THE COMPLEX RELATIONSHIPS BETWEEN MATHEMATICIAN'S RELIGIOUS BELIEFS AND THEIR MATHEMATICAL IDEAS: HISTORICAL SNAPSHOTS

Thesis

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Abstract

Religion has existed for as long as humans have, and mathematics for nearly as long. The two have been inexplicably linked together by virtue of both being ways to find a meaning and purpose to human existence. I specifically wanted to understand the relationship between Christianity and mathematics, their coexistence and how, why and if they fed from each other. As such, I researched six mathematicians, three Catholic: Galileo Galilei, Rene Descartes, and Blaise Pascal, as well as three Protestant: John Dee, Johannes Kepler, and Leonhard Euler. I read histories regarding their religion, their history, and their personal interactions with their respective churches to understand if the relationship between mathematics and religion was the same during their time as it is now. There are similarities between the past and the present in that humans do not change their nature. From my case studies, it appeared that the Catholic Church was not as forgiving of mathematicians who wanted to understand more than what the Bible explained. In contrast, the Protestant Church welcomed the ideas of mathematicians as a blessing from God. In a way, that relationship with mathematics and science is still upheld by religion today; a push and pull between believing the Bible and believing science and mathematics.

Acknowledgements

I would like to thank Dr. Cynthia Taylor, Dr. Michael Wismer, and Dr. Kevin Robinson for their help throughout the course of my research. I especially wish to thank Dr. Taylor for her encouragement, starting with History of Mathematics, and continuing to this day. I appreciate Dr. Taylor for listening to me talk about weird mathematicians for the past two years, and her wisdom in helping me narrow my thesis down, without curbing my enthusiasm. Thank you Dr. Wismer for helping me find a purpose in my research, and for helping me clarify the point I was trying to make in this thesis. Thank you, Dr. Robinson, for finding me in Wickersham to suggest edits for my thesis. I would also like to thank my partner Christian Martell for listening to me rant about religion and mathematicians for the last two years, for supplying me with the caffeine necessary to write, and for constantly encouraging me to continue writing, even when I hit a wall. I am eternally grateful to all the people who helped me arrive at this point in my life, their constant encouragement and support, and the love that they have shown me.

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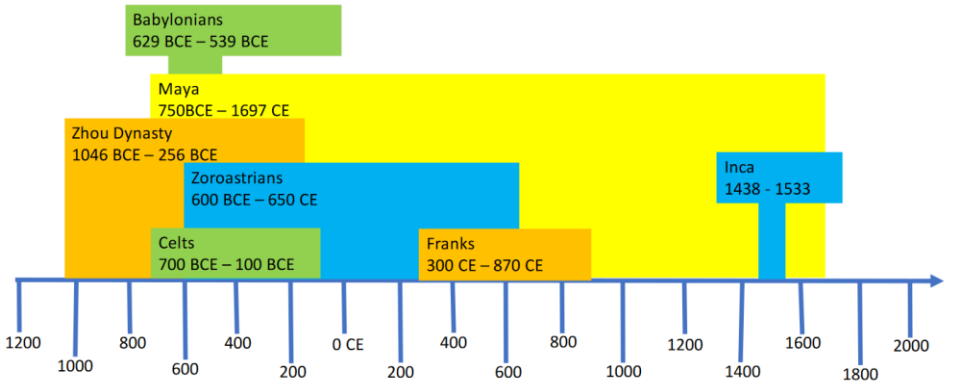
Chapter 1: Introduction

Throughout the history of civilization, there is one thing that every individual society has in common: belief in a higher power. Hunter-gatherers, who existed about 11,000 to 12,000 years ago, practiced animism, the belief that all objects, places, and creatures have their own spiritual essence (Britannica, n.d.). From Zoroastrians, Babylonians, Celts, Franks, Maya, and the Indigenous of each continent, they all had a societal religion. Eventually, polytheism (the belief in more than one God) was replaced with monotheism (the belief in a singular god), seen by the conversion of the Franks (Germanic speaking people who invaded the Western Roman Empire circa 400 AD) from German paganism to Christianity (Smit et al., 2023). See Figure 1.

Figure 1

Timeline of Civilizations

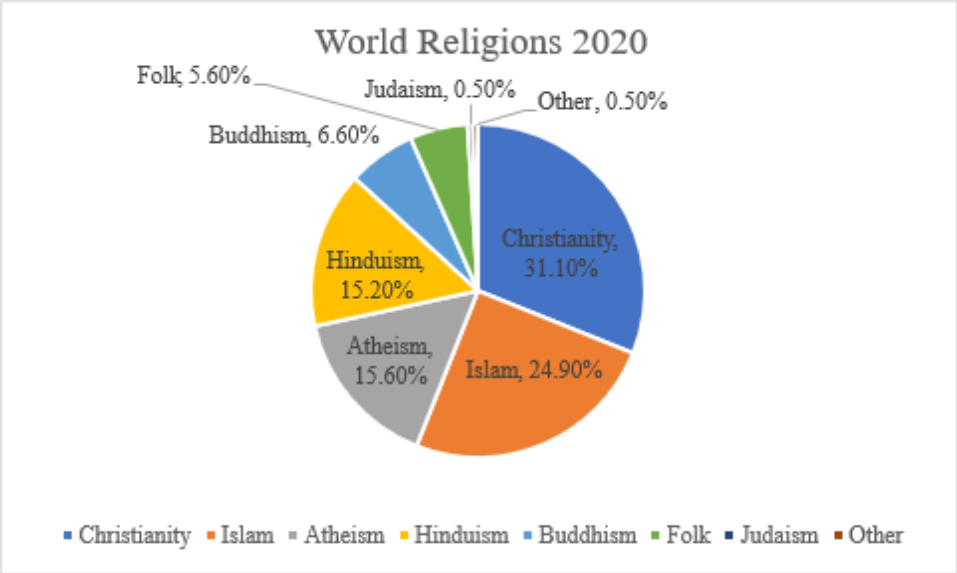


Today, the main belief systems can be generalized as the three Abrahamic religions (Judaism, Christianity, and Islam) and Hinduism. People who follow one of the three Abrahamic

religions make up 54.9% of the world's population and 15% of the world's population practices Hinduism (Find Easy, 2023). See Figure 2.

Figure 2

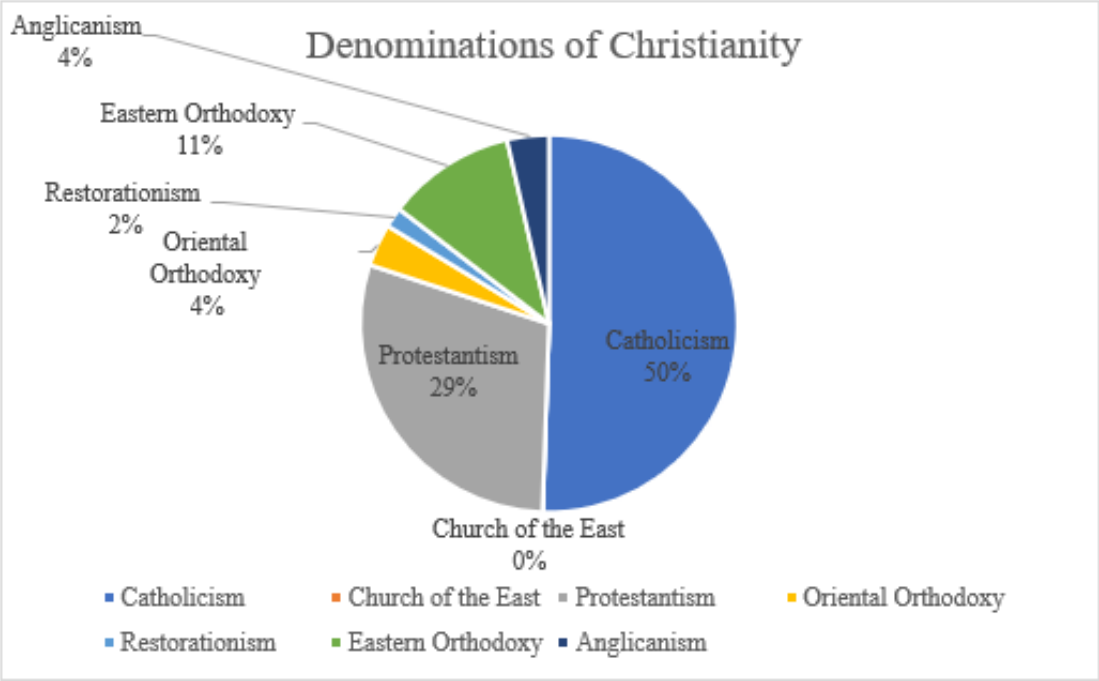
World Religions 2020



Christianity is made up of many denominations such as, Protestantism (e.g., Calvinism, Anabaptism, Anglicanism, and Lutheranism), Catholicism (e.g., the Latin Church and Eastern Catholic Church), the Eastern Orthodox Church, the Oriental Orthodox Church, and the Church of the East (i.e. Assyrian Church of the East and Ancient Church of the East). See Figure 3.

Figure 3

Denominations of Christianity



The Church of the East and the Oriental Orthodox Church are two of the oldest denominations of Christianity, starting in 431 AD and 451 AD respectively. The Eastern Orthodox Church and the Catholic Church split during the 11th century, in what is known as the Great Schism. Protestantism came about during the Protestant Reformation in 1517 after Martin Luther posted the 95 Theses on his church's door. Each denomination of Christianity also has its own sects within those denominations, such as Adventists, Pentecostal, Presbyterian, Methodist, and Baptists. Within Judaism, there are Orthodox, Reform, Conservative, and Reconstructionist, while Islam is split into Sunni and Shia Muslims.

As religion developed and spread, more people became believers, and various denominations came about to align with personal beliefs. People of all creeds have practiced religion since humans existed; however, the belief in a higher power is not the only common belief

that all civilizations have shared. Humans also looked for a way to observe, explain, and explore their understanding of the world they lived in.

As a society, most of us now have access to a tiny computer in our pockets that can do a million more things than the first computer could. We have self-driving cars and timed pet feeders. There exists an uncountable number of products to make our lives easier and it all goes back to the exploration of mathematics. There are records showing how the Egyptians kept track of their livestock, offerings, and slaves. The Maya had their own number system, as did the Babylonians, base 20 and 60 respectively. The Greeks built circular temples, because circles were found in nature and thus were thought to be the work of the gods.

