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MATHEMATICS in the Light of Eternity:

Toward an Adventist Understanding of Mathematics

Pythagoras, born on the Greek island of Samos in the sixth century BC, devoted his early life to traveling and learning. He studied with Mesopotamian astronomers and traveled to Egypt, where he learned mathematics from the priests. It is speculated that he made it as far as India, bringing together the mathematical findings from these diverse cultures. He is credited for providing the first proof of the Pythagorean Theorem, which relates to the side lengths of a right-angled triangle.

Pythagoras's experience is a testament to how mathematics can transcend otherwise competing worldviews. In my own experience (currently approaching the completion of my doctorate in mathematics), I've studied with mathematicians on three continents and with colleagues representing nearly every major worldview and religion. The mathematics community takes great pride in how our ancient discipline has been a meeting point for individuals throughout the world.

Consequently, we may be tempted to believe that since mathematical truths appear independent from one's religious commitment, there is little motivation for a person of faith to integrate his or her faith with the study of mathematics. History, though, tells another story. Pythagoras developed quite a following of disciples, who formed a religion around mathematics, believing numbers to have divine features, especially those with interesting mathematical properties. Plato, the great Greek philosopher who influenced so much Western thought, made mathematics central to his ontology and epistemology, believing that mathematical objects were eternal entities and that studying them was the best way to draw the soul toward truth.[1] And it was no accident that many later philosophers and theologians, such as Pascal and Descartes, doubled as mathematicians. Kant made Euclidian geometry so fundamental to his theory of knowledge that the discovery of non-Euclidian geometry the following century, despite being a purely mathematical discovery, posed a greater challenge to his arguments than any philosophical critique.[2]

Why the interest of philosophers and theologians in mathematics? Because of their interest in understanding the nature of reality (and how human beings can come to a knowledge of reality), and because mathematics has demonstrated itself to be the most reliable tool in studying the natural world. More than that, though, mathematics is unique because it appears to offer certainty in the form of proof. Scientific theories and historical study, while helpful, remain open to revision, while mathematics alone appears to ground truth on irrefutable deductive proof.

Mathematics and Adventism

Enter Adventism. At the heart of Adventism are radical claims about the nature of reality and the Source of true knowledge. We've built a global educational system that teaches students to learn in the light of eternity: to make God's revelation in Scripture the foundation of their learning, to understand the natural sciences as testifying of a majestic and loving Creator, to see history as leading to a great climax in Christ's return, to value the human body as the temple of the Holy Spirit, and to discover the joy of service.

What of mathematics? How does Adventism speak to this subject? We ought to seriously wrestle with this question; in fact, we're commanded to: "'Love the Lord your God . . . with all your mind'" (Matthew 22:37, NKJV).[3] "All" includes math, especially for those of us who spend a great deal of time studying and teaching mathematics.

The mathematics standards for Adventist education include the goal to "help students learn to see and reflect God's image while developing proficiency in different aspects of mathematics" by coming to "recognize God as Creator and Sustainer of an ordered universe."[4] Noble goals, but what does being made in God's image or recognizing God as Creator have to do with mathematics? Indeed, until we answer that question and are able to make it clear in the minds of students, can we really consider mathematics education part of Adventist education?

There are two ways we commonly think about mathematics. The first is to treat it as merely a useful tool for being productive in society and appreciating the structure of the created world. Scripture commands us to pay taxes and points us to the heavens to see God's glory on display—since mathematics is essential to these tasks, we conclude that we've integrated the discipline. Indeed, mathematics is an incredibly useful tool for these tasks, but what value does this leave for studying mathematics in its own right?

For instance, Pierre de Fermat claimed that there exist no integers a, b, and c that satisfy the equation $a^n + b^n = c^n$ where $n \geq 3$ (there are many solutions for $n = 2$ such as $3^2 + 4^2 = 5^2$). After 300 years of failed attempts to prove this theorem of Fermat, mathematicians finally succeeded. Is this accomplishment valuable in itself? Or does this work remain devoid of meaning until one can apply the mathematical result to understanding some natural phenomenon? And how do we answer the student who asks *why* mathematics is so adept at explaining the natural world?

