditation, "to ask for what I desire").[62] Ignatius saw in these desires a locus for communicating with God. From the various writings of Clavius, we see someone who had great "desires" (perhaps better called "passion") about the mathematical sciences and was desirous of setting others on fire about mathematics itself as well as about its many applications.

Perhaps it was Clavius's experience with justifying the Gregorian calendar that led him to proclaim the pervasiveness of mathematics in so many areas of human life and to argue about the necessity for Jesuits to learn enough mathematics to feel at ease with the logical and technical side of nature. Ricci, who styled himself as a disciple of Clavius, was able to present the Greek and European mathematical traditions to the people of China as disciplines based on logic and reason, which derived mathematical truths from fundamental axioms. Given the years Ricci and Clavius spent together in Rome and their subsequent correspondence, it seems plausible that Ricci's approach was inspired by Clavius. Since mathematics is based on logic alone, it is a system of truths not bound to any sort of divine revelation and provides a topic about which individuals of different religious traditions, or no religious tradition, can discuss starting at a common ground.

Clavius's insistence on the importance of mathematics also suggests to me that he might have had an inkling into the role mathematics would play in the world of science, just then beginning to expand. Certainly Clavius examined Copernicus's work in his efforts to reform of the calendar and is also known to have met with Galileo. These insights translated into his insistence that Jesuits be well enough grounded in the foundations of mathematics (and the various "mathematical sciences") to help guide the path of scientific progress in its infancy.

In fact, Jesuits played a significant role in science in the seventeenth century (when the modern divisions into separate disciplines

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[62] *General Examen,* in *ConsCN* 101f. passim; *SpEx* $48^{v.1}$ (p. 40).

were not as clear-cut as they are today and many were highly mathematical). We read, for example, that

> [t]he Jesuits had a particular zest for experimental science; they were interested in every newly discovered phenomenon, from electrostatic attraction to the barometer to the magic lantern, and Jesuits played a major role in discovering many new effects on their own, such as diffraction and electrical repulsion. A recent history of early electrical science awarded the Jesuit order the honor of being the single most important contributor to experimental physics in the seventeenth century. Such an accolade would only be strengthened by detailed studies of other sciences, such as optics, where virtually all the important treatises of the period were written by Jesuits. . . . Another admirable feature of the Jesuit scientific enterprise was their appreciation of the value of collaboration. One might well argue that the *Society of Jesus,* rather than the *Accademia del Cimento* or the Royal Society, was the first true scientific society.[63]

Elsewhere we find this evaluation:

> The Society of Jesus in the 17th century contained within its ranks an astonishing number of enthusiastic students of the natural world. Indeed, for the first sixty years of the century, the Jesuits were the only scientific society in existence anywhere. At a time when experimental science was decidedly unfashionable, Jesuits were charting sunspots, calibrating pendulums, timing the fall of weights off towers, and devising a variety of ingenious inventions. Indeed, in the field of geometry, optics, magnetism, cartography, mechanics, and earth sciences, most of the principal authors throughout the century were members of the Society of Jesus. The Jesuits were a remarkably bold and imaginative scientific body.[64]

Contemporary Jesuit Scientific and Technical Ministries

Lest it seems that I am overlooking contemporary Jesuit involvement in mathematically related sciences and other areas of technology, let me acknowledge the work of the Society at the Specola Vaticana (Vatican Observatory). Papal support of astronomi-

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[63] David C. Lindberg and Ronald L. Numbers, eds., *God and Nature: Historical Essays on the Encounter between Christianity and Science* (Berkeley: Univ. of California Press, 1986), 154 f.

[64] William B. Ashworth, *Jesuit Science in the Age of Galileo* (Kansas City: Lowell Press, 1986), 5.

cal science finds its origins with the observatory established at the Roman College at the time of Clavius. The current Vatican Observatory was refounded by Pope Leo XIII in 1891 and moved to Castel Gandolfo in the 1930s. There are also Vatican Observatory sites at the University of Arizona at Tucson, Arizona, and on Mona Kea on the island of Hawaii. Many of the current scientists associated with the Vatican Observatory are Jesuits, as is the director, George Coyne, of the Maryland Province.