Throughout time, people discovered mathematics to explain and experiment with the things they knew to be true. Archimedes famously discovered or understood volume displacement while taking a bath. As children, we're told the story of Newton understanding gravity after being hit on the head by an apple. Newton went on to discover mathematics that mimicked real world motion and created calculus. While observing the world, Fibonacci realized that a specific pattern of numbers would be found in the spiral of a shell, or the structure of a pinecone. The golden ratio comes from Fibonacci's sequence of numbers but was explored by mathematicians as far back in history as Euclid, and from multiple parts of the world (Sigler, 2002). The golden ratio, found in nature first, was used in architecture and art, such as Leonardo da Vinci's "Vitruvian Man" (Livio, 2008). Music, which is based on intervals or the space between sounds to create harmony, is mathematical. Pythagoras was credited as the first to identify the physics of intervals, we still use the harmonic system he created today (Sanders, 2015).

Mathematics is everywhere. Football (soccer), the world's favorite game and most popular sport, relies on physics and the law of inertia. To determine the best baseball players,

their average hits, home runs, and ball speeds are calculated. These statistics are also used when determining batting line ups and who will play in the next game. We gauge distances when driving and use calculations to figure out how long a tank of gas will last before we need to fill up again. While mathematics is not the priority of the mind of some people while living daily life, people are constantly drawing on mathematics to exist in life.

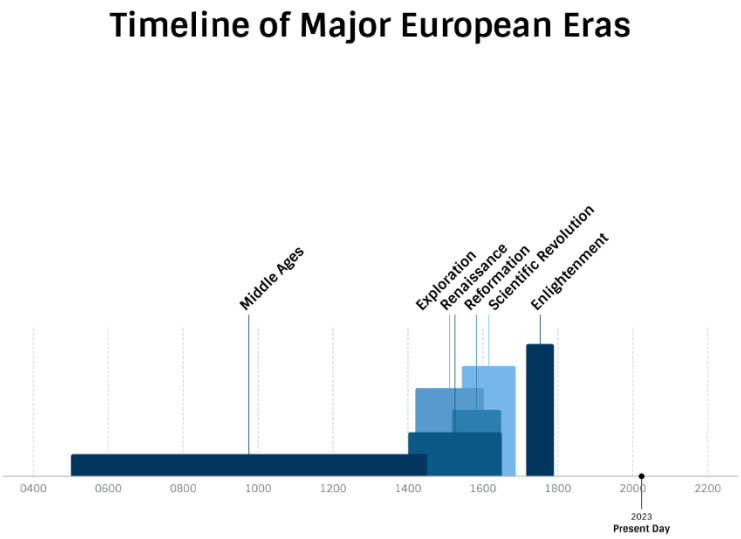
Mathematicians throughout history were often religious — growing up in times where religion was expected and engrained societally. While it was common for them to believe in a god, it was less common to devote time and understanding to mathematics as its own subject, and not the basis of medicine as seen with Galileo, Dee, and others (Wootton, 2013). People "proved" a god's existence because of his creations. However, one spending hours poring over proofs without real world applications didn't prove that mathematics had meaning. Many mathematicians took inspiration from their spiritual beliefs to prove their mathematical notions to the world. For example, Georg Cantor (1845-1918) was influenced by his time with a sect of hesychast monks in Russia. The monks believed that speaking the name of God or Jesus, brought God into existence. This then influenced Cantor's understanding of infinite sets, and trans infinite numbers (Harman, 2010). In addition, mathematicians have used mathematics to define religion such as Blaise Pascal (1623-1662), who argued that through probability, God must exist (Hájek, 2022). Hypatia (born between 350-370 CE, died 415 CE), recognized as the first female mathematician, believed that mathematics had a spiritual side to it and could be split into arithmetic, geometry, astronomy, and music, with numbers acting as the sacred language of the universe. She extended this belief of abstraction to her pursuit of astronomy and mathematics, leading to her creation of devices (e.g., the astrolabe and devices that measured density) that extrapolated from observable phenomena

(Osen, 1974). Throughout the centuries, there have been many mathematicians that reflect the religious or non-religious values of their time.

The dark ages spanned from 500 CE to 1000 CE and were characterized by a lack of advancement in art, literature, and science in western Europe after the collapse of the Roman empire (Ferguson, 1962). The Renaissance period began in the 1400's and lasted until the end of the 16th century, followed by the Reformation and the Enlightenment ages. All three of these periods are characterized by advancement and modernity (see Figure 4). During this time, the arts, mathematics, science, and logical thinking were heavily funded by sponsors (Cahill, 2014). There was a shift from religious intolerance to the coexistence of different religions and different sects of the same religion such as Protestants and Catholics, post Protestant reformation (Guggisberg, 1983).

Figure 4

Timeline of Major European Eras



Between the 1400's and 1700's, numerous mathematical ideas, theorems, and proofs that were discovered were written down and shared among the mathematical community. For example, in the 1400's, Jamshid al-Kashi (1380-1429) wrote "The Key to Arithmetic," which contained work on decimal fractions and applied arithmetic and algebra to solve multitudes of problems, including geometric ones (Struik, 2014). In the 1500's Gerolamo Cardano (1501-1576) learned a technique for solving depressed cubic equations, and as a result, found a method to depress cubic equations to solve any cubic equation (Ore, 1965). During the 1600's and 1700's Blaise Pascal (1623-1662) worked with Pierre de Fermat (1607-1665) to develop the theory of probability based on a gambling problem that the Chevalier de Mere, Antoine Gombaud (1607- 1684) asked Pascal to solve (Devlin, 2008). The time between the 15th and 18th centuries was a period of extreme mathematical growth. As a result, in this thesis, I sought to compare mathematicians who contributed major mathematical works during this period and the way that their worldview and their religion aligned or misaligned with their works.

Significance of the Study

Mathematicians and historians have written on the mathematical works of other mathematicians and have built mathematics in a way that we have a history of the evolution of various mathematical concepts. Through these works, there has been mention of how religion has impacted each of the various mathematicians and their individual work; for example, Cantor writing about his time living with monks (Harman, 2010), or Hypatia being murdered by a Christian mob for her religious views (Osen, 1974). However, there has been no research comparing and connecting religious beliefs of multiple mathematicians to the development of their mathematics. Also, there is some research on mathematics used in religion such as the numerical interpretation of the number 153 in the Bible, or the specific mathematics developed

in the Vedas to build a temple properly (Lawrence, 2015; Pearce, n.d.), but not the influence of religion on the growth of mathematics or a comparison of mathematicians and their personal religious beliefs or worldview.

For mathematicians who developed world changing mathematics, there have been many attempts to understand more about their personal lives. There have been publications of personal letters, many biographies, with historians trying to create an insight to the mind of these mathematicians who seem to be geniuses such as the many biographies on Galileo, Newton, Euler, Gauss and more (*Biographies of Mathematicians*, n.d.). For example, *Lettres de Mr Descartes* was published in 1663 and were written to Marin Mersenne (1588 – 1648) about the work he would be publishing in *Meditations*, and *Lettres à une Princesse d'Allemagne* were published starting 1768 where Euler detailed mathematics and science in a way a non-mathematician could understand (Descartes et al., 1667; Euler et al., 1795). These letters, and those like it help to understand the process of thinking mathematicians went through to justify their mathematical ideas and give insight to any religious beliefs that mathematicians may have had, especially in their personal letters (i.e., any letters speaking of personal issues, not mathematical correspondences). These identified processes give an insight to the worldview, the collection of attitudes, values, stories and expectations about the world around us, which inform our every thought and action, of individual mathematicians. Thus, this study is significant in that it examines the works and beliefs of multiple mathematicians and explores possible relationships regarding the effects of their religious beliefs and personal worldview on the development of their mathematical ideas.

Research Question

I sought to understand and document ways that religion affected the pursuits and interests of six European mathematicians between the 1400's and the 1800's based on the divide between Catholics and Protestants after the end of the Middle Ages. I chose these mathematicians because they all contributed major mathematical works while they were alive and were either extremely religious, or enemies of the church they belonged to due to their mathematical beliefs. Their mathematical works were affected by their religion, or lack of religion, and thus were the subjects of interest when researching the effects of combining mathematics and religion together. The specific research question was, in what ways did mathematician's worldview, as expressed in their beliefs and work, align or misalign with different expression of Christianity during the Reformation, Renaissance, and the Enlightenment periods?

Method For Narrowing the Thesis

When I was deciding how to narrow my thesis, I started with a list of questions regarding how math and religion could possibly be related. I borrowed one history of mathematics textbook (Katz, 1998) and identified all mathematicians whose biographies referenced a connection between their mathematics and religion. Next, I created a chart of 23 mathematicians, where I listed and organized information on them, ranging from birthplace, religion, mathematics, homelife, and geographic location. A group of 23 mathematicians was too large of a pool to research, so I narrowed the time frame down to the 1400's through the 1700's, when the Reformation occurred, the Renaissance occurred, and the Enlightenment occurred. Next, I identified mathematicians who had a connection with Christianity (e.g., they were raised to be clergymen, they attended theological schools, they used religious arguments to justify mathematical concepts). I identified ten mathematicians within these parameters: Michael Stifel,

Gerolamo Cardano, John Dee, Galileo Galilei, Johannes Kepler, Rene Descartes, Bonaventura Cavalieri, Blaise Pascal, Gottfried Leibniz, and Leonard Euler. However, upon closer analysis of their personal lives, their mathematical works, and their interactions with religion, I identified a divide between the treatment of Catholic and Protestant mathematicians. I narrowed the list to six mathematicians—three Catholic mathematicians (Galileo, Descartes, Pascal) and three Protestant mathematicians (Dee, Kepler, Euler).

Framing for the Thesis

Growing up, my parents took me to church every Sunday to praise God and the sacrifice he gave us in the form of his son. I went to Sunday school until I was old enough to sit with the congregation and then continued in youth studies once I was a teenager. As a child, my favorite questions were "why?" and "how?" I was told to have faith, that if we just believe in God then our sin is forgiven, and that answer never changed. I was told to look for an explanation of God in everything I did and everything I saw. I was told that God could be seen in the way that flowers bloom in the spring or seen in the way that a kind stranger helps someone in need. But it did not stop me from wondering "Why? How?"