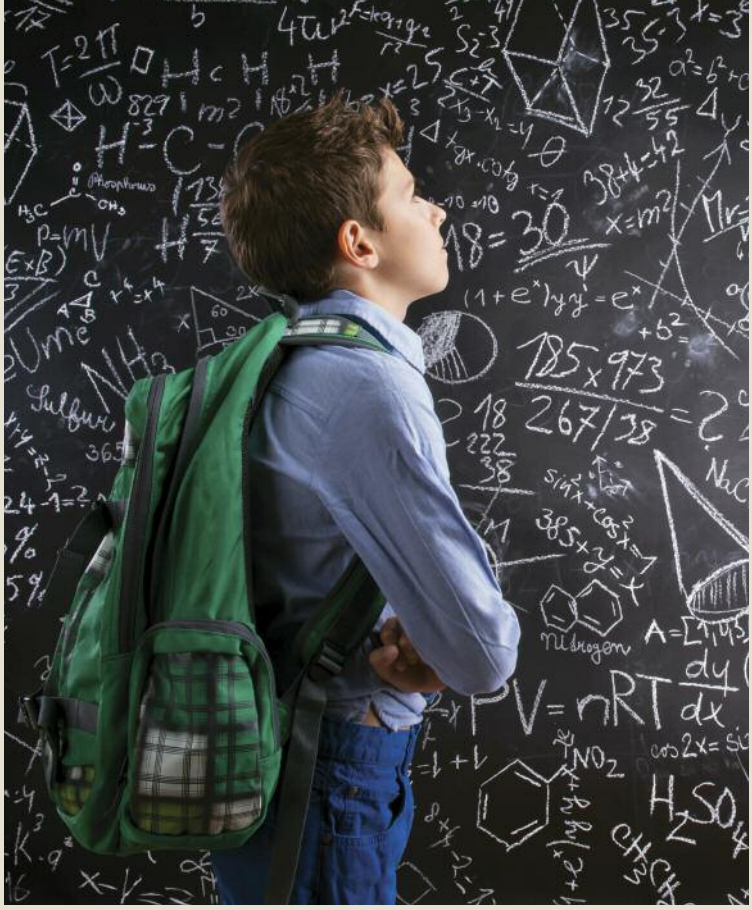
The second approach attempts to answer the question of *why* we should value mathematics by sweeping mathematics in with the natural sciences, suggesting that mathematical objects, such as numbers, sets, and functions, are just as much a part of God's creation as are rocks, trees, or galaxies. Do we want our students to think of numbers as a part of God's creation? If so, do we teach that God created the integers first, then the rationals, followed by the irrationals? What about the imaginary numbers? The Adventist mathematics standards appear to endorse this view when they include the goal of teaching students to appreciate "God's gift of the number system."[5] Referring to the number system as "God's gift" leads students to believe God established the Peano axioms, the foundation of arithmetic, just as surely as He gave the commandments to Moses. Are we committed to that position?

Perhaps God Himself is a mathematician! Galileo suggested God created the universe using the language of mathematics, and hence mathematical objects are really the thoughts of God or objects existing in the mind of God. This can be seen as a theistic repackaging of Plato's view that mathematical objects exist among the eternal, unchanging "forms" that can be accessed by properly trained reasoning. But Christians would do well to give some thoughtful consideration before embracing this view, for the New Testament rejects reason as sufficient means to discern God's thoughts.[6] Do we want to teach that mathematical proof is a means for us to access God's mind?

In the rest of this article, I offer insight into how I've come to understand the nature and value of doing and teaching mathematics from an Adventist perspective. I must admit, many of these are still live questions that I fully expect to continue engaging with throughout my life. My prayer is that this article will help to generate some meaningful dialogue and future scholarship. Ultimately, I hope to see a generation of students whose faith in Christ serves as a motivation to seriously study mathematics and whose enjoyment of mathematics strengthens their love for God.

Mathematics and Reality

Despite the rich history of mathematics, we are still without a historical consensus regarding what mathematics is or why it works. Many have taken the view of Godfrey Hardy that "mathematical reality lies outside of us, that our function is to discover or *observe* it, and that the theorems which we prove, and which we describe grandiloquently as our 'creations,' are simply our notes of our observations."[7] Certainly, we often speak of mathematical objects as if they are real objects that exist somewhere, but this view introduces the very hard questions of where this mathematical



reality actually exists and why logical proof is our means of observing it.