Perhaps one of the best-known Jesuit scientists of the twentieth century was Pierre Teilhard de Chardin (1881–1955), whose writings attempted to bridge the gap between the world of science and the world of theology. Interestingly enough, some recent commentators have seen in some of Teilhard's remarks about scientists being linked together in a "vast organic system" as a hint of our contemporary global interconnectedness via the Internet.

Jesuit scientists in Europe have had a tradition of regular meetings and host their own Website (www.jesuitsinscience.org), and a number of U.S. Jesuit mathematicians and lay colleagues have met as the Clavius Group since around 1970.[65]

Although not exactly "scientific" ministries in the commonly understood sense, I think it is also important to acknowledge the Society's work in two areas that make use of modern technology. The Vatican Radio, founded in 1931, was entrusted as a specific ministry to the Society. There are also the various spiritual ministries conducted by Jesuits via the Internet. Perhaps the most widely accessed Website of these electronic ministries is *Sacred Space* (www.sacredspace.ie), sponsored by the Irish Jesuits.[66]

Educational Challenges: Jesuit Formation and Academic Institutions

Early Jesuit education was innovative in introducing into universities the study of mathematics alongside philosophy and

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[65] See the Website at: www.faculty.fairfield.edu/jmac/cl/clavius.htm.

[66] Two other sites (among numerous others) focusing on Jesuit spirituality are at Creighton University (www.creighton.edu/CollaborativeMinistry/online.html) and at the Singapore Jesuit Website (www.jesuit.org.sg).

physics.[67] Especially in the first 1586 *Ratio,* mathematics was presented as a key to understanding physical reality as well as the model of correct rational procedure,[68] in this way serving the understanding of the physical world as well as of ultimate, that is, metaphysical, reality. But, as already noted, merely prescribing that mathematics be taught in a Jesuit university did not eliminate all the anti-mathematical prejudices of scholars from other disciplines.

The tradition of mathematics and the science that is part of the Society's heritage raises for me some questions about the present, both for the formation of Jesuits and for the formation of students in our schools. One foundational question is whether the current guidelines (that is, core-curriculum requirements) in mathematics, science, and technology are appropriate for the contemporary world? It seems that Clavius would have preferred a more rigorous curriculum than what the 1599 *Ratio,* in fact, prescribed. Perhaps the final version was more realistic, given the variety of countries in which Jesuits were establishing schools, but, as noted earlier, some have seen the final requirements as giving in to pressures of the culture of the sixteenth century.

Centuries ago, the Church seemed to be an enemy of science and technology, with the condemnation of Galileo's thesis in the seventeenth century and Gregory XVI's more recent prohibition of railroads and gas lights in the Papal States in the early-nineteenth century.

In our contemporary world that is so dependent on technology, what should be the minimum background in mathematics, science, and technology for Jesuits in formation?[69] What should be

[67] Dear, *Discipline and Experience,* 35.

[68] Feldhay, *Galileo and the Church,* 222.

[69] All Jesuit scholastics in formation currently take a significant number of philosophy courses to provide a foundation for studying theology. Such courses are required even though few Jesuits ever teach philosophy and some find philosophy quite difficult. Is it not also reasonable to recommend, and even require at least on an assistancy level, some minimum number of mathematics, science, and technology courses to equip Jesuits to understand our technologically dependent world, especially since Jesuits will be in leadership roles (as priests and teachers) in that

the minimum required for students in Jesuit secondary schools and universities? Are there other modern technical disciplines that may play the same role for the twenty-first century as mathematics did for the seventeenth and how should courses in these disciplines be introduced into the formation of Jesuits and into the curriculum of Jesuits schools?[70]

Needless to say, requiring more mathematics and technical courses means having instructors who can make the technical subjects come alive for students, and such instructors are not always easy to find and retain. (This is a problem Clavius addressed over four centuries ago in regard to mathematics in *De re mathematica instructio.*) In addition, recently published reports about the competency of U.S. primary students in mathematics when compared with students in other countries imply that many secondary schools or colleges may need to provide students with significant assistance for them to achieve a desired minimal mathematical and scientific competency.