I fell in love with mathematics when I was nine. I was in 3rd grade learning multiplication and division tables and while I struggled at first, when I understood the concept, it felt like the entire world opened to me. It was the first time I understood "why." Multiplication and division were explained as fast addition and subtraction. I just needed to add or subtract numbers a certain number of times to get the answer. Learning why it worked sparked my soul into continuing learning mathematics. I learned why a triangle is a triangle and why we can use placeholders (variables) in a problem to solve for a value we did not know. I learned why we could find a mean and variance to determine where a value falls on the normal curve. Because I finally received an

answer to my favorite question, I was able to connect things to other areas of my life. When I stopped going to church, I had a newly influenced faith in something other, I had a faith in mathematics.

I organize the remainder of the thesis in the following manner. I begin by articulating the connection between religion and mathematics, expounding on several religions and how their followers interacted with mathematics in a general manner. Next, I explore several historical religious leaders and their impact on mathematics. Finally, I analyze six mathematicians, three Catholic and three Protestant, and the different ways their respective churches responded to them and their mathematics. The terminology used in this study may be found in Appendix A.

Chapter 2: Belief Systems and Mathematics

Throughout history, humans have based their beliefs and knowledge on the world around them. While taking History of Mathematics at Millersville University of Pennsylvania, I noticed the recurring pattern in every civilization and time we had studied, that humans took their observations of the world around them and the mathematics they had developed and used it to reach or honor a higher power. The Greeks built temples in circles because circles were found in nature and nature was created by God (Ancient Greek Astronomy and Cosmology). The Vedas, the holy book of Hindus, had mathematical instructions for building altars (Kashyap, n.d.). The Chinese used astronomy to predict dates for festivals as did the Hindus (Parpola, 2021). Humans have strived to search for an explanation for the way that life was around them at the time. They turned to faith, mathematics, or science, and believed they could find an understanding of their existence. Like religion, mathematics requires faith. Some children are taught two plus two equals four, but not why. Mathematics becomes memorization to them. In later mathematics classes, students learn about integrals and how the area under the curve is equal to the sum of all the parts under the curve. They learn that some sets never end, and that there are numbers larger than even a computer can count, and they believe it is true just as religious people believe in their god(s). Mathematicians create proofs as a foundation to explain and justify mathematical concepts the same way that Christians use the Bible as a foundation to explain their faith. Mathematics works the same way a Buddhist may see karma at work. Buddhists see the results of karma, whereas mathematicians see the results of reality. Mathematics and religion are inextricably linked together, as separate entities but also as justification for each other and the work that was pursued to explain both.

Monotheistic Religions (e.g., Christianity/Catholicism)

Christianity is the world's largest religion, first coming into being alongside Roman paganism (753 BCE – 392 CE) and the ancestral Jewish tradition (beginning 600 – 500 BCE). Following the conversion of the Roman emperor Constantine, it evolved into one of the most widely practiced religions of the modern ages (Britannica, n.d.). Christianity has developed over a millennium, taking from surrounding cultures and religions to convert more people; however, mathematics often developed independently as to fit the needs of each civilization until trade allowed for societies to influence each other and spread information. The use of numerology, "a type of understanding of mathematics that imbues numbers with the capacity of signifying more than just the quantity they materially refer to" (Lawrence, 2015, p. 105), was immensely popular within the early Christian Church as a form of interpretation. For example, Saint Augustine provided four different interpretations of the number 153, which comes from the number of fish that was netted in John 21:11, and other interpreters have found at least 14 others. A less subtle form of arithmology (the field of study that intersects traditional numerology with contemporary mathematics) within the Christian religion would be the numbers 15 and 12. The number 15 is considered the five senses (5) sanctified by the Holy Trinity (3). The number 12 is indicatory of the spreading of the Trinitarian Gospel (3, Father, Son, and Holy Ghost) to the four corners of the world (4) (Lawrence, 2015). The mathematics found within the Bible is also found to be divine. For example, the Ark of the Covenant and its dimensions has numeric and geometric significance (Valente, 2020).

After the Middle Ages (400 CE – 1400 CE), the Roman Catholic Church was its own centralized power. Citizens relied on the Catholic Church to tell them how to behave socially, to impart religious knowledge, and to help them solve personal issues as well (Heijer, 2015).

However, the Renaissance (1300's - 1600's) also brought about the age of Humanism, the belief that humans are the center of their own universe and as such, they should celebrate their human achievements rather than leave those achievements to God alone (Pinn, 2021). Humanists were one of the main critics of the Roman Catholic Church, as before the Renaissance, the Catholic Church was in control of religion, education, and overall, society. Before the printing press was invented in 1436, books were not widely printed, thus monastery libraries contained most books (Riché, 1978). The only place to get an education outside of being privately tutored were monasteries, which were controlled by the Catholic Church. If people were too poor to be educated, and were not literate, the Church was the entity that told them how to behave religiously through their interpretation of the Bible (Riché, 1978). There was one interpretation of the Bible until the humanists began forming their own religious sects, leading, in part, to the Great Schism (Kennedy, 2023). Thus, the power of the Church was threatened when scientists, mathematicians, artists, and others began to use their freely available education to question the Church's hierarchy in societal life.

Polytheistic Religions

Other polytheistic religions used mathematics to celebrate and worship their gods as well. The major practice of astrology was found throughout multiple polytheistic religions including Babylonian, Greco-Roman, and Egyptian traditions. The Babylonians were the first identified to use cosmic geography and numerology regarding religious beliefs about the afterlife (Lindsay, 1971). The Egyptians followed the use of constellations and the proportional relations that the Greeks used, adding their own meanings to the mathematics and the sanctification of their Kings as Gods (Lindsay, 1971). By the 1100s, the practice of witchcraft, as either an extension of Christianity or Paganism, was dependent on mathematics for many of their traditions. Divination

in the form of tarot card reading, and the numerology associated with it was reliant on mathematics. Witches would perform rituals on pagan holidays, such as the Roman religious date of Lupercalia, to honor the goddesses of fertility (Russell, 1972).

Hinduism is the dominant religion of India that emphasizes dharma with its resulting ritual and social observances and often mystical contemplation and ascetic practices (Merriam-Webster, n.d.). The "holy book" of Hinduism is called the Vedas. It is four canonical collections of hymns, prayers, and liturgical formulas that comprise the earliest Hindu sacred writings (Merriam-Webster, n.d.). The Vedas contains 555 sutras, split into four chapters that detail philosophical and spiritual ideas. Of those 555 sutras, 16 of those contain some sort of mathematics. The sutras detail the natural thinking processes allowing students to use personal methods to produce answers to certain types of problems (vedicmaths.org, n.d.). It is important to note that while a lot of mathematics came from India, most came from astronomers, not mathematicians. One of the most important tasks that astronomers had taken upon themselves was the determination of the most precise date for their religious holidays. In the Rig Veda, it is mentioned that a priest could accurately determine the date of an eclipse. The Yajur Veda details how to determine the length of the year, mathematically dating it as more than 365 days, but less than 366 (Sora, 2011). Vedic times saw mathematics as being integral to the religion, with its most important holidays and rituals being reliant on them. In Hinduism there are hundreds of gods, and even those hundreds of gods can have multiple forms (Rankin, 1984). It is speculated that the belief of multiple gods was part of the reason mathematics were so widely explored in the Vedas and in Indian society. There were multiple forms of each god, with multiple stories of the creation of life, with those stories even contradicting each other (Torrance, 1999). Thus, if everything can create life, there are multiple ways to explain life and the universe with mathematics.

An Overview of the Relationship of Mathematics and Religion Throughout Time

Religion has been spread far across the world and for an extended period of time, it was a strictly imposed social standard, specifically within Western Europe. Many European mathematicians identified themselves as being religious, even if whichever religious sect they identified with was not a popularly held belief at the time. For example, Pythagoras, known for his theorem of finding the side lengths of a triangle, started his own religious sect (some considered it a religious cult). His followers believed in numerology and reincarnation and the group was closed off to the world. The followers were chosen by their intellect, as they led lives of strict study and research. Pythagoras specifically created a religion based on mathematics (Zhmud, et al., 2012).

Another example is Nicholas de Cusa (1401-1464) who was appointed vicar general by Pope Nicholas V. De Cusa wrote about squaring the circle, but he focused his mathematics on orienting the human mind towards God (i.e., mathematics was used to expand the human mind enough to allow God to enter it and prove his existence). He also believed that there was a plurality of worlds, or what we would now call the multiverse theory of quantum physics. De Cusa bonded mathematics and religion together during his life (Cusa, 1997). He believed that mathematics "emulates the creative power of God insofar as it is a manifestation of humankind's ability to create knowledge and to completely understand this creation," (Valente, 2020, p. 86) or in other words, it was an essential and mutually beneficial way to bring people closer to God.

Not every religious individual respected or valued mathematics, and not every mathematician respected religion. An example of the former would be priest Diego de Landa Calderón (1524-1579). Landa was a Spanish Franciscan priest who traveled to the Americas (e.g., Mexico) to preach to the indigenous people there. At first, he protected the indigenous people that

were decimated by disease, until he was named the Franciscan provincial of Yucatan in 1561. He then proceeded to annihilate Maya culture. He started by torturing thousands of Maya people, due to their practice of human sacrifice, which he abhorred. Landa observed and kept note of the destruction he caused, not just with the torture of the Mayan people, but the destruction of their statues and temples and a burning of all their religious and mathematical texts, causing one of the greatest losses of Indigenous American mathematics (Landa & Gates, 1978).

Georg Cantor also spoke with countless church leaders who did not believe in the difference of transinfinite sets (mathematics) and a transinfinite world (God). Cantor was a devout Lutheran Christian and believed that God communicated the theory of transinfinite sets to him (Dauben, 1979). Both Cantor's mathematical contemporaries and philosophical contemporaries resisted his proofs, the former because his proof was counter-intuitive, the later because it was "a challenge to the uniqueness of the absolute infinity in the nature of God" (Dauben, 1979, p. 120). One mathematician, Leopold Kronecker, publicly opposed Cantor, and went so far as to use personal attacks, calling Cantor a "scientific charlatan," a "renegade" and a "corruptor of youth" (Dauben, 1979, p. 89). However, Cantor was careful to specify the difference between a philosophical infinity and a mathematical one in his 1883 work *Grundlagen einer allgemeinen Manniffaltigkeitslehre*, while also explaining how his philosophical beliefs connected to his mathematical proof (Dauben, 1979; Hallett, 1986). Cantor suffered from depression, and the criticism of his work by Kronecker and others weighed so heavily on him that after he submitted to and was rejected from the journal *Acta Mathematica*, he struggled to work on mathematics and struggled with his faith in God, and eventually was placed in a sanatorium in 1899, which was his second of many stays, occurring every few years. Fortunately, although Cantor stopped publishing

his mathematical works, he did lecture periodically on the paradoxes of set theory, before he retired in 1913 (Dauben, 1979).

