MAKING SENSE OF SCIENCE AND RELIGION

Strategies for the Classroom and Beyond

Joseph W. Shane • Lee Meadows • Ronald S. Hermann • Ian C. Binns

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National Science Teaching Association

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Beyond the Classroom

Preface

Dr. Shane, you are not taking this seriously … and you need to.

—Preservice biology teacher, Shippensburg University, 2005

This class helped me to be less of a [jerk].

—Science-religion honors seminar student, Shippensburg University, 2015

For more than 10 years, understanding and addressing the complex interactions between science and religion has become part of my mission as a scientist, science teacher, and science teacher educator. I never intended to walk this path. Now, though, I embrace the role and I am grateful to a former student for, rather bluntly, initiating the interest that led me to this current effort to assist all teachers of science.

My first year at Shippensburg University in central Pennsylvania coincided with the 2005 *Kitzmiller v. Dover Area School District* trial (400 F. Supp. 2d 707, M.D. Pa.; see National Center for Science Education 2005), which is often referred to as Scopes II in reference to the well-known Scopes Monkey Trial from 1925 in Dayton, Tennessee. During the fall semester, a student in my science teaching methods class regularly came to my office hours to discuss the trial (the "this" in the first quote above). He was, to put it mildly, unimpressed with my knowledge of the proceedings, the legacy of the Scopes trial, other related Supreme Court cases, and evolutionary theory in general. He challenged me to take a more active role, and thus began my journey.

I first read Judge John E. Jones III's *Kitzmiller* ruling (National Center for Science Education 2005) where he determined the teaching of intelligent design to be inherently religious and thus in violation of the Constitution's Establishment Clause. After acquainting myself with the judicial history, I discovered vast areas of historical, philosophical, and theological scholarship devoted to nuanced understandings of science and religion that included, but also went beyond, specific scientific theories and concepts such as evolution, geochronology, climate, and genetics.

Since 2005, I have been fortunate to use these insights to better prepare my preservice science teachers. In 2007, the pastor at my church asked me to teach a three-week adult Sunday school class on science and religion, and I have been teaching similar courses ever since at regional Christian churches. I host an annual forum on science and religion at

Shippensburg, and the director of our honors program invited me to teach a seminar in 2015. The 12 students were, as far as I could tell, divided into three groups from a religious perspective. Four were active members of various Christian denominations, four had been active Christians earlier in their lives, and the remaining students were devoted atheists. An interesting group to be sure!

During one of the final class periods, a colleague with expertise on the sociology of science and religion (and author of the concluding chapter of this book) spoke to the class about his work, and he asked the students about their experiences in the course. One student quickly proclaimed, "This class helped me to be less of a [jerk]." She used a more college-appropriate and slightly cruder word, and I wish she had written this on the course evaluation.

My efforts eventually led me to engage my primary professional group, the Association for Science Teacher Education, a National Science Teaching Association affiliate. I befriended several colleagues who were addressing similar issues in their regions and science teacher preparation programs. After some conference presentations and a journal article, we decided that a broader effort was needed. And that's how this book was born. Those colleague friends are Lee, Ron, and Ian, the three other editors of this book.

With this book, we wish to assist you, our colleagues at all levels of science education, with understanding science-religion interactions in a broad sense to complement your personal experiences with your students and surrounding communities. We have written this book specifically for an audience of our fellow science educators, but it will also be of interest to any advocates for good science and quality science education, including parents, administrators, elected officials, and other policy makers. As you will notice from the modest chapter lengths and overall book size, it should be read as a primer that encourages additional reading and discussion. We asked each contributor to write in a conversational tone that is engaging to read while providing excellent resources for continued study and consideration.

We understand that science teachers have long seen the teaching of evolution in particular as a tough issue and an almost intractable one in many regions of the United States. To respond to this, we urge you to step beyond evolution into bigger issues at the interface of science and religion. We want to guide you in exploring those broader issues to provide a framework to make better sense of how to teach evolution and other science concepts. To genuinely understand science-religion relationships requires some understanding of history, sociology, religious experience and theology, and the Constitution and case law, as well as principles of good communication of complex ideas. You may even need to brush up on your own scientific knowledge. The other editors and I are not experts in all of these areas, so we have tapped the wisdom of a great group of additional authors to lend their perspectives.

Science has progressed to the point where it is rapidly changing our notions of matter, space, and time as well as addressing questions once thought to be outside of empirical investigation. Thus, it is no wonder we are challenged to reconcile scientific discoveries with our personal, often religious, beliefs. Sociobiology and neurology, for example, shed light on the fundamental aspects of human thought and behavior that can profoundly affect one's sense of identity and purpose. Physics, cosmology, and geology now contribute to our understanding of the origins of life. In this sense, science has grown far beyond isolated subdisciplines for the select few. Science is ingrained in our everyday culture, and it lends insight into and asks questions about topics of personal and universal significance, in a manner similar to literature, music, and other artistic expressions.

