Ad Fontes Scientiae

by Ravi Jain

The phrase '*Ad Fontes'* or 'To the sources' was a common refrain during the 16th and 17th centuries among European scholars. Many prominent Christian reformers such as John Calvin were part of a movement of Christian humanists which returned to the primary sources, namely the Greek and Hebrew texts of Scripture and the writings of the early church fathers, in order to better understand the true meaning of the Bible. The phrase was also a call of the Italian Renaissance thinkers, and today the phrase has recently been echoed by educators in the Christian classical renewal. Thus, in many Christian classical schools, students read works of Homer, Aristotle, and St. Augustine and are challenged by luminaries of the English language such as Chaucer or John Donne. Yet we tend to think of a return to the sources as an exclusive project of the humanities. Could we return to the primary sources in natural science and mathematics as well?

Ancient authorities influenced not just men of the Renaissance and Reformation but also the early modern scientists. Copernicus knew Ptolemy inside and out and named ancients, like Philolaus, as authorities who believed the earth moved. Galileo expected mathematicians everywhere to know, not simply the *Elements* of Euclid, but also the work of Appolonius on conic sections. Gassendi, Descartes, and Newton all discovered foundations for their natural science in the atomism of Democritus while trying to reinterpret his work through a Christian lens. Since these modern scientists brought a new emphasis on quantitative observations, people today surmise that they eliminated any dependence on their predecessors. But the scientists knew that they were building on the foundations laid out by the great minds that had preceded them. Galileo found his muse in Archimedes, Kepler in Plato, and Descartes in Euclid. But where is our cry "*Ad Fontes Scientiae*" today? Could we possibly follow the actual process of scientific discovery in the original writings of the scientists? Or are we bound to learning only 'fully-formed' systems as if they had sprung complete from the head of Zeus? Is there an alternative to wandering through the shifting mazes of state standards? What would it look like for us to return 'to the sources of science', *Ad Fontes Scientiae*?

Using primary sources in science and mathematics is a better and more human way of learning for at least five reasons. First, reading the great scientists' accounts of their own discoveries allows the objective disciplines of science and math to have a more personal and rounded dimension. Second, focusing on the seminal thinkers and their advances narrows the canon of important scientific material and establishes a continuous and coherent narrative of discovery out of an endless sea of possible information to teach. Third, patterning our thoughts after the habits of mind of the greatest scientists and mathematicians is the best training for teaching students how to think and not just what to think. Fourth, learning to read the primary sources is the best preparation for students to become real lifelong learners in mathematics and science. And finally, allowing them to engage with the best of the best scientists develops in them a sense of confidence regarding science and math because they have become familiar with its chief exemplars and its highest authorities. Discarding all textbooks would be a rash and unhelpful move, but why not, instead, use the technical narrative of discovery as told by the scientists themselves as our primary focus and use textbooks to augment that, fill in the gaps, and provide contemporary applications? In this manner, mathematics and science are then returned to their appropriate status as true humanities and not just servile arts.

Let us consider these five reasons. Over the years the majority of students in my junior and senior Calculus and Physics classes have come to love reading the primary sources because they encounter the personal and rounded dimensions of the scientists. The students who had already enjoyed math and science marvel at the depth and breadth of its founders, and those students that had initially found these subjects boring and meaningless discover salient points of personal contact to inspire them. When years ago my students first read a short five-paragraph introductory biography of Johannes Kepler and realized that his father was a 'soldier of fortune' (or mercenary), they were fascinated. Suddenly Kepler had a context that was intriguing. They sympathized to learn that his wife and children died young of illness. His intense Christian faith impressed them. And Kepler's discarded hypothesis of cosmic Platonic solids supporting the planets in their orbits offered a wonderful case study in the hard work of scientific hypothesizing and evaluation. We only dipped a toe into the shallows of Kepler's life. Though we study the great scientists, we will never exhaust them. Our class focuses on Kepler's three laws which form an essential foundation for Newton's world-shattering *Principia Mathematica*. These were some of the greatest discoveries of all time, yet most physics textbooks barely devote one page to Kepler's laws and are unlikely to mention his intense Christian devotion. However, these stories, personal elements, and plot twists in the history of science cause the students to relate and even want to emulate these great scientists. They are humanized.