Throughout the ages, mathematicians have attempted to use religion to define mathematics and mathematics to define religion with much push back from both mathematicians and religious leaders for doing so. Between the 1400's and 1700's, several mathematical ideas, theorems, and proofs were written down and shared for the whole of the western world to be taught. In the next chapter, I will expound on six mathematicians who contributed major mathematical works during this period and the way that their worldview as expressed in their beliefs and work align or misalign with different expressions of Christianity.

Chapter 3: Results

In the pursuit of research and in the effort to narrow my thesis, I explored the lives of mathematicians, their mathematics, and their religious pursuits, and identified mathematicians the belonged to one of two Christian denominations: Catholicism or Protestantism. In this chapter, I developed case studies for each mathematician, organized chronologically. The three Catholic mathematicians identified were: (1) Galileo Galilei (1564-1642), (2) Rene Descartes (1596-1650), and (3) Blaise Pascal (1623-1662). The three Protestant mathematicians identified were: (1) John Dee (1527-1608), (2) Johannes Kepler (1571-1630), and (3) Leonhard Euler (1707-1783). Below, is a deeper dive into the effects of religion and worldview on their mathematics and their mathematics on their worldview or religion.

Case Study in Catholicism

Galileo Galilei

The earliest mathematicians identified was Galileo Galilei. Galileo was born February 15, 1564, in Pisa, Italy. He was sent to a monastery in Vallombrosa, located in Florence, Italy, as a child to become a friar. However, his father pulled him out at age thirteen before he could take his vows. While at the monastery, he was given the standard humanist education at the time. He studied Latin, Greek, and Aristotelian logic. After being removed from the monastery, he was sent to Ostilio Ricci, a member of the Medici court in Pisa, to be supported while he studied medicine at the University of Pisa. He hid from his father that he was really studying mathematics for years, before moving back to Florence to teach mathematics. Galileo had a long-term partner he never married and had three children with her— two daughters and a son (Virginia (Sister Maria Celeste), Livia (Sister Arcangela), and Vincenzo), his daughters whom he pushed to become nuns at the local convent due to their illegitimate births (Wootton, 2013). The illegitimate births of his children went against the worldview of the Catholic Church, and that

worldview is what pushed Galileo to make it so his illegitimate children would not continue a line of other illegitimate children.

Galileo's approach to mathematics was not standard procedure for mathematics at the time. A friend of Galileo's, Lodovico Cardi said of him that "a mathematician without a diagram was only half a mathematician, as disabled as a blind man," (Wootton, 2013, p. 57). To align to this analogy by Cardi, Galileo used diagrams to see what he was attempting to solve regarding mathematics, and then would later form an Aristotelian proof of what he showed in the diagram. Galileo published a number of works regarding centers of balance (La Balancitta), theories of motion (De Motu, which was never formally published), astronomy (Starry Messenger, Discourse on floating bodies, and Letters on the sunspots) and the movement of a pendulum, the acceleration of free-falling bodies, and the motion of objects on an inclined plane (Discourses and mathematical demonstrations concerning the two new sciences) (Galileo Galilei (1564 – 1642), 2006).

Overall, Galileo's most famous work was that of the expansion of the Copernican heliocentric model. Through his study of the solar system, Galileo observed that Venus had phases like the moon, and thus must orbit the sun rather than the Earth (Galileo Galilei (1564-1642), 2006). This led to Galileo believing that the Copernican model must be true, and at the time, tried to privately support the matter. However, an enemy of Galileo ensured that a letter of his to the Grand Duchess Christina Lorraine, arguing that the Bible must be interpreted from what science has proven true, rather than interpreting the Bible and not allowing science to say otherwise, was sent to the Inquisition, a group empowered by the Catholic Church to investigate crimes of heresy. The letter to the duchess was a clear example of the worldview that Galileo held, that while religion is important, science and mathematics are important, and should not be

hindered by religion. This led to the Inquisition deciding whether Copernicus (1473-1543) had argued a theory versus a physical reality, and ultimately to the decision that the teachings of Copernicus would be condemned, and Galileo would be forbidden from holding those views (Galileo Galilei (1564-1642), 2006). Nicolaus Copernicus was a Prussian polymath, who studied law, and was a mathematician, astronomer, physician, translator, governor, economist and diplomat, just before his death in 1543, he published *De revolutionibus orbium coelestium* (On the Revolutions of the Celestial Spheres) which triggered the Copernican Revolution and inspired the views of Galileo and many others (Rosen, 1986).

Galileo became friends with Pope Urban VIII, the successor of Pope Paul V, the pope who decided that Copernicus should be condemned for his work. Pope Urban worked closely with Galileo as an admirer and a benefactor, having Galileo speak to papal audiences' multiple times, leading Galileo to believe that he had support for his views and scientific pursuits. In 1632, Galileo published "Dialogue on the Two World Systems" and was brought before the Inquisition himself and persecuted for the crime of heresy. Galileo expressed that he did not believe in heliocentrism as a real phenomenon, rather that it was a scientific theory and since it was unproven, did not expressly count as heresy. He accepted a charge of suspicion of heresy in 1633 and was put on house arrest until his death. Had he admitted to heresy, Galileo would have been executed and his works banned by the Church (Wolf, 2016).

The Church's objection to Galileo directly interfered with Galileo's work. He was forbidden to pursue astronomical work as his research explicitly went against the teachings of the Bible and the worldview of the Catholic Church. After the death of his daughter Maria Celeste in 1634, Galileo began once again on Discourses and mathematical demonstration concerning the two new sciences, which had to be smuggled from Italy to Holland, a treatise that included work

on the movement of a pendulum, the acceleration of free-falling bodies and the motion of an object on an inclined plane and was the last work he published (Galileo Galilei (1564-1642), 2006). Due to the false support of the Pope, the death of his daughter and caretaker, and his inability to research heavenly bodies as he wished to, Galileo lost interest in any sort of research into the physical sciences and mathematics for years, depriving the world of his insights into the world of the natural sciences. The Church stifled Galileo's brilliant mind due to an extremely rigid worldview and because Galileo's ideas were a threat to that worldview. How could the Church retain control when this upstart expressly argued that the Church should remain separate from science, when science could be used against them and their Bible? And as such, the upstart had been shut down and stopped from further leading the public to question their social leaders.

Rene Descartes

Rene Descartes was born on March 31, 1596, in La Haye in Touraine, France, now known as Descartes, France. His mother died a year after his birth, and his father was a member of the Parlement of Brittany at Rennes, thus Descartes was raised by his grandmother and great uncle. Descartes spent much of his childhood in poor health, and started his studies late, entering the Jesuit College Royal Henry-Le-Grand at La Fleche in 1607. There he studied mathematics, physics, and hermetic mysticism. Afterwards, he studied at the University of Poitiers, to fulfill his father's dream of becoming a lawyer. In 1618, he then became a mercenary and joined the Protestant Dutch States Army in Breda. He spent years traveling after leaving the military, settling in La Haye for a period, until the death of his daughter to scarlet fever, before moving to the Netherlands and finally to Sweden. He died in Sweden, and as he stayed a devout Catholic his whole life, was buried among orphans in the only graveyard not bound to the Protestants (Nadler, 2015).

Throughout his life, Descartes studied and published papers on multiple disciplines in mathematics and physics. While part of the Protestant Dutch States Army, he studied military engineering, and after the death of his daughter, he studied free fall mechanics, catenaries, conic sections and fluid statics (Nadler, 2015). Descartes specifically wanted to create a method that linked mathematics and physics together. Descartes developed Cartesian Geometry in his essay "Le Geometrie" which was part of the greater body of work *Treatise on the World* (Descartes & Gaukroger, 2004). However, after the treatment of Galileo due to the Catholic Church's rigid worldview, Descartes censured himself, publishing essays from *Treatise on the World,* rather than the full work as he feared he would be persecuted due to his mathematics challenging the rigid worldview of the Catholic Church. He instead published the introduction, "Discours de la methode", and then "Les Meteores", "La Dioptrique", and "Le Geometrie." Descartes also published three philosophical works, *Les Passions de l'ame, Principia Philosophiae,* and *Meditations Metaphysiques.* Descartes best work is held in *Meditations Metaphysiques*, where he explicitly criticizes atheism, offers logical proofs of God (based on the method of thought he explained in "Discours de la methode") and argues that God is separate from humans, and the human mind and body are separate from each other (Descartes et al., 2006). Descartes also argued that only God was a true substance, and that if the brain is a substance, then God must be necessary for humans to function. Descartes' religious beliefs were a direct extension of the worldview held by the Catholic Church, and clearly influenced Descartes' view on the metaphysical world.

The Catholic Church never communicated with Descartes regarding his theological beliefs. There is a possibility that their indifference was due to how far from the center of the Catholic Church's power he lived (Italy to Sweden). The other possibility is that the Catholic

Church was aware of what Descartes was publishing, however, Descartes did not publish in Latin, nor did he publish his works in Italy. Descartes was surrounded by Protestants, and as such, what harm could he do with his ideas? Since he was surrounded by people the Church already believed to be lost to them, they suffered no loss in power by him spreading his ideas of God as a substance, or that his mathematics showed a physical reality that the Church opposed as contradicting the Bible, since the Protestants already accepted Kepler's work without issue.

Blaise Pascal

Blaise Pascal was born on June 19, 1623, in Clairemont-Ferrand, France. His father was a tax collector, and his mother died when Pascal was three. His father taught him and his siblings and was considered a prodigy from a young age. At 16, he wrote his first mathematical treatise on conics, which Descartes believed to be the work of Pascal's father. Pascal never married nor had any children (Connor, 2009) He spent much of his life traveling between his home in Paris, France and the convent where his sister lived.