And in a world in which science and technology are commonplace, leadership in tomorrow's world demands familiarity with mathematics and technology and with the ways it helps or harms human progress.

One of Ignatius's principles for choosing ministries was "the greater good—the *magis*" (*ConsCN C* 622f., passim). In a world where more and more people are leaving organized religion behind, perhaps one of the greatest goods that Jesuits and students of Jesuit schools could choose to pursue is making use of the language of mathematics, science, and technology to begin a conversation with

world? Some Jesuits may find it difficult (but, I hope, not impossible) to complete, for example, two courses in calculus, a lab-science course, and a course in computer programming, but the resulting experience of the world of mathematics, science, and technology, albeit cursory, may well be worth any difficulty. In this way, they may be at least minimally equipped (beyond being able to use a word processor, send e-mail, or surf the Net) to interact with a world ever more based on the mathematical sciences and dependent on technology.

[70] I attempted to address the issues of contemporary technical disciplines in Jesuit schools in "The *Ratio Studiorum* and New Technology: Opportunities and Challenges," *Explore* (Journal of the Santa Clara University Bannan Center) 4, no. 1 (Fall 2000): 22–30. (Available via: www.scu.edu/bannancenter/publications/explore)

people of little or no faith and together tackle the problems of our global society, especially issues of justice. As one example, in a world in which some companies make significant profits selling virus-protection software because bright individuals take delight in wreaking havoc in our electronically interdependent world, how can Jesuits and Jesuit alumni influence the conversation about new sources of electronic evil and electronic terrorism in our world?

In some of my daydreams, I am, perhaps, as unrealistically optimistic about mathematics (and science) as Clavius seems to have been, but I have also wondered what impact and symbolic statement would be made if, in Jesuit schools, there were more Jesuits teaching mathematics, science, and technology than Jesuits teaching theology. I continue to find people who seem to be amazed and confused when, after they ask me, "What do you teach?" I respond, "Mathematics and computer science." Their retort is usually, "But I thought you are a priest, so why are you teaching math?" Such a response seems to reflect a contemporary perception about Jesuits and science that appears to be in stark contrast to the Society's reputation in the seventeenth century as a society of science. What kind of paradigm shift would occur today if students saw non-Jesuits as dedicated enough to their faith to obtain the required competency to teach religious subjects and saw Jesuits as dedicated enough to the often perceived a-religious world of mathematics, science, and technology to dedicate their lives to these subjects as well. Recent advances and developments in the world of mathematics and science may mean that the Society may never be able to regain its reputation about being a major scientific society, although there may continue to be individual Jesuits who will be known as excellent scientists. Yet I hope that, institutionally, the Society will continue to commit its energies and willing Jesuits to engage with the world of mathematics, science, and technology as one area where the "greater good" can be achieved in a world ever more dependent on these scholarly disciplines.

That is what "helping souls" is about, and that is where we may seek and, yes, even be able to "find God."

VI. Concluding Thoughts

Unlike the debates about mathematics in the sixteenth century, today there is little disagreement about the appropriateness of disciplines such as mathematics or other technical or scientific fields being offered in a university or about their academic stature. Centuries ago, the Church seemed to be an enemy of science and technology, with the condemnation of Galileo's thesis in the seventeenth century and Gregory XVI's more recent prohibition of railroads and gas lights in the Papal States in the early-nineteenth century.[71] But in the twentieth century, the Church has taken a significantly different approach.

Perhaps it was John XXIII who introduced the new emphasis when, in his 1963 encyclical *Pacem in terris,* he wrote: "[T]he progress of science and the inventions of technology show above all the infinite greatness of God. . . . And since our present age is one of outstanding scientific and technical progress and excellence, one will not be able to . . . work effectively from within unless he is scientifically competent, technically capable and skilled in the practice of his own profession" (no. 3, 148). The 1990 apostolic constitution *Ex corde Ecclesiæ* speaks to the work of Catholic universities in the fields of science and technology (see nos. 7, 18, 45). The existence of a Vatican Website is a welcome sign that the Church has embraced technology to help spread the Gospel message. The Ignatian tradition of "finding God in all things," even in mathematics and related scientific and technical disciplines, is accepted without debate today. Thus, perhaps the more important questions deal with the opportunities and challenges that studying such disciplines presents to Jesuit schools and their students.

