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Faith and STEM Education: A Path to Mutual Elevation in Catholic Schools

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Abstract: Amidst increasing religious disaffiliation, often due to a perceived tension between faith and the STEM disciplines, Catholic schools provide critical opportunities for young people to recognize how these domains can be mutually elevating. The field, however, lacks guidance as to how this integration should occur in practice. This conceptual paper first provides an overarching framework for how aspects of the Catholic tradition, like Scripture and the Catholic social tradition, can shape traditional educational domains of STEM teaching and learning. Secondly, we provide a heuristic of three criteria for deeply engaging students at the interface of the Catholic faith and the STEM disciplines. Finally, we narrow in on K-12 science standards and provide six examples of how the three criteria can be applied to authentically and deeply advance understanding at the intersection of science and the Catholic faith.

Keywords: STEM Education, Catholic schools, integral formation, faith and science

In the thirty years since *Catholic Schools and the Common Good* (Bryk et al., 1993), Catholic schools have attempted to navigate shifting demographics, enrollment pressures, challenging financial terrains (Miserandino, 2019), and broadening environments of school choice (Stanford, 2023). One consequence has been the rise of specialized Catholic schools, including micro-, dual language, classical, and STEM-focused schools—the last of which emphasizes the disciplines of science, technology, engineering and mathematics and their integrated relevance for engaging with the natural and built world (some Catholic schools use the term STREAM to include

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the arts and religion). These novel models have opened new opportunities for young people to encounter their faith within their education and have bolstered the need for research and tools to support Catholic schools in accomplishing their perennial aim of a "synthesis of culture and faith . . . by integrating all the different aspects of human knowledge through the subjects taught, in the light of the Gospel" (Sacred Congregation for Catholic Education, 1977, section 37).

The increasing prevalence of STEM-focused education in Catholic schools (Laurienti, 2016)—with its explicit commitment to integration across disciplinary boundaries—has cast a spotlight on what it means for educators to meaningfully integrate the Catholic faith with core disciplinary content (e.g. Florida Catholic Conference, 2024). Since the deposit of faith is not solely a set of propositional knowledge, a collection of moral commitments, or the participation in sacred rites, there exists a full array of ways to incorporate and communicate the Catholic faith within a school community (National Conference of Catholic Bishops, 1973). Nevertheless, educators remain wanting for instructional guidance. Some resources from dioceses and Catholic nonprofits have outlined high-level themes and student outcomes (e.g. Archdiocese of Detroit Office of Catholic Schools, 2017; The Cardinal Newman Society, 2016), yet specific instructional advice for teachers is often limited to brief or ancillary connections between a given content standard and a Christian idea.

Approaching STEM education through a Catholic lens surely has institutional value for schools, but perhaps more importantly it attends to deep personal and spiritual tensions for students. U.S. demographic trends of the last two decades have shown a precipitous decline in religious affiliation: 40% of Millennials are religious 'nones' and, surely, a higher proportion of Gen Z (Pew Research Center, 2019). Disaffiliation has several self-identified rationales, but as Kinnaman and Hawkins (2011) contend in their book *You Lost Me*, the perceived antagonism between religion and science is one major factor for those leaving the faith behind. The Kinnaman and Hawkins (2011) study cites nearly 30% of Christians as seeing "churches [out] of step with the scientific world [they] live in" (p. 136) and a quarter as seeing Christianity as anti-science. Recent historic and political events, including the COVID-19 pandemic, have placed science and technology in the crosshairs of public debate (Nasr, 2021), often inflected by religious discourse. Despite the popular perception of a conflict between science and religion, there are other, more compelling ways of relating the two (Barbour, 1990) that are more reflective of people's actual beliefs (Ecklund, 2010). Notably, the Catholic intellectual tradition consistently seeks a consonance between scientific knowledge and religious faith (Catechism of the Catholic Church [CCC], 1997, para. 159; John Paul II, 1988). On this foundation, Catholic schools offer a supportive environment for young people to meaningfully engage scientific ideas in deep and authentic dialogue with the richness of the Catholic faith. If there is a place for young people to unknot the perceived antagonism between science and faith, the Catholic school can be it.

These contours serve as a strong rationale for more explicit and concerted approaches to STEM education in Catholic school communities and for practical guidance on implementation. In this paper, we highlight this need and provide a pathway that mutually elevates the Catholic faith and STEM disciplines within a Catholic school environment. We begin by outlining a general framing for how STEM education can support a culture in which the school's Catholic identity is part and parcel to all learning experiences. Set in this way, we contend that a concentrated approach to connecting specific STEM concepts with the Catholic faith is both appropriate and ultimately more impactful for students, and we outline a general heuristic of three criteria—applicable across STEM disciplines—for deeply engaging students at the intersection of STEM learning and faith. Such an approach focuses on a smaller number of more authentic connections, in contrast to an approach in which teachers are asked to make connections—sometimes superficially or artificially—for every disciplinary concept. To illuminate this point, we present and examine a short vignette of practice in light of the heuristic. Lastly, we apply the heuristic to science as one of the STEM subjects; the same approach is relevant to the other STEM disciplines, though beyond the scope of this paper. We identify six core science ideas studied in Grades K-12 that offer authentic connections to the Catholic faith. For each core idea, we explain how the scientific concepts intersect with elements of the Catholic faith and then describe how learning experiences might move students toward a greater understanding of the universe and their place within it.