Pascal was an inventor and a mathematician; publishing works from the age of 16. As an inventor, he created the Pascaline, the first basic calculator, capable of doing addition and subtraction, to help his father get through his work as the king's commissioner of taxes faster. At 16, he published *Essai pour les coniques,* and as a young man, he worked with Pierre de Fermat to develop the mathematical theory of probabilities, developed the idea of expected value, and their work together helped Leibniz formulate calculus. Pascal is also famous for Pascal's triangle, an arithmetical triangle used to calculate the presentation for binomial coefficients. It was published in *Traite du triangle arithmetique,* his final work before the religious experience that led him to quitting mathematical work.

On November 23, 1654, Pascal had an intense religious experience, and wrote himself a note beginning “Fire. God of Abraham, God of Isaac, God of Jacob, not of the philosophers and the scholars...” and ending with Psalm 119:16: “I will not forget thy word. Amen.” (Serratelli et al., 2010, p. 1160) He kept that note sewed in the lining of his coat, and transferred the note when he changed clothes (Miel, 2019). It was found by a servant after his death. Earlier, in 1646, Pascal’s father broke his hip, and as a result, Pascal became close with the two doctors treating his father. These two men, Deslandes and de la Bouteillerie, the two best doctors in France, were followers of Jean Guillebert, an advocate for Jansenism. After becoming acquainted with the doctors and borrowing their books on Jansenism, Pascal had a quiet conversion and began writing on theology later the same year. After Pascal’s father passed away in 1651, Pascal’s sister, Jacqueline wanted to join the Jansenist convent of Port-Royal, which saddened Pascal as his sister was his confidant and because she took care of him when he was in poor health. After his experience in November 1654 and stopping his work in mathematics, Pascal began to travel frequently between the convent his sister was a part of, and Paris. He started writing *Lettres provinciales*, an attack on casuistry, a method used by Catholics to sound clever, but used unsound logic to argue morality. These letters were so complex, they angered King Louis XIV, and he ordered the book shredded and burnt in 1660, as well as Pope Alexander VII publicly opposing them (Miel, 2019). The letters also led to Port-Royal being shut down and condemned as the king became incensed by the Jansenist sect in its entirety. Pascal’s greatest theological work, however, remained unfinished before his death. The *Pensées* is an examination and defense of Christianity. Pascal used the contradictory philosophies of Stoicism and Pyrrhonism to show that the unbeliever remains in such despair and confusion that he must embrace God (Pascal et al., 1965). The first version of the work was found on scraps of paper and put together

by servants to be published after Pascal's death, and became a literary masterpiece known throughout France. The *Pensées* were a direct example of the worldview held by Pascal after his religious experience. It was clearly influenced by the views held by the Catholic Church and contains key pieces of their worldview, such as disbelievers in Christ would remain in despair until their deaths unless they embraced Him. It is also likely, the rigid worldview that the Catholic Church was the final authority on mathematics, science, religion and society, being affirmed by Pascal's religious experience, is what led to Pascal never working with mathematics again, as he could no longer have the religious flexibility needed to pursue mathematics.

Analysis Among the Lives of the Three Catholic Mathematicians

Commonalities between all mathematicians were identified related to their personal lives, their religions, in the mathematics they studied, and how their contributions influenced society. The most prevalent similarity between Galileo, Descartes, and Pascal was their shared Catholic faith. Below, the similarities of their personal lives and families of each mathematician, the personal relationship with religion each mathematician had, as well as the influence each mathematician had on society is articulated.

Personal Lives. All three men lived semi-similar lives. Galileo and Descartes both had children, and both lost their children as well. Galileo's daughter died shortly after he had been convicted of suspicion of heresy, while Descartes' daughter died of scarlet fever when she was young. Similarly, both mathematicians stopped pursuing mathematics for a time. Galileo published only one more mathematical work after his daughter's death and Descartes strayed from mathematics entirely, choosing only to work on philosophy. While Galileo had been sent to a monastery at a young age to be taught before university, both Descartes and Pascal were tutored by family. Descartes was ill as a child, so his grandmother and great uncle kept him at

home until he was old enough to attend university, while Pascal was considered a child prodigy, and his father tutored him until he no longer required tutelage.

Personal Faith in Religion. Galileo remained quietly religious throughout his life, sending his daughters to the Church, while Descartes and Pascal were feverishly religious, both having some sort of religious experience causing them to devote the rest of their lives to the learning of theology. Descartes learned from the actions the Church took against Galileo and stayed far from their reach when he published similar topics to Galileo, while Pascal drew the ire of Pope Alexander VII, just as Galileo drew the ire of both Pope Urban VIII and Pope Paul V. However, Galileo, unlike the other two mathematicians who gave up mathematics to pursue theology, explicitly argued that mathematics and religion should remain two separate entities, and that solely supporting science that supports the Bible would keep humanity back in terms of scientific advancements.

Response of the Catholic Church. As can be seen in Table 1, the three mathematicians were treated very differently by the supporters of the Catholic Church. Galileo was almost executed for his belief that mathematics and religion should remain separate, and that only pursuing the natural sciences as far as the Bible can be interpreted to contain them would only hinder the advancement of society. Similarly, Pascal believed that Catholics were not defending their faith correctly; that they used unsound logic to argue morality and that would be the downfall to their faith. As such, his work was burned by the king of France and banned by Pope Alexander VII. In different ways, the Church sought to shut down those who could be opposition to their centralized power over the religious society. Contradictory though, was the indifference that Descartes received at the hands of the Catholic Church. He censured himself as to not receive the same treatment as Galileo and was ignored for his religious views. Along with

Pascal, Descartes believed that religion should be argued and defended mathematically. While his views were extreme in believing that God was the substance that controlled all people, it did not affect societies belief in the physical reality of the known universe, and as such was not a threat to the worldview created by the Catholic Church.

Table 1 *Catholic Mathematicians' Relationship between Religion and Mathematics*

Catholic Mathematicians	Religion and Mathematics	Response of the Church
Galileo Galilei	Believed religion and mathematics should remain separate	Put under arrest by the Inquisition, no longer allowed to teach or study mathematics
Rene Descartes	Used mathematical methods of logic to prove God and criticize atheism.	No response, as he lived in Sweden, far from the Church's center of Power in Italy
Blaise Pascal	Used Catholic logic against itself to prove and defend Christianity.	Pope Alexander VII publicly opposed his letters and King Louis XIV burned them, had the Port- Royal shut down and condemned.

The Catholic Church had, until the invention of the printing press and the start of the Renaissance, remained a centralized power integral to the development of western Europe. Galileo and other mathematicians and scientists became a threat to that power, not just because their findings were contradictory to the Bible, but because they made their findings available to the public, in a way the public could understand. The language of the universities in Europe was Latin or Greek, due to the Aristotelian education all scientists, doctors, astronomers, etc. were given as they became learned. Galileo specifically fought against the elitist nature of education, Wootton writing "... in the universities the Aristotelian science that Galileo was committed to attacking held sway. By publishing in Italian, Galileo was appealing against the universities to an

educated laity...” (Wootton, 2013, p. 41). Galileo published in Tuscan, the language of Florence, Descartes and Pascal published in French, all three made their research understandable to those who had no education. As long as one person could read, an entire group of people could understand scientific findings, rather than other academics being the only group to understand advancements in research.

All three mathematicians did not only have revolutionary scientific ideas, but they published those ideas in a revolutionary way. The Church was threatened by the upset of social norms, the Church was threatened by the upset of religious ideas, the Church was threatened by the upset of scientific ideas that completely changed what was believed about the universe and for the first time ever brought up the idea that the Church would lie to society when they were meant to be the bringers of light and education to the common people. The mathematicians challenged the rigid worldview upheld by the Catholic Church. Galileo’s belief that religion and science should remain separate, all three mathematicians’ affinity for publishing in the common language, and all three mathematicians’ new mathematics and science that did not follow academic norms shook the foundation of the Catholic Church as a centralized power.

Case Study in Protestantism

Above, I analyzed the interactions between the Catholic Church and three Catholic mathematicians. In the next section, I analyze the interactions between the Protestant Church and three Protestant mathematicians: (1) John Dee (1527-1608), (2) Johannes Kepler (1571-1630), (3) Leonhard Euler (1707-1783). First, I provide a brief overview of their lives and their mathematical contributions. Next, I elaborate on their personal relationship with religion and how it affected their mathematics, before articulating how their church leadership responded to their mathematical and philosophical ideas.

John Dee

John Dee was born in London, England, in 1527, though the exact date is unknown. Not much is known about his life overall, at least not about his early life, nor his life after returning to England. Dee was born right before the Church of England split from the Catholic Church during the English Reformation, not to be mistaken with The Reformation, which occurred when Martin Luther posted his 95 Theses. Dee attended St. John's College in Cambridge at 13 and was later offered, but refused, readership of mathematics at Oxford University (Fell Smith, 2014).

Dee was a strong supporter of the crown, and even went so far as to associate himself with King Arthur and the mythical side of the Elizabethan "British Empire." Dee worked on navigation and mathematics and as the scientific advisor to Queen Elizabeth and was the first supporter of "The British Empire" (MacMillan, 2001). Throughout his life, Dee went on missionary trips to Cracow, Poland, and to Prague, Bohemia, where he stayed with a noble family in the court of Emperor Rudolf II. Dee moved back to England after his trips with his wife and children after his wife became pregnant again, where they moved to Manchester, and Dee worked as a consultant for trials on demonology and witchcraft until his unremarkable death in 1608 (Yates, 1979).

John Dee was known for his mathematical work, even becoming the astrological and scientific advisor to Queen Elizabeth.

> Dee thinks of the universe as divided into the natural, the celestial, and the super-celestial spheres. The tendency of the movement towards concentration on number as the key to the universe...is carried forward by Dee in a yet more intensely 'mathematical' direction. (Yates, 1979, p. 81)

Dee's mathematical works in astronomy were applied practically when he advised navigators, artisans, and technicians. He also had a strong grasp on abstract mathematical theory,

including the theory of proportion, which he used to influence a change in the way that music was composed (Yates, 1979). John Dee was a self-taught mathematician as no university in England at the time offered a degree in mathematics—just basic courses in arithmetic and geometry. Dee was a principal member of the English Group of Mathematics, an informal group of scholars who promoted advancement and study in mathematics (Fell Smith, 2014). Overall, Dee was extremely important to English society taking mathematics with a more serious treatment than it previously had.