This leads us to the second point: canon and narrative. Should Kepler's work and laws hold such a prominent place in an introductory physics class? Amidst the greatest trove of information ever existing in history, how does one select what material is crucial for the students' education and what is incidental? How does one decide on the canon of math and science? A postmodern thinker, Jean Baudrillard, has quipped 'information is entropy' to describe the problem of information overload in our age. In college, I remember the claim that the world would produce as much information in the 1990's as was produced since the beginning of civilization, but in 2010 Google CEO, Eric Schmidt, outdid that assertion. He suggested that humanity now produces as much information in two days as we did from the dawn of time until 2003. The more information that is produced by our culture, the more difficult it is to determine which pieces of information are important. How does one distinguish the signal from the noise? The only way to do this is to have some kind of tuner, to focus on one wavelength and look for the patterns on that band. Closely following the technical narrative of discovery in science and recapitulating both the great discoveries and the great proofs of our scientific predecessors is the best way to establish a canon and 'tune in' to the proper wavelength. But is this practical? While in an introductory course students can't cover every detail, by retracing a basic narrative of discovery they can accomplish quite a bit more than might be expected. Our juniors and seniors when electing to enroll in our school's integrated AP Physics and Calculus sequence trace the primary source narrative from Plato's *Timaeus* through Einstein's 1905 paper, "The Electrodynamics of Moving Bodies," in which he proves the theory of special relativity (the stretching and shrinking of relative time and space). Imagine how it feels not only to understand this paper in a general textbook way, but to be able to follow many of the particular moves of Einstein's argument for $E=mc^2$ (discussed in a short follow-up paper). Once this has been done, the students know why the role of Kepler is crucial to the narrative. They also know what kinds of textbook problems are extraneous busy work. They have internalized the canon.

This leads to the next critical benefit. By following and recapitulating this process, they are effectively imitating the greatest scientific and mathematical minds of all time. As they do this they acquire not just a sense of what to think but how to think. Instead of a slavish repetition of facts and drills (which is at times important), this develops creative and inquisitive habits of mind which can focus and distill the essential issues from the chaff. It nurtures genius. A few years back, a class of seniors was able to outstrip all of my expectations. They were eager to understand Einstein's theory of General Relativity. So at the end of our two-year sequence we took about six days to read through as much as possible of Einstein's 1916 "Foundation of the General Theory of Relativity." I was both excited and astounded. I didn't honestly expect them, or me, to learn much, since this topic is usually only covered by physics graduate students. I didn't know what to expect. While grappling with tensors, new mathematical methods, and mind-blowing thought experiments, we culled one nugget that I doubt we would have learned any other way. We found a major parallel between Newton and Einstein that I had never heard before. The basic insight in general relativity is to develop an invariant quantity, a *ds*, based off a four-dimensional vector where time is treated as a spatial dimension. This invariant then becomes a foundation upon which Einstein builds his system. This directly parallels a method early in Newton's work in which he develops the derivative. This step in Einstein's paper is a beautiful analog to the breakthrough for Newton. And interestingly each scientist is using his new method to solve a problem in his respective theory of gravity. Students can only discover these kinds of deep parallels when reading the primary sources instead of pre-digested versions. Students would never encounter Newton's geometric reasoning for the derivative in a contemporary calculus text. Math textbooks almost exclusively present the derivative through a Cartesian algebraic notation and a limit method not developed until hundreds of years after Newton and Leibniz. While we should still teach Weierstrass's limit notation in its proper place, it is foolish to allow it to eclipse the brilliant reasoning of Leibniz and Newton in their founding of Calculus. Focusing on more minor advances does not cultivate genius. It will not produce another Einstein, Faraday, or Newton. It does not develop the deeply powerful habits of mind that teach students how to discern the central kernel from the chaff and to think creatively about transcendent problems.

Another impressive benefit of studying the primary sources in mathematics and science is that it prepares students to become lifelong learners in these challenging and expansive subjects. Studying primary sources prepares students to continue to learn the new technical discoveries that are constantly emerging. Thus, the best way for our students to be able to competently discuss relativity theory, evolution, or artificial intelligence as adults is for them to read the most significant primary sources in mathematics and natural science leading up to these theories. Watching "This Elegant Universe" on PBS may play a very fine role in stimulating our wonder at the cosmos, but it does not alone constitute 'lifelong learning in science' any more than reading Tom Clancey's *Hunt for Red October* counts for continuing education in literature. American students and even college graduates seldom attempt to engage seriously with ideas outside of their narrow specialties because they are told that there is too much knowledge out there. But to be honest, not much of that knowledge is important for understanding the broad strokes of modern natural science. If students focus on the central narrative of Western scientific thought and its canon, another generation of genius such as that of the 17th century Scientific Revolution may indeed arise. Most of the fathers of modern mathematics and science from that era were broadly educated and wrote as much in philosophy and theology as they did in math and science. In order to achieve that level of erudition again, we have to follow their method of reading the actual authors themselves, not pre-digested systematized summaries. Thus, using primary sources to sift out the central narrative is a key to teaching our students how to be lifelong learners.