Toward a framework for integrating the Catholic faith and STEM education

Previous research on Catholic schools' desire to adopt a STEM-focused model highlights the central role that Catholic identity plays in the decision-making of schools (Kloser et al., 2018). Viewed through the lens of organizational identity (Gioia et al., 2000), case studies of these schools show a spectrum of enacted implementations ranging from less successful (e.g. compartmentalization/independence) to the more effective, in which schools make links between the domains of faith and the STEM disciplines and with Catholic identity remaining the ultimate decision-making lens (Pratt & Foreman, 2000). Kloser and colleagues' (2018) exploration of Catholic schools attempting to adopt a STEM-focused model suggests that while schools act strategically in their transformations, they do not necessarily make decisions based on a foundational framework. In this section, we connect existing markers of Catholic schools with three criteria for how decisions can be made by educators to thoughtfully integrate STEM core ideas and practices.

Adopting a stronger STEM focus within a Catholic school will be successful only so long as the school meets John Paul II's (2004) criteria for all Catholic school models—being "genuinely Catholic" in both their self-understanding and identity (section 1). Drawing on the Holy See's teaching on Catholic education, Miller (2006) identifies five essential benchmarks of a Catholic school identity. First, the Catholic school is inspired by a supernatural vision, wherein it is believed

that all in the school are created in the image and likeness of God and called to a constant seeking of Truth and love of neighbor. Second, Catholic schools are founded on a Christian anthropology that seeks to develop the whole person, centered on Christ, in service to others. Third, the school is animated by community and communion (Congregation for Catholic Education, 1988) evidenced in multiple ways, like designing learning and social experiences that promote the whole community over the individual. Fourth, the school is sustained by the gospel witness of teachers and administrators.

A potential for integrating STEM learning and the Catholic faith exists across each of these four marks, but the remaining mark, in particular, presents an important opportunity for intersection as schools imbue the Catholic worldview, or "the spirit of Catholicism" throughout its curriculum (Miller, 2006, p. 42). This worldview permeates the entire educational experience, which includes the STEM disciplines. This mark of the Catholic worldview, however, has the potential to be unhelpfully interpreted as requiring each discrete science, mathematics, or engineering standard to have a one-to-one connection to some element of Catholic heritage. In fact, our review of multiple sets of diocesan science standards evidences an alignment between each performance expectation and an element of Catholic identity (e.g. a Bible verse, a Catholic scientist, a liturgical symbol). While helpful and clearly appropriate for some topics and standards, an exhaustive curriculum alignment policy fails to recognize the broad sense in which the curriculum of a Catholic school lies not only in what is taught or how secular sets of standards in math, science, engineering, or technology are adapted. In addition to its standards, the planned units and tasks of a subject, the Catholic school is constantly teaching through its culture, dispositions, and instructional interactions. Its curriculum, understood in this way, provides constant transformational moments that augment the formal STEM standards and lessons that students encounter. Thus, an underlying foundation for every encounter in Catholic schools is a gospel-oriented worldview, which grounds education not in students' personal gain or achievement, but rather in learners' integral flourishing in Christ and in communion. As such, the culture of learning and fraternal community fosters dispositions toward wonder, awe, and curiosity of nature, the elegance of mathematics, or the ingenuity of the built and technological world. These dispositions continually orient learners toward a Catholic vision of reality, whether in the clear examples of exploring the morality of genetic engineering or simply the more abstract process of protein synthesis.

Scripture—and its interpretation—and the social tradition of the Church are two particularly relevant aspects of the Catholic tradition that intersect the STEM classroom. In some instances, the intersections occur through the broad dispositions and culture of a Catholic worldview as described above. Yet Catholic schools are also presented with authentic opportunities wherein students can engage in robust and sustained thinking at the nexus of Catholic faith and STEM content and instruction. We aim to illustrate how education that delves deeply into these authentic

intersections supports learners to transform this cultural heritage in light of the gospel and relate it to their faith in practice (Miller, 2006, p. 49). This contrasts with a certain approach in which every daily lesson and content topic is seen as needing to be aligned to a different Catholic connection. Such an approach, we suspect, can lead to an inauthentic veneer of the Catholic school's synthesis of culture and faith, and may thwart youths' conceptual understanding of disciplinary ideas or curate facile encounters with their faith.