Dee's worldview drew from the concept of heaven and hell, and of angels and devils, but remained primarily Protestant. He was a Christian; however, he combined ideas such as angels and devils from Christianity and drew strength from occult philosophies. Dee owned several occultist books and expanded on that work, including Agrippa's *De occulta philosophia,* Giorgi's *De harmonia mundi,* and the works of Pico Della Mirandola and Reuchlin. Above all, Dee believed in alchemy (i.e., what led to the development of chemistry), and his time in Prague was dedicated to pursuing alchemical work as well as the summoning of angels.

> Like Reuchlin, Agrippa, and the Christian Cabalists generally, Dee was intensely aware of the super celestial world of the angels and divine powers. His studies in number, so successful and factual in what he would think of as the lower spheres, were, for him, primarily important because he believed that they could be extended with even more powerful results into the super-celestial world. In short, as is well known, Dee believed that he had achieved... the power of conjuring angels. (Yates, 1979, p. 82).

Dee fully believed in alternate worlds and a higher power, as well as believing he could access those worlds with the power of mathematics, with his success as a mathematician being empowered by the sensational angel-summoning side of his activities.

Dee constantly tried to use mathematics to prove the existence of heaven and hell. The leaders of the Church of England did not approve of his activities and spread the idea that Dee

had been summoning demons causing him to lose favor with the Queen of England, as well as with his contemporaries (Yates, 1979). Dee's mathematics had nothing to do with how the leaders of the Church of England treated him and everything to do with how they targeted him. Even so, once Dee began to cross mathematics into religion (e.g., when he used mathematics to separate the world into three planes and use that mathematics to summon angels), the leaders of the church took it as an attack against their faith. His mathematics and influence over the Queen did not wane until he left for Prague to pursue research in alchemy and to perform experiments in summoning angels. After he left, the leaders of the church began spreading rumors that he was a devil worshipper and that allowing him around the Queen would be the end of British royal family. Dee

> ... believed that such daring attempts were safeguarded by Cabala [i.e., the ancient Jewish tradition of mystical interpretation of the Bible] from demonic powers. A pious Christian Cabalist is safe in the knowledge that he is conjuring angels, not demons. This conviction was at the center of Dee's belief in his angelic guidance, and it explains his pained surprise when alarmed contemporaries persisted in branding him as a wicked conjuror of devils. (Yates, 1979, p. 82)

The belief that Dee was a demon-summoner hurt him deeply, as he truly believed that through his faith, he would only summon angels.

Johannes Kepler

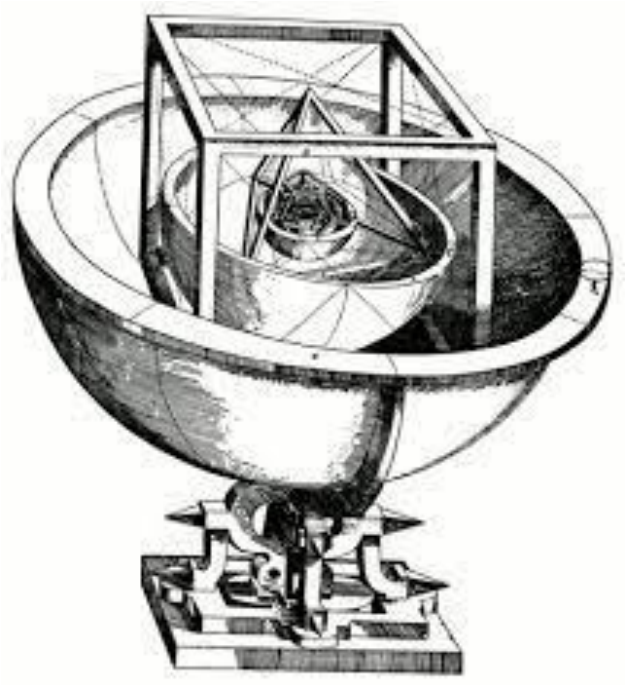
Johannes Kepler was born on December 27, 1571, in Weil Der-Stadt, Germany to a mercenary father and an innkeeper/herbalist mother. In 1587, Kepler attended the University of Tubingen, where he studied theology. However, before he could graduate and become a minister, his professors recommended he take a post teaching Mathematics in Graz (Connor, 2008). Kepler had mixed feelings about astrology, but he deeply believed in a connection between the cosmos and the individual. He eventually published some of the ideas he had in school, in the *Mysterium Cosmographicum* in 1596. In 1595, he was introduced to a widow with a young

daughter, and eventually married her after he published the *Mysterium Cosmographicum*, and they had three more children who lived. Archduke Ferdinand of Graz required all citizens of Graz to convert to Catholicism in 1600, and the Kepler family refused, were banished and moved to Prague. There, Kepler worked under Tycho Brahe, and after his death, took Brahe's post as the imperial mathematician under King Rudolph II. After his first wife's death, Kepler married once more, and on November 15, 1630, Kepler passed away in Regensburg, Germany (Connor, 2008).

Kepler had been enchanted by astronomy since he was a child. He had observed the Great Comet of 1577, and in 1580 he observed a lunar eclipse (Koestler, 1959). Kepler worked with Tycho Brahe using observations of Mars to determine that its movement was elliptical. Kepler's work on the *Mysterium Cosmographicum*, was the first published defense that our solar system is heliocentric, known as the Copernican system. In the *Mysterium Cosmographicum,* Kepler used regular polygons and a circumscribed circle at definite ratios to determine the geometrical basis of the universe; however, he was unable to determine a unique arrangement of polygons that fit the numerous observations he had of the planets. He eventually used three dimensional polyhedrals and found that the five Platonic solids could be inscribed by spheres, and nesting these solids corresponded to the six known planets at the time: Mercury, Venus, Earth, Mars, Jupiter, and Saturn (Kepler & Schenkel, 1993) as seen in Figure 6.

Figure 5

Johannes Kepler's Polyhedra



Kepler's work, *Astronomia Nova,* included the first two laws of planetary motion and introduced the concept of planetary orbit replacing the idea of planetary orb (a shell that a planet is attached to) (Goldstein & Hon, 2005). He wrote numerous astronomical and musical texts, using mathematics to explain planetary orbit and musical intervals, and his work was questioned until his death in 1630 by other astronomists due to his use of physics along with astronomy.

Kepler had a complicated history with religion. When he was born, Weil Der-Stadt was a Catholic town, and as a result, he was baptized by the Catholic Church. When Archduke Ferdinand gained power, he required all habitants of Weil Der-Stadt to convert to Lutheranism, which Kepler had been granted exception to, although his oldest daughter was baptized as Protestant. Ferdinand changed his mind and converted to Catholicism once more, although this time, Kepler and his family did not oblige, and thus were banished from Graz. Kepler, in every

work he published, praised God. He believed that God enlightened him to the secrets of the universe. He likened the Sun to God, and argued in the *Mysterium Cosmographicum* that the Bible itself argued the sun was the center of the universe. Kepler had an extremely flexible worldview, and he often argued with theologists regarding his beliefs in theology, such as his belief that there was no distinction under God between Catholics, Protestants, and Lutherans, and as such they should be able to take communion together. It was also suggested that he take the mathematics post due to his professor's belief that his worldview was not Calvinist enough to become a Calvinist minister. The church he was a part of also denied him communion due to his arguments regarding religion (Mazer, 2012).

Leonhard Euler

Leonhard Euler was born April 15, 1707, in Basel, Switzerland. His father was a pastor of the Reformed Church, and his mother was the daughter of well-known scholars of the classics. He spent most of his childhood in the town of Riehen, Switzerland after his father became the pastor of a church there (Gautschi, 2008). From a young age, Euler's father taught him mathematics he had learned from Jacob Bernoulli at the University of Basel. At 13, Euler was enrolled at the University of Basel, and taught mathematics by Johann Bernoulli, the younger brother of Jacob Bernoulli. At this time, Euler's father gave him permission to stop his studies as a pastor and was allowed to pursue mathematics (Calinger, 2016). He applied to be part of the faculty of the University of Basel in 1723, and in 1726, and was denied positions both times.

Euler obtained a physiology post in Saint Petersburg due to his friendship with Johann Bernoulli's son Daniel and was promoted from medicine to mathematics. He also took an additional job as a medic in the Russian Navy. Due to politics in Russia at the time, Euler lost funding and was not allowed into the Gymnasium or universities in Russia (Calinger, 2016). He

refused a promotion to lieutenant in the Russian navy, choosing to retire instead, and after the death of Peter II, Euler was able to rise the ranks of the academy and become a professor of physics. Euler married in 1734 and moved to Berlin in 1741, arguing he needed a milder climate as his eyesight was failing. He spent 25 years in Berlin at the Berlin Academy, as a tutor for Frederick the Great of Prussia's niece, but continued to publish papers in Russia, while assisting Russian students that visited him in Berlin. After Catherine the Great ascended the Russian throne, Euler moved back to Russia and rejoined the St. Petersburg Academy, where his second wife (his first died) received a pension, his sons received high-ranking appointments, and he received a 3000-ruble yearly salary (Calinger, 2016). He died on September 18, 1783, after having lunch with his family due to a brain hemorrhage.

Euler wrote hundreds of papers, letters, and manuscripts during his productive years, and even after his eyesight began to deteriorate. It is estimated that Euler was the author of nearly a quarter of all mathematics, physics, mechanics, astronomy, and navigational works during the 1700s (Assad, 2007). He popularized multiple mathematical notations, such as $f(x), e, i,$ and π (although, π was created by William Jones, a Welsh mathematician). He developed infinitesimal calculus even further, although his proofs did not reach the modern standard of mathematical rigor. He analyzed power series and used it to solve the Basel problem in 1735. He introduced what is known as Euler's constant, introduced exponential functions and logarithms into analytical proofs, elaborated transcendental functions by introducing the gamma function and introduced a new method for solving quartic equations. Euler was interested in both number theory and graph theory, proving the relation between perfect numbers and Mersenne primes, also finding the largest prime until 1867 (Calinger, 2016). He contributed to physics, astronomy, and engineering, solving real-world problems analytically, improved logical arguments by

creating Euler diagrams, and then refining them to Venn diagrams, and were incorporated later into the teaching of set theory in the 1960's. Euler's contributions to the whole of mathematics have changed every mathematical genre since their conception.