The renowned anthropologist Margaret Mead once said, "The solution of adult problems tomorrow depends upon the way we raise our children today." We cannot deny that the future leaders of corporations and nations are those students in school today. And in a world in which science and technology are commonplace, leadership in tomorrow's world demands familiarity with mathematics and technology and with the ways it helps or harms human progress.

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[71] See Hans Kuhner, *Encyclopedia of the Papacy* (New York: Philosophical Library Inc., 1958), 225.

Today's science and technology provide opportunities never before possible in our world. The early Jesuits saw education as a way to transform society, and the 1599 *Ratio* provided structures to provide an excellent education. In a sense, including mathematics in the *Ratio* forced Jesuits and their students to become familiar with this foundational language used by intellectuals of a world on the brink of what we now call "the scientific revolution." Through the mathematical sciences, Jesuits and their students became engaged, perhaps unknowingly, with a culture that was only beginning to make its influence felt, the culture of Galileo and Newton, among others.

Near the end of the *Constitutions,* Ignatius speaks about various means to glorify God and to preserve the Society. While speaking about such religious topics, Ignatius noted that "the human means ought to be sought with diligence, especially well-grounded and solid learning" (*C* 814[v.4]). The *Ratio studiorum* provided a plan to obtain "well-grounded and solid learning," and the influence of Clavius enabled students in Jesuits schools to be "well-grounded" in the newly developing mathematical sciences.

The *Constitutions* also remind us that "the end of learning which is acquired in this Society is . . . to help the souls of its own members and those of their neighbors" (*C* 351[v.2]). Whatever helps build up God's Kingdom on earth, whatever helps ensure that God's justice will prevail, whatever helps promote peace and unity among peoples and relieves pain, disease, and poverty, whether it involves the classics or mathematics or the latest modern technology, that is what "helping souls" is about, and that is where we may seek and, yes, even be able to "find God."

Appendix 1: Jesuit Craters on the Moon

	NASM name	name in Sommervogel	nationality	born: time/city	died: time/city	field
1.	Bettinus	Mario Bettini	(Italian)	1582 in Bologna	1657 in Bologna	math/astr
2	Billy	Jacques de Billy	(French)	1602 in Compiegne	1679 in Dijon	math/psys
3.	Blancanus	Giuseppe Biancani	(Italian)	1566 in Bologne	1624 in Parma	math/astr
4.	Boscovich	Roger J Boscovich	(Croatian)	1711 in Ragusa	1787 in Milan	math/phys
5.	Cabaeus	Nicolas Cabel	(Italian)	1586 in Ferrara	1650 in Genes	math/astr
6.	Clavius	Christopher Clavius	(German)	1538 in Bamberg	1612 in Rome	math/phys
7.	Cysatus	Jean-Baptiste Cysat	(Swiss)	1588 in Lucerne	1657 in Lucerne	math/phys
8.	De Vico	Francois de Vico	(French)	1805 in Macerata	1848 in London	astr
9.	Fényi	Gyula Fényi	(Hungarian)	1845	1927	astr
10.	Ferneries	George Fournier	(French)	1595 in Caen	1652 in La Flech	math
11.	Grimaldi	Francesco Grimaldi	(Italian)	1613 in Bologna	1663 in Bolognia	phys
12.	Gruemberger	Chris. Grienberger	(Swiss)	1564 in Tyrol	1636 in Rome	astr
13.	Hagen	Johann Hagen	(Austrian)	1847 in Bregenz	1930 in Rome	astr
14.	Hell	Maximilian Hell	(Hungarian)	1720 in Schemnitz	1792 in Vienna	math/astr
15.	Kircher	Athanasius Kircher	(German)	1602 in Geisa	1680 in Rome	science
16.	Kugler	Francis X. Kugler	(German)	1862 in Konigsburg	1929 in Lucern	hist/math
17.	Malapert	Charles Malapert	(French)	1580 in Mons	1630 in Victoria	math/phil
18.	Mayer	Christian Mayer	(German)	1719	1783	astr/math
19.	McNally	Paul McNally	(American)	1890	1955	astr
20.	Moretus	Theodore Moretus	(Belgian)	1601 in Antwerp	1667 in Breslau	math
21.	Petavius	Denis Petau	(French)	1583 in Orleans	1652 in Paris	hist/astr
22.	Riccioli	Jean-Bap. Riccioli	(Italian)	1598 in Ferrara	1671 in Bologna	selenograph
23.	Riccius	Matteo Ricci	(Italian)	1552 in Mavrata	1610 in Peking	math/geog
j24.	Rodés	Rodés	(Hungarian)	1881	1939	astr
25.	Romaña	Romaña	(Spanish)			astr