To be clear, we recognize the importance of connecting secular standards more strongly to the Catholic intellectual and social traditions. Rather than shoehorn connections for every school topic, though, the following heuristic of three criteria leads to more engaging and meaningful exploration between STEM subjects and the Catholic faith. The criteria include:

1. *Mutual elevation:* Connections made between faith and the STEM disciplines should mutually elevate both domains in the minds of students. That is, connections to Scripture and the Catholic social tradition should create opportunities for cognitive struggle and growth of the core ideas and the topic should provide an environment for deeper theological insight or spiritual growth.
2. *Ongoing engagement:* Connections made between faith and the STEM disciplines should provide students multiple opportunities for engagement. Giving students multiple opportunities to grapple with and make sense of ideas over time, through engagement with multiple texts, resources, and tasks will better position young people to deeply encounter questions at the intersection of culture and faith throughout their lives.
3. *Positioning as sensemakers*: Students should be positioned to make connections between faith and the STEM disciplines as sensemakers—learners who build an explanation to resolve a lacuna in their understanding or knowledge (Odden & Russ, 2019), with guidance from the teacher. Single mentions of Church teachings or models of faith are still relevant, but teachers would benefit from identifying opportunities in which students make the relevant connections rather than doing it for them. To truly elevate both disciplines, the learner must have the opportunity to grapple with ideas, and, with support from the teacher, consider how their learning can foster what is envisioned for all disciplines in a Catholic school, "a more profound integration of the gospel in their particular situation" (Miller, 2006, p. 50).

Applying the heuristic to current practice: A vignette

The above criteria are conceptually rooted in theories of learning and instructional practice; but do they hold practical relevance for connecting the STEM disciplines and the Catholic faith in classrooms? While it is beyond the scope of this conceptual paper to provide extensive empirical evidence from the field, the following vignette is drawn from the authors' experiences of analyzing

actual diocesan standards and reflective of their experiences observing and working with STEM-focused Catholic schools:

> *St. Zenobius Catholic School's new strategic plan highlights the expansion of learning opportunities in STEM education and aspires for these to reflect the Catholic identity central to the school's mission. Initial implementation saw the increase of dedicated time to previously untouched disciplines like engineering and computer science, as well as a capital campaign to raise funds to build a new STEM lab. In reviewing the important strides made, school leaders recognize the need for more intentionally interweaving the Catholic faith into these initiatives. Drawing from existing resources across local dioceses, the school generated a document aligning each STEM standard with an aspect of the Catholic faith called, "Catholic Connections" to be used by teachers in their lessons.*
>
> *To wit: After teaching a kindergarten lesson introducing forces as "pushes" and "pulls," Mrs. Langley drew on the aligned Catholic Connection and had a conversation with her students on why it was not Christ-like to "push" or "pull" on the playground. In 3rd grade, Mrs. Mitchey engaged students in an engineering design challenge to create Noah's ark out of popsicle sticks and read the story of Noah to emphasize his attention to mathematical precision. In 4th grade, Mrs. Corby researches and tells students about the lives of different Catholic scientists and the patron saints of various STEM fields. And in Mr. Zahm's 7th grade science class, after teaching a series of lessons on how electric and magnetic forces can change how a system functions and moves, he brought up the Catholic Connection from his standards guide by telling students that the concept of non-contact forces produced from fields reflects our lived moral experience in the Catholic faith that "when we are not in direct contact with one another, our actions can still have an impact."*

This compilation of actual experiences witnessed in Catholic schools and existing alignment of standards raises questions about the efficacy of many current, well-intentioned attempts to bring together the STEM disciplines and the Catholic faith. In the vignette, we see a range of experiences, some of which may be valuable, though are unlikely transformative for students; in others, the attempt may actually impede cognitive and spiritual growth.

For the attempts in both kindergarten and 3rd grade, the experiences are not mutually elevating. The proposed Catholic connection tied to a moral injunction against pushing on the playground not only fails to support students' thinking about Newton's Laws, but it also suggests a misconception that all forces and Newton's laws themselves are somehow un-Christian. In the 3rd grade example, the negative impact may be on spiritual growth, as the teacher's emphasis on Noah's mathematical precision overshadows the salvific truths about God's faithfulness and the covenant relationship found in the scriptural passage. In the 7th grade example, students may be intrigued by the analogy of our actions working over a distance, but internalizing this understanding will require multiple opportunities for connection and thought. Finally, the 4th grade presentation

of Catholic scientists and patron saints is a well-advised practice and one that likely is fruitful for seeing connections between faith and science; as presented, though, the teacher has done all of the investigation and students have not had the opportunities to cognitively and spiritually draw close to these examples. Rather than position young people to see "faith and reason [as] two wings on which the human spirit rises to the contemplation of truth" (John Paul II, 1998, prologue), some of these examples risk causing confusion or staying at a surface-level, while the others are additive but could be elevated by different instructional decisions.