Euler was extremely religious throughout his life. He was a devout Christian who believed that the Bible was inspired (that God directed the human authors of the Bible to compose and record His message to humanity in their original writings) (Euler, 1805; Armstrong, 2021). He opposed Leibniz's monadism (the belief that reality, and particularly matter, are composed of invisible entities, created by the German mathematician) and insisted that knowledge is a part of the basis of precise quantitative laws (Calinger, 2016). Euler constantly argued with Voltaire (a French philosopher, writer and satirist) about philosophical ideas while in Berlin, although Euler argued to argue and could not match Voltaire's wit, according to later accounts. Euler also argued with Diderot (a French philosopher, art critic and writer), and there is a legend that he responded to Diderot's insistence of a proof for the existence of God with "Sir, $\frac{a+b^n}{n} = x$, hence God exists" (Struik, 1967, p. 129). Unlike other mathematicians, he did not write about the existence of God using mathematics or using logic to prove God's existence. He only remained devout in his personal life, and kept science and mathematics separate from religion.

Analysis Among the Lives of the Three Protestant Mathematicians

The overarching similarity between Dee, Kepler, and Euler was their shared Protestant faith. In addition, there were commonalities in their personal lives, in their religions, in the mathematics they studied, and how they influenced society. Below, similarities of the personal lives and families of each mathematician, the personal relationship with religion each mathematician had, as well as the influence each mathematician had on society is analyzed.

Personal Lives. In the personal lives of all three mathematicians there were many similarities and differences among them. Not much is known about the early life of John Dee, but we do know that he was married and had multiple children, which both Euler and Kepler did as well. Both Kepler and Euler had more than one wife, their first wives dying young. Kepler attended the University of Tubingen where he studied theology and Euler attended the University of Basel for theology, until his father gave him permission to change his studies to mathematics. Dee attended St. John's College in Cambridge and was later offered readership for mathematics at Oxford University. Coincidentally, the reason that Euler was able to study mathematics as its own study was due to Dee's influence by rejecting readership at Oxford, since the university only focused on rhetoric and grammar (Fell Smith, 2014).

Personal Faith in Religion. All three mathematicians were fervently religious in their own ways and had flexible worldviews. Dee believed that his strong faith would allow him to summon angels and would protect him from demons trying to harm him while attempting to do so. Kepler used God to justify his understanding of the mathematical world, praising Him with hymns at the conclusion of his mathematical works and thanking Him for allowing him to know more of the universe. Euler, on the other hand, kept mathematics and religion separate. While Euler believed that the Bible was inspired, he did not use his religion to justify his mathematics like Kepler, nor did he use mathematics to further his religion like Dee. The only time he brought mathematics and religion together was a tongue-in-cheek response to Diderot not meant to be taken seriously.

Response of Church Leaders. As can be seen in Table 2, the three mathematicians were treated differently by the leaders of their respective churches. Overall, the leadership of different Protestant Churches were flexible in their worldview and the authority they had over society.

The leadership of the Church of England managed to turn Dee's contemporaries against him by claiming he was summoning demons because he enjoyed combining mathematics and religion to summon angels. Dee believed that his faith in God and his mathematical ideas would allow him to summon angels, and because that infringed upon the rights of the leadership of the Church of England to dictate what is and is not possible in their religion, they ensured that no one would take Dee seriously ever again. A similar situation also happened to Kepler. The leaders of the church he attended did not intervene when Kepler published his work regarding the center of the universe. However, when he spoke to his local church leaders regarding communion, specifically that Catholics and Lutherans and Calvinists should be able to take communion together as they all worship the same god, his church leaders forbade him from taking communion ever again. Conversely, even though Euler wrote about many new forms of mathematics, he was never punished by the leaders of his church. In fact, he never wrote anything regarding religion or his faith, and evidence shows that he kept the two separate.

Table 2 *Relationship between Protestant Mathematicians' Religion and Mathematics*

Protestant Mathematicians	Religion and Mathematics	Response of their Church
John Dee	Believed he could use mathematics to summon angels and reach the plane of God's existence	Church of England turned the public against him by saying he summoned demons, isolating him from the support of the crown
Johannes Kepler	Believed that God provided him the expansion of mind to understand the development of God's plans	Allowed Kepler to research whatever he wanted so long as he did not d theological beliefs
Leonhard Euler	Believed that the Bible was inspired and that his mathematics gave insight to God's creation	Never interacted on a personal level with Euler as he gave thanks to God for allowing him to understand mathematics

It is very likely that the leaders of Euler's church(es) never involved themselves in his work because his work never involved them. And in the same vein, the leaders of the churches that Dee and Kepler were a part of, only involved themselves with the mathematicians when the mathematicians involved themselves in religion. It is likely that they only involved themselves with religious matters because the worldview of the leaders of the Protestant Church was that they only had authority over theology (Carlsson, 2023). Unlike the Catholic Church, the Protestant Church did not have as large of a hold over public opinion on matters of the world. So long as mathematicians and scientists were praising God in their work and daily life, there was not much for local church leadership to protest. That is, until mathematicians and scientists tried to foray into their church's area of expertise, religion. The Protestant Church was the head of only religious matters. There was no confession, no baptism, no mass, and most importantly no "corruption" in the Protestant Church. So long as a person believed that Jesus is the son of God, and that he died for their sins, they would be allowed to go to heaven after death. This allowed people more flexibility in their daily lives. Although the Protestant Church had ways of harming people who overstepped their boundaries on the knowledge of the Bible, they did not put people on trial for interpreting the world differently than the Bible interpreted it.

All three mathematicians were incredibly forward thinking, and there was strength in the flexible worldview of the Protestant Church. They were able to explore mathematics without the cognitive dissonance that they were disproving their faith, nor that religion or mathematics had priority over the other. It was their faith in God that allowed them to search for further answers regarding the world. Dee and Kepler looked beyond Earth, Kepler to the observable universe and Dee to the super-celestial plane that he believed contained angels. Euler kept his religion and mathematics separate from each other but believed that the Bible was inspired and believed his

God allowed him understanding of the universe, as did Kepler. The Protestant Church allowed much more personal freedom and flexibility, and inspired several centuries worth of new information since they did not punish people for trying to understand the world that God gave them, so long as non-theologians did not try to find theological answers, such as Kepler and his belief that Lutherans and Catholics should be able to take communion together. Overall, all three mathematicians contributed their faith to their belief in mathematics and were pushed to continue finding more to affirm the workings of the universe.

Comparison of the Six Mathematicians

Many of the six identified mathematicians had similar lives, and even researched similar types of mathematics due to them all living within ≈300 years of each other. Kepler and Galileo had known correspondences, including Kepler asking to borrow a telescope of Galileo's to see Mars more clearly, while he was working for Tycho Brahe (Goldstein, 2005). John Dee was the reason that Euler was able to study mathematics as a major rather than as an individualized course of study under only one professor. Descartes knew of Pascal, even writing that 16-year-old Pascal was passing his father's work as his own since there was no way a child was able to come to the conclusions that he had. There especially is an almost symmetry in how Galileo and Kepler were treated respectively by their religions and their mathematics. Below that idea is expounded on.

Galileo began his work on the orbit of the planets around 1610 when he noticed that Venus went through phases that would not be possible if Venus traveled around the earth. His first published work regarding the Copernican Theory in 1632. Kepler began his work in 1600, under Tycho Brahe, regarding the orbit of Mars. However, he was unable to do any real research until Brahe's death in 1601, as Brahe did not want Kepler to use his observations on the orbit of

Mars to prove the Copernican theory correct. Galileo believed that the center of the known universe was near the sun, and that all the planets traversed around it, whereas Kepler believed that the center of the universe was the sun, because the sun was the giver of life, and thus was the physical form of God.

The Catholic Church, once they found out Galileo published his work in the *Dialogues of the Two World Systems*, punished him severely. They put him under house arrest and forbade him from publishing any more mathematical work. In addition, he was no longer allowed to teach at the University of Pisa. The only reason he was not executed by the Catholic Church was because he argued that he only suggested a theory, and as a God-fearing Catholic, he would never believe anything other than what the Church taught, that Earth was the center of the universe because God made the Earth special. He was only introducing a mathematical theory, something that could never be proven or real, thus he was convicted of suspicion of heresy, rather than for the crime of heresy.

On the other hand, Kepler was pushed to do mathematics. Before he graduated from university, his theological professors insisted he take a post at a different university teaching mathematics. From there, he moved to Prague and met Tycho Brahe who wanted Kepler as an assistant. While Brahe was in Kepler's way to keep him from publishing about the heliocentric theory, there was no pushback by the Protestant church that Kepler attended once Kepler published work to confirm Copernicus. In fact, the leaders of the Protestant church did not involve themselves at all with the work of Kepler, until Kepler published his ideas on the Christianity.

Similarly, Kepler and Galileo had opposing opinions regarding the separation of mathematics and religion because of the worldviews pushed upon them. Galileo expressed to his

benefactor that he believed that the Church should stay out of matters of mathematics and science, and that the Church would only slow down progress by insisting that nothing goes against the worldview they upheld. Conversely, Kepler published hymns praising God in his mathematical works. Kepler believed that God inspired him and thus he was doing the will of God by pursuing mathematics and science due to the flexibility in worldview held by the Protestant Church.

Both men sent their children to church. Galileo sent his children to become nuns, while Kepler had his children baptized and sent to church as a part of their duty to God. Their respective churches had opposing opinions regarding their work, and the work of every mathematician after them. Specifically, the Catholic Church saw mathematics and science as an explicit threat to their power over society as the main barrier to education, whereas in the Protestant faith, mathematics and science flourished due to the belief that God was finally allowing people to understand more about the universe. These two men had two different responses to their life's work, and while the Catholic Church apologized for their reaction to Galileo in 1992, 330 years after they punished him with house arrest for his beliefs, both men have secured their places in history due to the revolutionary nature of their work. The effects of religion punishing or pushing for subversive scientific and mathematic achievements are still felt today. Human nature has always been to explore what more there is to human existence and religion and mathematics are still treated as two separate endeavors, however, mathematics and religion are still intertwined with each other, even today.