Others, especially more recently, have argued that mathematics is less like the natural sciences and more like the arts; that is, mathematical theorems aren't discovered, they're created. This allows us to understand Karl Weierstrass's statement that "the true mathematician is a poet."[8] While capturing the sense of creativity present in producing modern mathematics, the idea that mathematics is entirely a human construct faces some serious challenges that are well communicated by Eugene Wigner in his remarkable paper *The Unreasonable Effectiveness of Mathematics in the Natural Sciences*. First Wigner observes, "The great mathematician fully, almost ruthlessly, exploits the domain of permissible reasoning and skirts the impermissible. That his recklessness does not lead him into a morass of contradictions is a miracle in itself: certainly it is hard to believe that our reasoning power was brought, by Darwin's process of natural selection, to the perfection which it seems to possess."[9]

In creative endeavors, especially those undertaken by a large number of people, it is important to have a clear map of where one is going. We produce blueprints and models before building skyscrapers. But it appears mathematics has been a reckless addition of rooms and floors that, rather than producing incoherence, has consistently yielded results that the scientific community describes as surprisingly elegant and beautiful. For instance, there was no guarantee that the risky move of extending the real numbers to the complex numbers by defining $i = \sqrt{-1}$ would enrich the field. And yet, rather than lead to a logical contradiction, it made possible the discovery of beautiful and altogether surprising relationships, such as Euler's formula $e^{i\pi} + 1 = 0$. It is difficult to avoid the impression that such relationships are just waiting to be found.

Wigner went on to make the case that not only is mathematics surprisingly internally coherent, but it is unreasonably good at explaining the natural world. He noted that although mathematics may have been quite grounded in physical problems centuries ago when there was little distinction between a mathematician and a physicist, beginning in the 19th century, mathematics became an abstract discipline, quite detached from the world the mathematicians inhibited. For instance, complex numbers are widely considered essential for modern formulations of quantum mechanics, although the introduction of i was made entirely independently of natural consideration.

Or consider Euclidean geometry, which was built up from a foundation of five intuitive axioms that were very much grounded in the physical world. Mathematicians long struggled to show that the fifth axiom, which deals with properties of parallel lines and is more complicated than the rest, was a logical consequence of the first four axioms. However, they eventually discovered that it is logically independent from the other axioms and could be modified without contradicting the other axioms.

Hence, simply out of curiosity, in the 19th century they did precisely that. The result is what we call non-Euclidean geometries—descriptions of space that seem altogether counterintuitive. The common consensus was that the mathematicians were just playing games and that there was no real-world use for this work, but the 20th century's discovery of relativity and the curvature of space-time revealed that non-Euclidean geometry is precisely what we need to best describe our universe.[10]

Reflecting on this history, and several other similar episodes, Wigner concluded, "The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve."[11]

Wigner's mystery is threefold: Why are we capable of doing mathematics, why is there a deep structure to the

universe, and why does mathematics explain this structure so well? Here, the Christian worldview is particularly well suited to provide a compelling framework to make sense of these miracles.

Mathematics and Creation

We begin with Creation. As theoretical physicist and theologian J. C. Polkinghorne explains, "If the world is the creation of the rational God, and if we are creatures made in the divine image, then it is entirely understandable that there is an order in the universe that is deeply accessible to our minds."[12] This explains why so many pioneers in modern science and mathematics, such as Newton, understood their faith to be the great motivation for the work they were doing. Morris Kline, in his history of mathematics, argues that they were acting from that conviction that "God had designed the universe, and it was to be expected that all phenomena of nature would follow one master plan. One mind designing a universe would almost surely have employed one set of basic principles to govern related phenomena."[13]

Recognizing the value that the doctrine of Creation has had in advancing the mathematical sciences, it is prudent to review the Creation account in hopes of better understanding the nature of mathematics. Genesis opens with God creating the world, giving it structure, and moving it from a state of confusion to one of order. After humans—both male and female—are made in the image of God, they are then given a mandate to participate in creation: to extend creation ("'Be fruitful and multiply'") and rule over the creation ("'have dominion'"; Genesis 1:28). God creates animals, Adam names them; God creates a garden, the first couple are told to cultivate it. Thus we find a picture of human and divine cooperation in caring for and extending creation.