Next Generation Science Standards alignment: Authentic opportunities for integral STEM education

Just as our proposed heuristic serves as a tool to examine current practice, so too it can serve to envision future integral STEM learning experiences that are mutually elevating with faith. In what follows, we apply these three criteria to a select set of science standards from the *Next Generation Science Standards* (NGSS Lead States [NGSS], 2013). We chose the NGSS because they have been widely adopted in the United States and, even where not adopted, remain influential across sectors and provide proxies for many existing science standards. As mentioned above, a similar exercise could be conducted with standards of other STEM disciplines. The list below is not exhaustive, but it serves to exemplify how core disciplinary ideas might be connected with dimensions of the Catholic faith in ways that mutually elevate both domains, offer multiple opportunities to encounter this intersection, and position students to be sensemakers of both scientific and theological ideas.

Core Idea 1: Ecological systems, human impacts, and care for our common home

The contribution of Pope Francis's *Laudato si'* (2015) to the canon of social teachings may well have put to bed the colloquialism of Catholic Social Teaching (CST) being the Church's best kept secret. The call for stewardship of creation (U.S. Catholic Bishops, 1998), for many Catholic educators, is a clear and intuitive link between K-12 science education and the Church's social tradition.

The core life science idea of "Ecosystems: interactions, energy, and dynamics" (abbreviated by the NGSS (2013) with the alpha-numeric code LS2, specifying its discipline and core idea) is one of four central life science ideas that spirals upward throughout K-12 science education. Central to understanding the broad concept of ecosystems are the opportunities to explore interdependent relationships between biotic organisms—including social and behavioral interactions—and abiotic factors and to identify how matter and energy cycle through these ecosystems. Ultimately, learners are able to model these dynamic systems that, under particular conditions, support life and biodiversity and under other conditions stress survival. Humans play a significant role in these relationships, and the earth and space science core idea "Earth and human activity" (ESS3; NGSS, 2013) raises questions about how humans have changed the planet, including ecosystems and their

terrain. Over the K-12 learning trajectory, young people come to understand how living systems depend on natural resources and how humans impact, in a disproportionate way, the balance and vitality of these systems in both positive and negative ways.

The Catholic social tradition, drawing upon the collective wisdom of centuries and bolstered by the authoritative writings of ecclesial leaders, provides clear opportunities for students to better understand mechanisms that drive ecosystems and our call to care for the environment. The beloved St. Francis of Assisi provides one model for how young people might engage in learning about ecology and creation in a dispositional manner. Moving beyond the occasional mention of St. Francis as the patron saint of the environment and animals, educators can uphold his affinity for nature, his penchant to burst into songs of praise at the living world, and his "openness to awe and wonder" that can draw us away from attitudes of being "consumers [and] ruthless exploiters" (Francis, 2015, section 11). Learning about the world through this lens is seen not only as an academic task, but a "joyful mystery to be contemplated with gladness and praise" (section 12).

Faith perspectives elevate scientific understanding about ecology not only dispositionally but also conceptually. In *Laudato si'*, Pope Francis (2015) makes integral connections between faith and ecology with specific references to pollution and climate change, the issue of water scarcity, and the loss of biodiversity. Each of these topics has potential as not only lesson plans within a broader unit, but as anchoring phenomena that frame the unit to provide multiple opportunities for students to model interactions between the living and physical world (e.g., climate change, its mechanisms, and its impact on organisms), cyclic processes (e.g., natural resources and their renewable and non-renewable use), or the transfer of matter and energy that support homeostasis (e.g., trophic cascades and the link between biodiversity and ecosystem vitality).

Indeed, for this set of core ideas, the Catholic tradition pushes science learning beyond the mere acquisition of conceptual knowledge to empower change and ecological conservation. "Our goal is not to amass information or to satisfy curiosity," Pope Francis (2015) beckons, "but rather to become painfully aware; to dare to turn what is happening to the world into our own personal suffering and thus discover what each of us can do about it" (section 19). For elementary students this may include the collection, analysis, and charting of data for the amount of garbage created in the lunchroom 'ecosystem' of their school and drawing on engineering practices to design a solution to reduce waste and increase recycled and reused materials over the course of the school year. Middle and high school students may apply their knowledge to rehabilitating local watersheds or rehabilitating nearby land that was impacted by human intervention by transforming it into a community garden or a system of wildflowers and wild grasses that can help reconstitute an ecological niche for various flora and fauna. These examples require multiple opportunities for students to pose questions, make sense of concepts and data, and to put faith into action as advocates for ecological justice.

Core Idea 2: Cosmology, earth history, and the Big Bang theory

Somewhere in the U.S. cultural psyche is a latent belief that modern cosmology—and, specifically, the Big Bang theory—is antithetical to Christian religious belief. For many, it is a confounding surprise to learn that the earliest advocate of the theory was the Belgian physicist and Catholic priest, Fr. Georges Lemaître.