	NASM name	name in Sommervogel	nationality	born: time/city	died: time/city	field
26.	Scheiner	Christophe Schemer	(German)	1575 in Wald	1650 in Neiss	math/phys
27.	Schömberger	George Schömberger	(German)	1597 in Innsbruck	1645 in Hradisc	math/astr
28.	Secchi	Ange Secchi	(Italian)	1818 in Reggio	1878 in Rome	astrophys
29.	Simpelius	Hughues Semple	(Scottish)	1596 in Ecosse	1654 in Madrid	math
30.	Sirsalis	Gerolamo Sirsalis	(Italian)	1584	1654	selenography
31.	Tacquet	André Tacquet	(Belgian)	1612 in Antwerp	1660 in Antwerp	math
32.	Tannerus	Adam Tannerus	(Austrian)	1572 in Innsbruck	1632 in Tyrol	math/theol
33.	Zucchius	Nicolas Zucchi	(Italian)	1586 in Parma	1670 in Rome	math/astr
34.	Zupus	Jean-Baptiste Zupi	(Italian)	1590 in Catanzaro	1650 in Naples	astr
35.	Stein	Johan Stein	(Dutch)	1871 in Grave	1951 in Rome	astr/phys

Combined lists of the craters named to honor Jesuits: one is taken from the National Air and Space Museum (NASM) catalog, the other with vital statistics is from Carl Sommervogel, S.J. Recently the International Astronomical Union (IAU) codified lunar nomenclature eliminating conflicts: five Jesuit names were deleted, bringing the present number to thirty-five. There may have been other Jesuit names in the past and there will certainly be more Jesuit names in the future. Numbers are found on the map.

Adapted from MacDonnell, *Jesuit Geometers,* 74a.

Appendix 2: "De mathematicis" [On Mathematics]

(from the 1586 first draft of the *Ratio studiorum*)

[1] The *Constitutions* (*C* 451) reads thus: "Logic, physics, metaphysics, and moral philosophy will be treated, and also mathematical topics, insofar as they are in accord with the end proposed to us."

Nevertheless, they seem to be in accord not just a little, not only because without mathematics our academies would be lacking a great ornament, and indeed they would even be mutilated, since there is almost no moderately celebrated academy, in which the mathematical disciplines do not have their own (and indeed the highest) place; but even much more, because the other sciences also very much need the help of mathematics. For indeed, the mathematical disciplines supply and explain to the poets the rising and setting of heavenly bodies; to historians the shape and distance of places; to those who analyze *(analyticis)* examples of solid proofs *(demonstrationes);* to political leaders easily admired techniques to manage both domestic and military affairs well; to physicists the forms and distinctions of heavenly revolutions, of light, of colors, of transparent media, of sounds; to metaphysicians the number of spheres and intelligences; to theologians the major parts of the divine handiwork; to law and ecclesiastical custom the accurate reckoning of time. For the meantime, we pass over the benefits which flow to the republic from the labor of mathematicians in the healing of diseases, in voyages by sea, in the pursuit of farmers. Therefore, an effort must be made so that, just like the other disciplines *(facultates),* mathematics also may flourish in our schools *(gymnasiis),* so that from this also Ours will become more suited for serving the various interests of the Church; especially since it is not a little unseemly that we lack professors who are capable of presenting a lecture about mathematical topics, longed for in so many, such famous, cities. At Rome also, if you subtract one or perhaps a second person, there will be hardly any one of those left who is qualified either to instruct about these disciplines, or to be at hand for the Apostolic See, when there is a discussion about ecclesiastical times.

