NARRATIVE IN MATHEMATICS AND NATURAL SCIENCE

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Many of us that teach mathematics and natural science have at times considered whether to include a narrative element in our classes, because we know that there is a great story to tell within these subjects. Blaise Pascal was an eminent scientist, mathematician, and writer who sewed a famous prayer into his jacket with the word "FIRE" emblazoned at the top. Gottfried Leibniz, primarily employed as a diplomat, found time to discover calculus, construct the first mulitiplying calculator, write philosophy, and defend God's justice to a skeptical world. Did not Aristotle, that eminent ancient scientist, tutor the towering conqueror Alexander whom we now call "the Great"? Why should history and literature teachers have all the fun? Science can tell stories too.

But soon after we consider including a narrative element to our math and science classes a realization occurs, and we must face the reality. During this sobering stage most teachers go through three phases. First, the teacher recognizes that he does not know that much about the history of mathematics and science because he was never taught it in school or college. Of course he may know it in broad strokes, but researching the history of each individual concept that he teaches and learning how these fit together is a daunting task. Second, he wonders whether the narrative is really all that important. The stories are fun, but how will understanding Pascal, Leibniz, and Aristotle contribute to the real work of math and science? Will it improve the students' SAT, ACT, or AP scores or better prepare them for college classes? Hmmm . . . And third, the teacher hesitantly acknowledges that he just does not have spare time to include additional material in his already crowded class. After all, is he really going to put this on the test when his students can barely graph a parabola correctly?

Let me acknowledge that these are all real concerns. The time and effort involved in solving these problems can be substantial. But before these worries frighten our poor teacher into merely showing historical movies to check off the narrative box, let me offer a word of encouragement. You can do this. Start with baby steps, and over time progress can be made. Now is the best time to start. But consider that while one is beginning, it is important to attend to the blueprint. What should we as teachers be building towards? While science can be thought of as a narrative, the style differs from a literary narrative. The narrative of science is technical and full of important and complex details. Also, much physical science is mathematical, and as a professor of

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mine has recently said, "Mathematics is perpendicular to language." Moreover, all the little stories are fun and interesting, but how will these reinforce the students' understanding of the main topics in class—graphing parabolas for instance? And how do these little stories play into the grand story of the rise of natural science and modern mathematics? Do these narratives align with the history, literature, and theology classes at our schools? Answering these questions is not an easy task, but it can be much assisted by focusing our attention on the *technical narrative of discovery* in mathematics and natural science.

Western history and literature classes often cover elements of the story of math and science. The Copernican Revolution, the Galileo controversy, and Isaac Newton's groundbreaking *Principia* are clearly important general elements of Western civilization. Consider the cultural phenomenon that is Einstein. A history teacher can scarcely avoid discussions of these events or the men and women behind them. But it falls particularly to the science and math teachers to clarify the *technical narrative of discovery* for the students. What was discovered, when was it discovered, how was it discovered, and why is it important? This involves detailed conceptual analysis and can at times take students far deeper than an ordinary treatment of the material. For example, many scientists at the time of Isaac Newton recognized that if an inverse square law described gravity, then the law would be compatible with planets exhibiting circular orbits. The problem that won Isaac Newton fame was a different one. How could an inverse square law result in orbits resembling any conic section? Since Johannes Kepler had recently proven the planets to orbit the sun in elliptical paths, it was clear that if gravity were an inverse square law it must account for planets' elliptical orbits. Even the AP Physics C: Mechanics curriculum only calls for students to understand the link to circular orbits. To show the harder case, that all of Kepler's laws are compatible with an inverse square law, takes either reading Newton's account or waiting for the methods of polar integrals developed in Calculus II. The technical narrative is at times more detailed than the standard treatment.

An interesting thing occurs though when this approach becomes the ordering principle of one's curriculum. The students start to connect the dots. This nine weeks, I had the students memorize over 100 formulas. Let's just say that I also believe in the value of imitation (though I did keep some pearls from them that they will later have to discover themselves). As the students learned these equations, I recounted to them the basic narratives of how the formulas came about, how they fit together, and to what phenomena they pertained—springs, pendula, falling stones, etc. It is fascinating to note, first, that the students could memorize such a trove, and second, that they actually understood more than one might expect. In mechanics, Galileo's kinematics equations give rise to most of the other formulas. All of Newton's laws, as well as the basic principles of kinetic and potential energy, can be derived rather quickly from Galileo's analysis of constant acceleration. Amazingly, I did not realize this until my seventh year of teaching physics. I did not fully commit to this approach until I later recognized hints of it in Leibniz' own seventeenth century work. Now, I always introduce these concepts through this integrated history. After the formula test, on which the average grade was a 99.5% for a class of 20 kids, I asked one of the students how the test went. She recounted that she actually found it quite easy once she realized how all of the formulas fit together and how so many can simply be derived from Galileo's equations. Thus even in this highly mathematical subject, there is a story to be told—a technical one to be sure—but a story nonetheless.

While we have read about ten pages of Galileo as we developed those formulas and repeated his experiments, we have not yet read much this year from the other scientists nor recapitulated their experiments. We will do more of this over the course of the year. As one develops the narrative for the students, it is often helpful to include some readings from the primary sources, writings of the scientists themselves. When students read Plato's account of the elements in his *Timaeus*, for example, his vision of reality strikes them as surprisingly accessible. Some aspects are quite similar to those of contemporary mathematical science. He also forecasts the basic insight of high end computer graphics: it is all about polygon count. His vision of triangles composing polyhedra which constitute elements is actually not that different from the recognition in contemporary organic chemistry that geometry matters for molecules. Different isomers behave differently. There, in fact, can be no doubt that Plato was the one who planted the seed of this basic question, inherited from Pythagoras, deep within the fabric of Western thought: is there number at the heart of reality? So even the rise of natural science as a mathematical discipline has a story to be told that begins with the ancients. Moreover, this story does not culminate until the Platonic questions are answered by Christian faith. Yes, this story is more technical than the treatment would be in a history class, but it is still a narrative with many twists, turns, and fantastic climaxes.