In middle school science, students learn that the solar system is part of a vast and expanding universe (ESS1.A; NGSS, 2013) and that the Earth's fossil record documents the existence and extinction of many life forms throughout Earth's long history (ESS1.C; NGSS, 2013). Despite drawing from distinct sub-disciplines—cosmology for the former, geology for the latter—these two core ideas push forward an understanding of the long history of the Earth within the expansive and 13.7-billion-year-old universe. By the end of middle school, learners examine the stars of our universe, how our own solar system fits within the Milky Way galaxy, and how the vast universe of many galaxies began with a period of extreme and rapid expansion known as the Big Bang. They also explore the geological time scale of rock strata and the fossil record to provide evidence for deciphering the history of the Earth's landforms.

How does this scientific account relate to biblical accounts of God's creation? Within the Catholic intellectual tradition, Sacred Scripture is properly interpreted by attending to the sacred authors' intention, as communicated through its literary genre and conditioned by their time and culture (CCC, 1997, para. 110). The ongoing task of biblical exegesis, then, must be attentive to the coherence of the whole of Scripture, of the living Tradition, and the entirety of the truths of faith (CCC, 1997, para. 111-114). Therefore, within the Catholic tradition, the first three chapters of Genesis that detail the two accounts of God's creation are not understood to represent a literal timescale of six days (or even six epochs), as Pope Leo XIII detailed in *Providentissimus Deus*:

> The sacred writers . . . did not intend to teach mankind these things, that is to say, the essential nature of the things of the visible universe . . . . Hence they did not seek to penetrate the secrets of nature, but rather described and dealt with things in more or less figurative language or in terms that were commonly used at the time (1893).

While diocesan standards and curriculum vary, these principles of biblical interpretation frequently appear in standards for religious education in middle grades (for one example, see Office of Catechesis, 2010), and religious education curriculum developers usually include the first chapters of the book of Genesis in their middle school materials.

Starting in middle school, students are developmentally ready to engage—and likely concurrently learning about—the 'big questions' at the intersection of science and theology related to the beginning of the universe and God's creation. Teachers can pose the big question

and facilitate students in asking questions and thinking about these ideas. For example, a science teacher might frame the big question: "In 1931, a scientist defended a theory that the universe began billions of years ago in a 'Big Bang.' He was a Catholic priest. Did his theory disprove God's creation? Did it prove it?" With this question, students are positioned as seekers. Drawing on their ongoing learning about the universe, its stars, and the history of the universe, students come to understand the scientific concepts related to Lemaître theory. With facilitation, students can examine the first chapter of Genesis, with their focus drawn to the broad principles of Catholic biblical interpretation. By the end of a unit, students can debate Lemaître's response to critics, both believers and non-believers:

> As far as I can see, such a theory remains entirely outside any metaphysical or religious question. It leaves the materialist free to deny any transcendental Being . . . . For the believer, it removes any attempt at familiarity with God . . . it is consonant with Isaiah speaking of the "hidden God," hidden even in the beginning of the universe. (as cited in Laracy, 2009, from Godart and Heller, p. 171)

Core Idea 3: Evolutionary theory, creation, and human genesis

The theory of evolution, and its teaching in schools, has stirred a tremendous amount of public controversy in the United States. Nearly a century has passed since the court case *The State of Tennessee v. John Thomas Scopes*—often referred to as the Scopes Monkey Trial— created a media spectacle and raised legal and public debates about banning the teaching of evolution. Debate and dissent continue. As recently as 2005 the trial over the teaching of intelligent design (*Kitzmiller v. Dover Area School District*) ripped the small community of Dover, Pennsylvania in two, and more recently in Texas a proposed, but failed, piece of legislation required teaching "both sides" or "the strengths and weaknesses" of evolution (Hall & Woika, 2018). Today, these arguments take place in a context where over 40% of Americans believe that humans were created in their current form (Newport, 2014) and where rejections of evolution can reach up to 50% (Rice et al., 2011). In almost all cases, scientific evidence is deemed inimical to religious belief. Yet it is exactly the religious foundation of Catholic schools that creates a learning environment well-positioned to advance scientific understanding and present young people rich opportunities to grapple with their understanding of creation, Scripture, and human genesis. Young people bring to science classrooms their full selves—their cognition is shaped by their culture, history, and religion (Shane et al., 2016)—and Catholic schools provide an atmosphere in which it is permissible to engage both scientific and religious epistemologies.

From a scientific perspective, the NGSS establishes the foundations for components of evolutionary theory in early grades, as learners focus on the variety and diversity of traits and

behaviors in the living world and that some traits and behaviors are well-attuned to their environmental conditions (LS3, LS4; NGSS, 2013). As students progress to middle and high school, they more directly engage the fundamental principles of evolutionary theory, foremost, that all living organisms are at once connected across generations through common ancestry, but also magnificently diverse—from sessile sponges to the curious platypus—due extensively to mechanisms of natural selection and adaptation. Controversy turns not so much from the teaching of biodiversity or even the process of natural selection, but rather from issues related to human origins, biblical interpretation, and teleological arguments from design (McGrath, 2010).