[2] So that we may remedy such scarcity and want, we require two mathematics professors in the Roman College. Let one of these prepare a short course *(curriculum)* of mathematical topics for a year and a half with daily lectures to be heard by Ours and by externs; the professor should begin this course after the Pasch of the Resurrection in the morning at first school hour for students of logic; because at this time generally they are preparing themselves for the *Posterior analytics,* which without mathematical examples can scarcely be understood; and since they may be at that time a bit more advanced, they seem not unequal to the burden of three lectures. Nevertheless, it is appropriate that things be arranged that some of the thornier Elements of Euclid be always seasoned by an interpretation either of geography or of the sphere; since in particular these topics do not greatly need knowledge of all the principles of

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The translation of this passage is taken from collections of translations that appeared in *Science in Context* 15, no. 3 (2002): 459-64.

Euclid, but of certain of the first [principles], which after around two months will have been explained. After this, of the three-quarters of an hour to which a mathematical lecture is limited, to the two earlier [topics], the sphere or other more acceptable topics of that sort should be handed over, and this arrangement should be persevered even to the end of the studies. Afterwards, during the second year, the remaining part of the compendium of mathematics, to be completed by Fr. Clavius, will be expounded to the same students, who then will be studying physics, in the first hour of the classes after the midday meal. When, however, Easter approaches, let there be added for the benefit of new students of logic a second early morning lecture, in which the compendium of mathematics is begun again. This presentation and repetition in the same order is to be observed each year.

[3] Let a second professor, who could only be Fr. Clavius, be appointed; let him provide fuller teaching about mathematical topics over three years, and teach privately about eight or ten of Ours, who are at least of average ability and not averse to mathematics, and have studied philosophy; these should be recruited from various provinces, one from each one, if it is possible. And there will be not a few who will be eager to be of the number of these [special students], if, after philosophy in the time others are teaching humane letters, they devote themselves to mathematics, then also to theology; in this way, surely, as in the first two years, let them study nothing other than mathematics. But in the third year, [they will attend] also two lectures of scholastic theology with a brief repetition of them, which will take place only in the schools; but the entire remainder of the day they give themselves to mathematics. Afterwards, the excellent mathematicians of this academy will go forth, who will disseminate this discipline into all provinces to which they will return, and they will uphold the reputation of Ours, if at any time it behooves them to speak about mathematics. And it will not be a problem for any province to devote some one of their philosophers also for a third year to mathematics, with the hope of such excellent fruit.

Appendix 3: Excerpts from "Rules for Mathematics"

from the definitive *Ratio Studiorum* of 1599

Rules for the Professor of Mathematics

1. **What Authors Are to Be Explained, and at What Time and to What Students.** Let him explain in class to the students of physics for about three-quarters of an hour the Elements of Euclid. In these [explanations], after they have become somewhat familiar during two months, let him add something of geography or of the sphere or other matters which are wont to be heard gladly, and this along with Euclid either on the same day or on alternate days.

2. **Problems.** And let him arrange that every month or every other month some one of the students before a large gathering of students of philosophy and theology has some famous mathematical problem to work out and afterwards, if it seems well, to defend his solution.

3. **Repetition.** Once a month and generally on Saturday in place of the lecture, let the principal points that have been explained during that month be publicly repeated.

Rules for the Provincial Superior

20. **Students and the Time for Mathematics.** In the second year of philosophy all the students of philosophy shall attend class in mathematics for three-quarters of an hour. If there are some, moreover, who are fit and inclined towards these studies, let them be practiced in them in private lessons after the end of the course.

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