Summary

My understanding of the relationship between Catholicism and Protestantism and the rise of mathematics has become much clearing since I have completed my research. With exceptions,

the Catholic Church between 1500 and 1800 did not appreciate any mathematician proving anything that was not already proven and accepted by the Church. The Earth goes around the Sun? That is not said in the Bible and thus wrong. The length of a swing of a pendulum decreases after time? That is observable mathematics and thus correct. Anything that was not easily observable was a threat to the rigid worldview of the Catholic Church (Lehner, 2015) because those same things were used to justify their faith, and thus the trust and faith of the public, and should not have been proven wrong. Whereas the Protestant Church was more flexible in their worldview overall (Carlsson, 2023). Mathematicians were allowed to prove what they wished so long as they did not interfere with matters of religion, because that was what their churches oversaw. Since the Protestant Church did not have the same social hold that the Catholic Church did, there was leeway in proving matters of science and religion, because society went to the Protestants for matters of religion only, not religion, education, and social standing the way the Catholic Church was. Therefore, academic society was able to flourish when the mathematicians were Protestant, whereas the Catholic mathematicians were under constant threat by the Catholic Church should they offend them.

Chapter 4: Limitations, Implications, and Significance

The purpose of this thesis was to explore the ways worldview as expressed in the works and lives of mathematicians aligned or misaligned with different denominations of Christianity (specifically Catholicism and Protestantism) during the Reformation, Renaissance, and the Enlightenment periods. The growth of mathematical ideas (such as the belief that the earth orbits the sun, that imaginary numbers exist, and that infinite sets exist) indicate differences at the individual (Galileo's belief that mathematics and religion should stay separate, or Kepler's belief that God allowed him to understand mathematics) and societal (The Russian monarchy pushing mathematicians to discover more mathematics, or The Catholic Church's punishment of Galileo) level during the Renaissance and Enlightenment eras. This work makes a significant contribution to the literature as a connection between the influence of two denominations of Christianity upon mathematicians at the societal level. In this chapter, I discuss the limitations, implications, and significance of this thesis.

Limitations

I acknowledge several limitations of this study. First, focusing on six mathematicians, three who identified as being Catholic and three who were categorized as having a Protestant faith, and providing an analysis of the connection between their mathematics and religion provides new insights, I caution the reader about the extent to which these results are generalizable. Identifying additional mathematicians who practice these two faiths may garner additional connections. Second, this study is limited to the exploration of two monotheistic worldviews, Catholicism and Protestantism, and how they affected the work and lives of mathematicians. Since the goal of this study was to identify ways different expressions of Christianity affected the works and lives of mathematicians, there is also the extension of these results in multiple directions such as to other denominations of Christianity. There is also the

possibility of extending this study to the lives and works of mathematicians who practice other monotheistic religions such as Judaism or Islam. Finally, future studies could extend from the exploration of mathematicians who practice polytheistic or nontheistic religions, such as Hinduism, Buddhism, Taoism or ancestor worship.

Implications

What we know about the history of mathematics is vast. However, there is still much we can learn from historical accounts that are noted in written documentation. Results from this study indicate that there is a reoccurring theme between worldview and mathematics. To understand why a society pursued a type of mathematics, we also need to understand their worldview, and to understand parts of their worldview, we also need to understand their mathematics. The two are inextricably linked throughout history. Results from this study illustrate that when people are united through religion, or there is a more religious society, that religion affects how society understands new developments in mathematics. The worldview of the existing religion can affect the worldview of mathematicians and vice versa.

The worldview of the Catholic Church during the Renaissance and Enlightenment periods were extremely rigid, and without flexibility. Mathematicians like Galileo pushed back against the Catholic Church and Descartes fled from the power of the Church, while other mathematicians such as Pascal had an intense religious experience that confirmed the worldview of the Church, and never pursued mathematics again. To understand the relationship between worldview and mathematics, we first need to understand the relationship between personal worldview and mathematics. From the Catholic mathematicians: Galileo, Descartes, and Pascal, we see that at a personal level, they had an intricate relationship with their personal faith and how they pursued mathematics. The unified worldview under the Catholic Church implied they

were the authority concerning religion, society, mathematics, science and more, led to mathematicians and scientists rejecting that worldview. For example, from case studies, Galileo explicitly stated that religion and science should remain separate. He continuously pushed back against the Church's ban on the heliocentric theory, and the Church punished him for the crime of suspicion of heresy. His punishment was to never again be permitted to publish or teach mathematics (Galileo Galilei (1564-1642), 2006; Wolf, 2016). Galileo's rebelled against the worldview held by society, namely, that the Catholic church was the final authority on societal beliefs. Similarly, we see that Descartes fled from the Church's power in France, all the way to the Netherlands and later to Sweden, where there was a majority Protestant population (Nadler, 2015). Most likely due to the lengths that Descartes took to escape the Church and the fact that he was surrounded by Protestants, the Catholic Church never intervened in the life or work of Descartes, considering him lost to them since he was surrounded by "heretics" who already rejected the Catholic Church's teachings. In contrast, Pascal had an intense religious experience in 1654, but his relationship with the Catholic Church was strengthened due to his relationship with the Catholic doctors who treated his father in 1646. After Pascal's father passed in 1651 and his religious experience in 1654, Pascal began to travel frequently to his sister's convent and writing his penultimate theological work, for which he gave up mathematics to write (Miel, 2019). Pascal's religious experience confirmed the worldview of the Catholic Church, and thus, when he could not reconcile mathematics with his worldview, he gave up on mathematics completely.

The relationship between the worldview of the Protestant mathematics and the development and growth of their mathematics is the inverse to that of the Catholic mathematicians. For example, due to Dee's faith in God, he believed he could use mathematics

to understand more about the realm of angels. While the church leaders of the Church of England believed that he was summoning demons, Dee's faith never wavered, and he used that faith to continue pursuing mathematics until his death (Yates, 1979). Similarly, Kepler continuously praised the Lord in his mathematical works due to his faith that God allowed him to see what was happening in the world more mathematically (Kepler & Schenkel, 1993). While Euler never combined mathematics and religion together as the previous two mathematicians did, he remained extremely religious throughout his life, even while discovering more and more mathematics (Armstrong, 2021). From the case studies, it appears that the leaders of the individual Protestant churches tended not to intervene in the work of mathematicians unless those mathematicians were involving themselves with religion. There was more flexibility in the worldview of Protestants and this flexibility allowed the mathematicians to be both religious and mathematical because the Protestant Church believed themselves to be experts solely in theology—not in mathematics, not in science, not in societal matters.

The difference between how a flexible worldview (the Protestants) and how a rigid worldview (the Catholics) affected the growth of mathematics during the Renaissance and Enlightenment eras are stark. A diverse worldview allowed flexibility in beliefs, and thus Protestant mathematicians had no fear that their churches would retaliate against them for proving different mathematical and scientific ideas and were able to combine their faith in God with their love for mathematics. On the other hand, when the Catholic Church had a more prominent hold over society, there was a unified worldview, but there was no flexibility to allow for the growth of new mathematical ideas, and thus, Catholic mathematicians either rebelled against the Church in their pursuit of new ideas (Galileo), fled from the seat of the Church's

power so that they may pursue ideas in peace (Descartes) or completely gave up on the pursuit of new mathematical ideas completely (Pascal).

Results from this study illustrate that when people are united through a common worldview, or there was a more religious society, religion affected how society understood new developments in mathematics and religion. Extending the idea that worldview affects how mathematics are understood, a more diverse worldview, such as what occurs in today's world, is beneficial to the growth of mathematics and science unlike that of a rigid worldview that does not allow for any growth or change.

Significance

The relationships between worldview and the growth of science and mathematics are still symbiotic today. Currently society is no longer separated by a common religion, ethnicity, or gender in the way it once was, and there is no longer a singular worldview uniting society. With a more diverse culture, there are many conflicting worldviews that are prevalent today. For example, concerning religion and mathematics, in the United States, there are still issues with a major religion conflicting with the growth of mathematics. Over the past three years, we have seen the rise of COVID-19. In the United States, as a response, the "anti-vax" movement gained strength, and studies have shown that most of that movement is made of religious conservatives and Christian Nationalists (Corcoran, et al., 2021). These "Christian nationalists demand that their brand of Christianity be the sole source of moral authority for the United States and reject all competitors including science" (Corcoran, et al., 2021, p. 6615). There was a struggle between mathematics and science and religion over 500 years ago that continues today on a personal level, rather than at a church-led level. While having diverse worldviews is beneficial to the growth of mathematics and science, conflicting worldviews and conflicting religious beliefs

have the potential to lead to a decline in the understanding of mathematics in a similar vein to the way the rigidity of the worldview of the Catholic Church did.

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Appendix A: Terminology for This Study

For the purpose of this study, below is how the researcher defines the terminology referenced in this study drawing on the sources of Encyclopædia Britannica (n.d.), Merriam-Webster (n.d.), Oxford Reference (n.d.), and Wikimedia Foundation (2023).

Animism: The belief that objects, places, and creatures all possess a distinct spiritual essence.

Aristotelianism: The philosophical work of Aristotle characterized using deductive reasoning and an analytic inductive method in the study of natural sciences.

Catholicism: Of or relating to the body of Christians having levels of authority under the pope, a liturgy centered in the Mass, and a body of beliefs laid down by the church as the only interpreter of revealed truth.

Fideistic: The doctrine that knowledge depends on faith or revelation.

Franks: Germanic speaking people who invaded the Western Roman Empire in the fifth century.

Heliocentric: Having or representing the sun as the center, as in the accepted astronomical model of the solar system.

Hesychast: a member of a movement dedicated to contemplation, originating among the Orthodox monks of Mount Athos in the 14th century.

Hinduism: the dominant religion of India that emphasizes dharma with its resulting ritual and social observances and often mystical contemplation and ascetic practices.

Jansenism: created by Cornelius Otto Jansen in 1640 and worked to reconcile divine grace and human freedom.

Jesuates: A sect of Catholicism created by Giovanni Colombini of Siena who devoted themselves to taking care of the poor and sick.

Jesuits: Part of the Roman Catholic Society of Jesus founded by St. Ignatius Loyola in 1534, who devoted their lives to missionary and educational work.

Monotheism: The belief or worship of only one God.

Neoplatonism: A strict form of principle-monism that's strives to understand everything on the basis of a single cause that they considered divine, and indiscriminately referred to as "the First," "the One," or "the Good."

Numerology: The study of the occult significance of numbers.

Occultism: The belief or study of actions caused by the supernatural or supernormal powers.

Polytheistic: The belief or worship of more than one God.

Protestant: A member of any of several church denominations denying the universal authority of the Pope and affirming the Reformation principles of justification by faith alone, the priesthood of all believers, and the primacy of the Bible as the only source of revealed truth.

Worldview: A particular philosophy of life or conception of the world.