Rather than use pseudoscientific approaches (e.g. creation-science) or ignore evidence that exists within the natural world (e.g., the fossil record, carbon dating, and genetic tracing), Catholic schools can embrace the teaching of evolution in ways that not only are supported within the Catholic tradition but also which provide opportunities for young people to raise and answer questions alongside witnesses to the faith: their teachers. Established in Pius XII's encyclical *Humani generis* (1950)—and reiterated by his successors (Ratzinger, 1995; John Paul II, 1996; Francis, 2014)—the scientific evidence for evolutionary theory does not conflict with theistic belief or undermine God as Creator. Teachers can use these religious sources along with educative scientific resources about human genesis (e.g., the Smithsonian's *Human Origins Initiative)* to provide young people a unique look into the Catholic intellectual tradition while also removing barriers to exploring evolution of human species, so long as they do not misappropriate the scientific theory to philosophical or theological questions (e.g., the soul). Indeed, while Church writings provide support for engaging evolution as an appropriate scientific explanation of living organisms over time, teachers must be cautious to not convey a reductionist, scientific materialism (or evolutionism) that overextends the authority of science (Baglow, 2012; Salkeld, 2023).

This interrogation presents an opportunity for cross-disciplinary collaboration that pairs biological with theological expertise in order to present students with a coherent and coordinated way of understanding both faith and science. When coordinated in this way, learners can deeply probe the distinction between primary and secondary causality (CCC, 1997, para. 306-308) and its application to evolutionary theory and can explore the longstanding Catholic tradition of interpreting the creation narratives allegorically (e.g. McMullin, 1985). Students, guided by their teachers, can also grapple with how chance within natural explanations of evolution is consistent with Divine Providence and an active role of God in the cosmos (Baglow, 2012). These tools offer a richer, more complex understanding of the intersecting relationships between the natural sciences and the Catholic faith than a simplistic separation into "two non-overlapping magisteria" (Gould, 1997, p. 19). Enabling learners to look at evidence and think deeply about evolution positions them to make sense not only of scientific phenomena, but to spend time answering questions that surely arise and, if unexplored, might precipitate religious disaffiliation: How do I reconcile the Bible's accounts of creation with

evidence of the natural world? If evolution describes the origins of the human person, what does it mean to be created in the image of God? What is God's call for me?

Core Idea 4: Genetics and bioethics

The quintessential story of the humble friar, Fr. Gregor Mendel, and his pea plant experiments grace the pages of just about every biology textbook. Yes, Mendel reflects a model of Catholic intellectual curiosity and experimentation; but the study of genetics presents far greater opportunities at its intersection with Catholic thought than simply its attribution to a Catholic scientist.

Genetics—the basic science of inheritance—provides a unique opportunity for students to interrogate Catholic moral thought alongside their understanding of the complexities and wonder of genetics. While school-based science generally deals with core ideas and bodies of knowledge that are relatively settled, we still see cutting-edge advances made across the STEM disciplines, and advanced technologies have illuminated vast new understandings of genetics that extend far beyond Mendel's pea plants. These new technologies and their ability to manipulate genetic inheritance raise significant, contemporary ethical questions that can be analyzed through a Catholic lens.

"Heredity: inheritance, and the variation of traits" is the third of four core ideas in the life science strand (LS3) of the NGSS (2013) framework. In general, students learn how genes encode information that produce proteins—the central dogma of biology—that are then responsible for how traits are exhibited and function in a living thing. These genes come in different versions, or alleles, and various mechanisms produce diversity in the protein expression among individuals and generations. Throughout their K-12 education, learners are focused on identifying variation among and between members of a species and identifying the mechanisms by which this variety arises.

The standards offer little direct clarity as to how science and ethics intersect, but two separate and important lines of crossover may benefit students. First, a historical review including the tragedies of World War II eugenics can educate a generation about atrocities that should never be repeated and raises important questions about the use of scientific information in modern analogues (e.g., disability selective abortion). Second, over the past century, scientists have discovered new ways of manipulating genetic processes and genetic-environmental interactions. Indeed, human manipulation of genes is centuries old, with evidence of humans breeding particular plants that gave rise to today's corn. Contemporary efforts have resulted in manipulation of specific genetic sequences, gene therapy for debilitating diseases, and full organismal cloning. In order to debate the social and ethical ramifications of genetic manipulation, students benefit from informed understandings of the associated biological mechanisms. Understanding concepts like gene regulation, amplification, and manipulation provide opportunities for young people to apply a Catholic moral lens to socio-scientific scenarios.

Catholic schools can prove to be a fertile ground for these debates and conversations, yet many teachers are unaware of these ethical dilemmas or how to teach them (Lazarowitz & Bloch, 2005). Using principles from the Catholic moral tradition and CST, students in Catholic schools are primed to encounter these meaningful questions of the modern world. As a body of literature on socio-scientific integration has shown, the benefits of such exposure may extend to the quality of students' classroom interactions, their argumentation skills, and their motivation.