All of this leads us to the final observation: this method provides students with a level of confidence in math and science unmatchable by mere technical prowess. This approach is not simply knowing lots of facts; it is knowing and understanding a lot about the right facts. Richard Dawkins can argue interminably about the incompatibility of science and religion, but when students have read Kepler, Newton, and even Galileo defending the power and glory of God, they will have little fear of the ill-conceived critiques of the new atheists. The vast majority of significant contributors to math and natural science before the 20th century were Christians. It takes a lot of explaining to describe how devoted Christians were actively building and defending a system if that system was held to be in direct contradiction to their beliefs. Much to the contrary, they believed their math and science to be a natural outgrowth of their faith in an all-wise God who created an orderly world. In fact, Descartes, Newton, Pascal and Leibniz all thought their work provided an apologetic for the reality of God. Thus, studying the primary sources gives the students a first-hand acquaintance with the harmony between science and Christian faith and protects them from hostile skeptics.

If by now an interested educator thinks that this approach is worthwhile but is flummoxed by how to pull it off, let me encourage him. Take baby steps. This is by no means an easy or quick task because none of us was trained this way and our schools are not set up to make it easy. But may I suggest that an eager educator begin by endeavoring to learn the technical narrative for himself and from there develop a canon of which texts were truly influential and profound. Once this background is attained, the teacher may introduce a few pages of primary sources on occasion while teaching a related topic. Let the students read Newton's Laws from the *Principia Mathematica* itself. Have the class buy a copy of Pascal's *Pensees*, and read a few in class from time to time. Consider including appropriate excerpts from Lavoisier's "Elementary Treatise on Chemistry" or even Darwin's *Origin of Species*. Develop a Kepler, Galileo, Newton sequence and use it to teach some kinematics, dynamics, and the law of gravity. In the students' laboratory sessions they may reproduce Galileo's kinematics experiments or Pascal's proof that outer space is a vacuum. Whatever can be done to get a foothold in the primary sources will broaden their perspective. While the goal is for students to understand the great conversation in math and science, secondary sources are very helpful as the teacher strives to mediate that conversation to the students. I have used Morris Kline's *Mathematics for Non-mathematicians* and *The Soul of Science* by Pearcey and Thaxton for broad overviews. Specialty histories of the disciplines are also invaluable for subject teachers. I suggest *Creations of Fire* by Cobb and Goldwhite for Chemistry, *This is Biology* by Mayr for Biology, and *The Birth of a New Physics* by Cohen for Physics. These histories help develop the core of the story for the rise of mathematics and the key sciences. *The Modeling of Nature* by William Wallace offers a rare gem for those interested in a Christian classical philosophy of science. It may be one of a kind as no other book that I have found on the topic could be called both Christian and classical. Once a teacher has established the narrative of his discipline, the Great Books series does have many of the most significant primary source works from the period of the scientific revolution and more primary sources can be found online.

Over the course of a few years, if a teacher follows this path, he or she can introduce new primary source passages and texts one by one. A class does not need to read every work in full. Our classes at the Geneva School certainly don't; however, the broader the context that is given for a selected passage, the more insight the students will gain. Over time a teacher will be able to develop a coherent technical narrative from the primary sources and will be able to depend less on textbooks. But, there must be balance in this pursuit. While education necessarily involves nurturing passion in students and developing wisdom, it also requires technical details, habits, and discipline. Without the skills of algebraic manipulation and scientific reasoning the students will not be able to continue in college mathematics and natural science. Therefore, teachers should, little by little, discover what primary sources are effective instructional tools and only slowly adjust their curricula to these new richer places. Radical changes to a curriculum without adequate teacher preparation are almost certain to be short-lived. On the other hand, the steady and intentional approach here commended will continue to teach the students the tools of learning and the basics of the subject but will also do more. It will nurture genius. While this path may sound like a lofty pursuit, it is attainable over time especially if we teachers support each other in this endeavor. Let us therefore strive towards this goal together, for the good of our communities and for the glory of God. And may we too, with Newton and Leibniz, unabashedly conceive of our instruction in mathematics and natural science as an apologetic for his Lordship.

After graduating from Davidson College, Ravi Jain taught mathematics briefly before pursuing an M.A. from Reformed Theological Seminary while considering vocational ministry. As he finished his seminary degree, Ravi returned to education and has been teaching Calculus and Physics at the Geneva School since 2003. During this tenure he has sought to understand and champion the role of math and science in a Christian Classical curriculum. Over the past four years he has had the opportunity to deliver over 35 talks or workshops on these topics at various schools and conferences across the country. He has just finished writing a short booklet entitled, "The Liberal Arts Tradition: A Philosophy of Christian Classical Education," that he co-authored with Kevin Clark. It is currently available for $7 electronically on Amazon. The paperback version is due for release in October and will be available from Amazon or the publisher, Classical Academic Press. Besides teaching and writing, Ravi enjoys spending time with his wife and two young sons and is pursuing further graduate studies in Mathematics.