I recommend keeping in sight three categories when retracing the *technical narrative of discovery* of one's discipline. Consider whether the major advances in the discipline resulted from a new physical discovery, a new development in rational thought, or a new way of looking at a known fact. These categories may be termed as the empirical, rational, and poetic. Science and mathematics advance on account of the interplay among all three of these perspectives and they often work in concert. But nonetheless, it helps to recognize that once a black swan was discovered in Australia—a new empirical discovery—zoology would have to change. This happened, for example, when in 1819 Hans Christian Oersted discovered that an electrical current deflected the needle of a compass. Within two years all of Europe was abuzz with further new discoveries about the relationship between electricity and magnetism.

On the other hand, when scientists apply or create new mathematics to solve problems, as was the case in Isaac Newton's development of calculus or James Clerk Maxwell's production of his laws, this can be called a rational advance. These advances represent new ways of organizing discoveries already made in a manner that is more simple, elegant, or offers greater intuition. The history of science is peppered with the interplay between the experimentalists and the theorists. This is another way of noting the interdependence between the empirical and rational perspectives previously mentioned.

Finally, there may be cases in which the fundamental assumptions of a discipline are misguided and must be realigned in order to make progress. For example, Kepler's belief that God would not let matter act chaotically led him to discover his three laws. A pagan Platonist would have disregarded the fact that the orbits of the planets were only imperfect circles—ellipses. Human observation of the world, for a Platonist, can never match mathematical perfection. But Kepler believed, on the contrary, that matter was completely subject to Almighty God and would have to obey his laws perfectly. And man, being made in God's image, could detect this order. Thus, through Kepler's convictions, astronomy became an exact science. All deviations from predicted orbits were then subject to scrutiny—a mind-boggling difficulty once the three-body problem was identified. This kind of advance may be termed poetic, a concept or conviction that arises from living in an embodied tradition of faith and practice. For Kepler his Christian convictions led him to this truth—a truth that has had profound implications for all subsequent science.

Keeping track of these three categories of advances—empirical, rational, and poetic—will help students to keep the narrative organized. Moreover, new observations and discoveries need not be unlearned. Upon these significant advances mathematics and natural science classes should focus. Mistakes and false assumptions made by the great scientists may be noted for context, but lasting accomplishments, whether empirical, rational, or poetic, of each era should be celebrated and studied. Galileo's discovery of the moons of Jupiter is a great empirical advance. His new definitions of uniform and naturally accelerated motion were exciting rational advances. His conclusion that God created the universe through the language of mathematics is a poetic conviction that has shaped all subsequent physical science. I do not mean to suggest that these three categories are neatly separable, simply that a dominant perspective can usually be seen in each advance. This rubric offers a helpful way of organizing a technical narrative to be used in one's classroom that reinforces student understanding and does not waste time. All of these advances are ones that students ought to know for their general knowledge of the subject. I have even seen some of the topics from our detailed study of Kepler and Newton arise on an actual AP Physics C test.

The zealous teacher may ask one or two further excellent questions: "Is including a narrative element to our science and math classes classical? And moreover, is this approach Christian?" These questions may be the most important, because nearly all of the Christian classical school teachers that I have met have a strong idealistic streak. Once we have been convinced of the best way to teach, we strive to implement the insights however imperfectly. Let me suggest two things. First, this method is closely akin to the medieval approach to doing science, because it emphasizes the dialectic of science. This approach is somewhat different in that it incorporates a robust mathematical component often neglected by the medievals. But it is similar because it treats science as a legitimate dialogue to be reasoned through and does not pretend that natural science is a fully formed system sprung from the head of Zeus. There is a contemporary strand of natural scientists and philosophers of science with Christian leanings that are actually trying to recover the idea of science as dialectic. Dr. William Wallace is among the best of these. By treating science as dialectic, the narrative elements arise naturally, thus this perspective seems to be an obvious fit for Christian classical schools. Second, this approach depends on an Augustinian understanding of truth and reality. Yes, we can know things truly but our reason is limited. Moreover, Augustine appreciated the value of classical sources. The Scriptures are authoritative but we may plunder the Egyptians for their treasures of knowledge. Thus, not only is this approach classical, but it is biblical and Christian as well, especially when we evaluate the poetic convictions of each thinker from the position of orthodox Christianity. There are many more profound arguments to be made in defense of the classical and Christian nature of this approach, but I hope that these two will suffice for most readers. I have found that the more I have followed the narrative of science and mathematics back to the sources, the more deeply I have been impressed by the urgency of the cause of Christian classical education.

The great poets and statesmen of the past are not the only ones worth imitating. The great scientists and mathematicians deserve our attention as well. The profound intelligence of these men is so stunning that recounting their thoughts makes one want to discard all distractions and simply study nature. Education as leisure is recovered—school as *schole*. What kind of training does it take to make men and women who can think like these? Of one thing I am certain: we have to tell their stories *in detail*, read their works, and believe them, if we, or our children, are ever to become great like them. Moreover, we have to do this together, as a network of schools all engaged in a common cause. For only a community can produce another Aristotle, Augustine, Pascal, or Leibniz. Individual savants may blossom, but they will not produce enough nectar to nourish an entire honeycomb. Only in community and over generations is this vision possible. Let us then join together and work in concert for the good of our children and unto the glory of God. May our mathematics and natural science indeed be a celebration of the love of wisdom and the love of God.