Core Idea 5: Natural hazards and the problem of evil

"Where was God in the tsunami?" (Hart, 2005). This question was posed by Hart in the subtitle of his book reflecting on the devastating 9.1 magnitude earthquake that shook the floor of the Indian Ocean on December 26, 2004, unleashing a wall of water that devastated the shorelines of Indonesia, Thailand, Myanmar, Sri Lanka, and India. Tens of thousands died instantly as the doors of the sea opened and enveloped them. The same question gets asked after every natural disaster: Why do bad things happen if God loves us? Young and old, we ponder the problem of pain—if God is both good and almighty, then why is there human suffering? (Lewis, 1996). In truth, there will always be a proximate need to comfort and console young people as they grapple with pain, suffering, and death in their own lived experience. Yet the science topics of severe weather and natural hazards as the result of natural processes (ESS3.B; NGSS, 2013) also present a somber period for reflection and for addressing this big question in a meaningful way for young learners.

The core science ideas related to natural hazards spiral throughout the NGSS appearing in kindergarten, elementary grades, and middle school. Central to their developing understanding is that severe weather and a variety of other hazards are the result of natural processes. These are catastrophic events—tsunamis, earthquakes, volcanic eruptions, tornados, hurricanes, floods, fires—for which the resulting evil may not be derived from the moral decision of another human being. This class of 'natural evils' confounds tidy rationalization, as Christians likewise affirm that God is all-loving (1 John 4:7-9; CCC, 1997, para. 218-221) and creation is good (Genesis 1:31; CCC, 1997, para. 299).

The problem of evil is not solely an intellectual problem in need of a rebuttal. The question posed is an experienced one that asks the haunting question: Where is God amid our world's suffering? In the days following the tsunami, theologian David Bentley Hart (2004) penned a harsh rebuke of easy-form answers:

> When confronted by the sheer savage immensity of worldly suffering—when we see the entire littoral rim of the Indian Ocean strewn with tens of thousands of corpses, a third of them children's—no Christian is licensed to utter odious banalities about God's inscrutable counsels or blasphemous suggestions that all this mysteriously serves God's good ends (paragraph 8).

The Catechism offers its own important note of caution: "To this question, as pressing as it is unavoidable and as painful as it is mysterious, no quick answer will suffice" (CCC, 1997, para. 309). Catholic educators, as witnesses to hope, do not need to cheapen the mystery or its response with empty platitudes. They can embody, instead, the model of Jesus Christ (Philippians 2:5-8). In the process of accompanying young people on their journeys of faith, Catholic educators can incorporate several aspects of theological merit, yet in full awareness that no single one of these is ultimately sufficient. At times, it may mean specifying how the presence of evil does not mean that God inflicts suffering, though God may permit it. At others, it may mean cultivating an awareness of the goodness of creation alongside the reality of moral and natural evils as the consequence of a fractured cosmos. It may mean taking up the call of missionary discipleship that empowers young people to help and heal others. And surely there is, ultimately, our Christian hope—as-yet unforeseen and unimagined—how God will weave goodness from the present shadow of evil.

There is no tidy solution to offer students for the problem of evil. Yet, to ignore or gloss over it is to spurn the model of Christ. Catholic schools are a place within which the question can be raised, heard, and examined, and within which faith can seek greater understanding. In fact, it is this lived journey that ultimately serves as the fullness of a response: "only Christian faith as a whole constitutes an answer to this question of evil" (CCC, 1997, p. 309).

Core Idea 6: The solar system and the Galileo affair

Galileo Galilei's trial, conviction, and censorship by the Catholic Church in the seventeenth century stands as the most widely recognized historical episode of how scientific inquiry and the Catholic faith have intertwined. The event is the standard-bearing example of the proposed "conflict thesis" of a longstanding and inevitable conflict between science—the vanguard of reason—and religion—sullied with calcified dogmas and lust for control (Numbers, 2009). The popular portrayals of the incident over the centuries, from Voltaire to Richard Dawkins, caricature the historical reality and perpetuate an assumed, *de facto* animosity between the reason of science and the authority of religion. Seen from this point of view, Pope John Paul II's (1992) attempt to rectify the wrong unfortunately is often cast aside as an apology a little too late. To bypass discussion of the Galileo affair, however, is to forsake a meaningful opportunity to understand the complex social implications of both science and faith convictions.

The historical episode itself concerns Galileo's evidence for and defense of the heliocentric theory of the solar system, first proposed by Nicholas Copernicus in 1543; the Catholic Church's censorship of Galileo in 1616; and, ultimately, the guilty verdict and house arrest of Galileo on suspicion of heresy in 1633. Strong historical analyses develop a compelling account of the complex and interweaving socio-political, empirical, and theological factors that illuminate the many facets of the scientific and the religious issues at play (Blackwell, 1991; Brooke, 1991; McMullin, 1999).