In our brief survey of the philosophy of mathematics above, we noted that there is good reason to think of mathematics as a process of both discovery and creation, although either account faces challenges on its own. The Genesis image of humanity being created to care for a garden serves as a rich model to resolve this tension. A garden is both discovered and created. The plants present existed in nature already, but the way in which they are brought together, arranged, and cultivated reflects the creativity of the human gardeners.

A similar story can be told of mathematics: We begin with ideas that appear very naturally within God's creation, and then, as image-bearers, we interact with creation by rationally extending these ideas. Having been made in the image of the One who made the cosmos, we quite expect some form of correspondence between the mathematical notions we develop and the structure we discover in the natural world, but we also expect our mathematics to reflect the people and societies that developed them.

Mathematics thus resists being classified as either a natural science or a creative art because it is both. The 19th-century mathematician Leopold Kronecker reportedly believed that "God made the integers, all the rest is the work of man."[14] However we choose to frame it, we should teach our students that the ability to do mathematics is part of what it means to be made in the image of God. In this sense, it is an incredibly powerful God-given gift, but the development of mathematics also reflects human creativity. The theorems of higher mathematics were not present before the foundation of the world; rather, humanity has been gifted freedom in how we extend the field via the mathematical definitions we choose and axioms we fix, just as a musician has freedom in the songs he or she writes, while still respecting fixed rules.

Some have sought to make a distinction between pure and applied mathematics, and while such a distinction of terms proves useful at times, it is rather difficult to draw that dividing line. As we noted above, a mathematician may pursue a line of study simply to satisfy mathematical curiosity, but often the notions he or she develops are later realized to be precisely the tools needed to describe some natural phenomena. My own area of mathematics research, knot theory, was completely pure for nearly the first century of its development, but in recent decades, a number of un-

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expected applications to biology and physics have been discovered. The truth that a mathematician seeks simply for its beauty or elegance is seen to occupy and describe creation, bearing witness to creation's good Creator.

But, one may ask, must mathematics find an application to the natural world to be considered valuable? Here again, Genesis's garden is helpful. Bearing fruit was not the only purpose of its trees—they are also described as being beautiful (Genesis 2:9). Beauty was valued in God's original creation independent of any utilitarian purpose. Humanity was designed to do more than just survive; our gardens grow both fruit to feed us and flowers to be enjoyed. Similarly, the value of mathematics can be found in both its usefulness and its beauty.

Mathematics and Eternity

A picture is beginning to emerge of how mathematics draws us back to our beginnings, reminding us of our role as image bearers of a good Creator. A proverb of Solomon states, "It is the glory of God to conceal a matter, But the glory of kings is to search out a matter" (Proverbs 25:2). Elsewhere, Solomon reminds us that eternity has been placed on the human heart (Ecclesiastes 3:11). In studying, learning, and searching out those concealed things and being exposed to fields of never-ending discovery and development, the desire for eternity is awakened in the human heart. Mathematics, in particular, seems to endear humans to the hope of eternity.

The New Testament closes with the vision of Christ restoring creation in new heavens and a new earth. Here it is recorded that the glory of God will illuminate the city, and the kings of the earth will bring their glory into the city where Christ dwells with His people (Revelation 21:23-26). While *glory* is a broad term, one of the few other references to the glory of kings in Scripture is found in Solomon's proverb recorded above. Thus, it seems we have here a vision of an eternity of God-glorifying study, discovery, and creative pursuits of humanity. In the mathematics community, we often regard the discovery of a great theorem as a means of immortalization; instead, Christian students should be taught that such intellectual accomplishments are to be laid in reverent awe at the feet of the One who alone has immortality. Rather than producing pride, mathematical discovery ought to lead the individual to worship.

Ellen White reminds us, "We may be ever searching, ever inquiring, ever learning, and yet there is an infinity beyond."[15] This never-ending learning she offers as a vision of the world to come: "Heaven is a school; its field of study, the universe; its teacher, the Infinite One. A branch of this school was established in Eden; and, the plan of redemption accomplished, education will again be taken up in the Eden school."[16] Does this mean that we will be doing calculus in the new earth? While we should stop short of suggesting that our modern conventions and formulations of the discipline will be employed in paradise, students should be taught that mathematics is a vital part of the eternity of God-glorifying study for which they were created.