John Hedley Brooke, writing specifically about teaching the Galileo affair (1990), argues that the story results in a caricature when it is abstracted from its historical context. With this in mind, we suggest two distinct strands of the episode for educators to focus on that can mutually elevate scientific and theological thinking. These strands are:

(1) How historical, social, and political factors impact scientific and theological endeavors.
(2) How epistemological considerations shape theological beliefs and scientific inquiry.

The first strand is appropriate for the middle school level. On the one hand, it invites students to consider the nature of science as a human endeavor (NGSS, 2013, Appendix H), how science is practiced by men and women who are embedded in social, cultural, and political settings, and how science ideas can be viewed as beneficial or harmful to society based on these factors. On the other hand, it allows students to enter into the history of Western Christianity to understand religion not only as an artifact of settled propositions but as a lived faith that has sought understanding in every generation.

Science standards related to "the Earth and the solar system" are the relevant core science ideas from the NGSS (ESS1.B; 2013). From their upper elementary experiences, students have used and represented data to examine observable patterns (e.g. related to length and direction of shadows, day and night, and seasonal appearances of stars) that can be explained using the heliocentric model of the solar system. In middle school, students focus on developing and using such a model to describe, predict, and explain evidence related to lunar phases, solar and lunar eclipses, the motions of the planets, and the seasons. The historical case of the Galileo affair, which ushered in the Copernican Revolution, offers a clear and compelling opportunity for students to evaluate the merits of the heliocentric model of the solar system versus geocentric models. It also is a fitting explicit curricular opportunity to engage students in discussions about the nature of science (Khishfe & Abd-El-Khalick, 2002) related to the social and cultural influences on science (e.g. Lederman et al., 2002). Indeed, it headlines the list of history of science case study examples in Appendix H of the NGSS (2013) and appears frequently elsewhere (e.g. McComas, 2008). Focusing on this first strand elevates students' learning related to the nature of science, as they can explore how societal factors are inextricably tied, in both positive and negative ways, to the pursuit of scientific understanding.

The Galileo affair also casts students headlong into a fascinating moment in Church history, which usually appears in religious education standards for middle grade. Students can unpack why Galileo had been well-supported by patrons within the Catholic Church early in his career, why his sound theological reasoning for interpreting Scripture was met with skepticism within the context of the Protestant Reformation, and why, 350 years later, a Vatican commission appointed by Pope John Paul II could conclude that the church officials had erred in their judgment (Coyne, 2005).

The second strand mentioned above is most appropriate for high school students. A rich engagement with the historical case of the Galileo affair offers an opportunity to enter into a discourse about rival scientific theories and the role of evidence, while also requiring a nuanced theological approach to Scriptural interpretation within the Catholic tradition going back to St. Augustine (McMullin, 1999). Through careful analysis, students can use the modern lens of gradations of certainty that might be afforded to varying scientific claims (yet unafforded to Galileo and his contemporaries) to better understand the complexity of the issue in the 17th century and yet also see a path through in the 21st century (Blackwell, 1991, p. 85; McMullin, 1999, pp. 186-7).

Conclusion

This paper draws on previous research and literature in cognition, instruction, theology, and Catholic education to propose conceptual and practical criteria for addressing the intersection of faith and STEM education in Catholic schools. Catholic school leaders and teachers require more nuanced understandings of how all dimensions of the Catholic school can help elevate young people's exploration and reasoning of the natural world. Indeed, through the culture of the learning environment and the interactions of all members of the school community that elevate the dignity of each student and promote the common good of the entire classroom, young people can live into this vision. Yet the rapid rise of disaffiliation, often due to misgivings about an inevitable conflict between faith and science, requires educators to recognize and have tools for addressing specific issues at their interface.

Rather than support many artificial connections that could be made between the Catholic faith and science standards—connections that often fail to address the cognitive and spiritual depth of the issues—we identify three criteria for how teachers, leaders, and (arch)dioceses can make decisions for how they make explicit connections between secular science standards (e.g. NGSS) and the Catholic faith. By providing six clear examples, we hope to push teachers to see how learners can move beyond exposure in order to explore deeply the big questions of their time. Importantly, we recognize that aligning standards is only one avenue for connecting the Catholic faith with the STEM disciplines. Multiple inroads exist, like adapting engineering design challenges that allow learners to apply principles of Catholic social teaching or engaging with Catholic STEM professionals for on-going mentoring experiences. As tools, curricula, and training continue to unfold, future work will need to answer: What ideas do young people have about these areas of intersection, and how does their thinking change over time?; What aspects of curriculum and instruction are most supportive in shaping students' cognitive and spiritual identities?; and, What other STEM concepts, including those not yet in state standards (e.g. AI), offer opportunities for deep, meaningful, and ongoing exploration imbued with a Catholic worldview? Investigating these questions may prompt us to revisit, in time, the complexities of religious disaffiliation and recognize how Catholic schools can support young people on their journey to a fullness of life in Christ.

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