Mathematics and Education

Through the lens of faith, mathematics is far more than just manipulating symbols. Rather, it is an image-bearer stepping into his or her role of being a co-creator with God. Thus, teaching mathematics is more than just helping students learn how to perform algorithms or manipulate symbols. I've come to think of chalkboards and whiteboards as windows into eternity, hoping my lectures will awaken students to the sense of endless discovery and co-creation for which they were created. Teaching mathematics is about helping students recognize their true identities, incredible worth, and the awesome place they occupy within the universe. Mathematics testifies to the reality that we're not here haphazardly but were designed to discover and extend creation while appreciating its beauty. And mathematics teaches us to long for the eternity where we'll be able to continue our education in the presence of the One who formed us in love.

While anticipating eternity, mathematics also teaches valuable lessons of character. Over the last few years, I've intentionally introduced my students to Carol Dweck's research on *growth mindset*.[17] Dweck uses this term to refer to the different ways students view their intelligence and hence respond to success and failure. On the one hand, students who believe intelligence is fixed—you're either born as a "math person" or not—tend to interpret their poor performance on a math activity as evidence that they are incapable of mastering the material. On the other hand, students who are taught to understand that intelligence is something that one can develop—like a muscle—tend to interpret poor performance as indicators of what further steps they need to take to master the material.

In my calculus courses, I've added the course goal of having students develop a growth mindset: I give them opportunities to recover some credit by reworking missed homework problems, to teach them to learn from their mistakes; I meet with students after the first midterm and ask them to bring corrections to their missed problems; and I use a flexible grading scheme that allows students to recover if they persist after poor performance on a midterm.

I've seen this make a profound difference for numerous students, such as Sarah.[18] She enjoyed vector calculus but became discouraged because she found it challenging. After she had received poor grades on both of her midterm exams, she began to disengage from the class. I met with her, and we discussed how to use those setbacks as learning opportunities. Together we formed a study plan. As a result, she finished the course with the highest grade on the final exam. A year after taking the course, she shared with me her ongoing excitement over the classes she was taking in the mathematical sciences. Students such as Sarah who belong to demographics un-

derrepresented in mathematics are especially at risk to opt out of mathematical studies after initial failures. Thus, teaching a growth mindset is especially important because it teaches at-risk students to persist and go on to make valuable contributions to mathematics and society.

Beyond persisting in mathematics, students who cultivate a growth mindset develop traits of character that transfer to every sphere of their lives. As Christians, we understand this character growth to have an eternal value: "We also glory in tribulations, knowing that tribulation produces perseverance; and perseverance, character; and character, hope" (Romans 5:3, 4).

Finally, although anticipating the restoration of God's good creation, we are constantly reminded that there is something seriously broken in this present world. Mathematics, like art, can give individuals glimpses of the world to come, but if we're going to take Jesus' call to service seriously, we must go a step further and actually address the suffering of this present world.

Enter the great applicability of mathematics. I've developed a growing burden to inspire and challenge my students to employ their training to address the great want of the world in whatever life course they pursue, be it as educators, engineers, medical professionals, lawyers, or even mathematicians. In one calculus course, for instance, after teaching a number of methods of integration, I set aside a week for students to work on projects that applied these skills to various other disciplines. They discovered numerous opportunities: for pre-med students to analyze blood flow and cardiac output, for business majors to study consumer surplus, for engineers to explore hydrostatic pressure, and for mathematically curious students to wrestle with the paradox of Gabriel's horn. Thus, beyond just letting the students practice the skills of the course in an engaging way, I used the projects to guide them in recognizing that the end of education is the joy of service, in both this world and the world to come.

While the problem-solving methods and results of mathematics exist independently of one's worldview or religious commitment, there exists an important role for Adventist educators to teach their students to let their faith inform the way they view the nature and purpose of mathematics. Incredibly, this can transform the subject into a perpetual testimony of the great plan of redemption—from Creation to eternity—and remind students of their identity as image-bearers, inspiring them to worship an awesome Creator. Moreover, mathematics can equip the student for an eternity of useful Christlike service. "In the highest sense the work of education and the work of redemption are one."[19]

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3. Unless stated otherwise, Bible quotations in this article are quoted from the New King James Version®. Copyright © 1982 by Thomas Nelson. Used by permission. All rights reserved.

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