The chapter authors have demonstrated their ability to help navigate these waters. We invite you to do the same. We suggest that all teachers of science have some responsibility for understanding interactions between science and religion, two indisputably profound and durable cultural forces so often characterized as inherently in conflict with, or simply mutually exclusive of, one another. These all-too-familiar conflicting perspectives or simplistic dichotomies are inadequate in our view.

In Part I of the book, we introduce you to science-religion scholarship. We emphasize the historical roots and persistence of opposition to evolution given that it is the most prevalent science-religion theme in the United States. In addition to summarizing the relevant judicial and political history, we describe a precise framework for addressing science-religion issues in a legal, constitutional manner.

Part II is written for teachers of science at various levels: elementary/early childhood educators, middle school and high school science teachers, college professors and teacher educators, and colleagues who work in informal science education settings. We hope that you find this information useful not only for your work, but also for your collaborations with other science educators in your building, district, and beyond.

Part III recognizes that science-religion interactions often extend beyond our specific classrooms and other learning environments, and we offer advice for engaging other constituencies such as parents and families, administrators and school boards, legislators and policy makers, and faith communities. We include expert advice about how to best respond when issues of science and religion arise, and we look to the future regarding how controversies around teaching evolution might shift in the years ahead.

We have invited authors who are in many ways personally and professionally invested in these ideas. Some contributors are K–12 teachers and university professors. Some are science teacher educators like us. Others are from prominent organizations such as the American Association for the Advancement of Science and the Smithsonian National Museum of Natural History. We have encouraged them all to share memorable and illustrative stories along with their expertise, selected references that are most appropriate for all teachers of science, and take-home advice and recommendations for action. We are hopeful that you will find the concise yet comprehensive nature of this book useful to your everyday work and to your greater understanding of science and religion.

Dr. Joseph W. Shane
Shippensburg University of Pennsylvania

REFERENCE

National Center for Science Education. 2005. *Kitzmiller v. Dover*: Intelligent design on trial. *https://ncse.com/library-resource/kitzmiller-v-dover-intelligent-design-trial.*

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Science and Religion in Middle School and High School Classrooms

Lee Meadows, Lindsey Porter, Nathan Einsig, and Josh Hubbard

This chapter brings us to the heart of the conflict around teaching evolution—the classrooms of middle and high school teachers across America. These are the classrooms where science teachers have to bring all of the issues, in evolution and beyond, home to their actual teaching practices as they engage students in learning about and making sense of evolution and other topics with potentially religious implications.

Many American science teachers know the issues faced by students who are resistant to learning about evolution. We have seen them struggle. We have had a student raise her hand and say, "You mean God didn't create the world?" We have seen a little bit of fear in her eyes. We have watched a bright student take his first zero ever because he would not even attempt the evolution test. We may have been impressed with his zeal but saddened by the impact on his academic record. We have tried patiently to answer the same objections period after period from the students who had been given a list of "Questions to Ask Your Teacher About Evolution." We could tell that those students were wholeheartedly devoted to a life-or-death battle as they had been taught. We know now that, for many of our students, studying evolution goes beyond science and touches on issues much bigger than just fossils and change over time.

Some of us may also dread the evolution unit about as much as our students do. Those of us who teach middle school know how important it is to nurture our students through the life changes they are facing and how confusing their lives can be at times. Those of us who teach high school know how important it is to guide our students to solidify their understandings of science in the last biology course they will probably take. For middle and high school students, the topic of evolution can actually increase the confusion and conflict in their lives, and sometimes we may be tempted to wonder if teaching the topic is necessary or even appropriate.

The problems we face may not necessarily be due to evolution itself, however. They may be due to big-picture issues pressing on teachers and students from outside the classroom, as this book has been laying out. They can also be due to internal issues inside the classroom, especially with the approach that some science teachers take. This chapter brings together some of those external and internal issues into an overview of a different teaching approach, one that offers a method for engaging students without threatening their personal beliefs. We begin by introducing ourselves as authors, so you can know a little about the journeys that brought us to teaching evolution and the kinds of classrooms we teach in. We then provide eight practical strategies we have found to be effective for both teaching science with integrity and respecting the worldviews of each of our students.

OUR JOURNEYS TO A COMMON TEACHING APPROACH

As authors of this chapter, we came to a common teaching approach through different journeys. Lee grew up in fundamentalist Christianity in north Mississippi. He was the kid who asked about faith issues in biology class and about science issues in church youth group. He was also the kid who learned those questions were not welcome in either place! When Lee began to realize as an adult that he did not need to come to a nice, clean resolution of his faith and science, he began to get traction on the personal conflict he had felt about evolution. This traction propelled him to two decades of work with science teachers in the American South to help them understand that they can teach evolution well without throwing religious students into turmoil. Lee works as a science teacher educator at an Alabama university, he writes and speaks on the teaching of evolution, and his book *The Missing Link: An Inquiry Approach for Teaching All Students About Evolution* (Meadows 2009) lays out a pathway for teaching evolution in public school settings where students may have strong, personal objections.

Nathan remembers as a 13-year-old middle school kid waiting in line in at a restaurant after church witnessing an exchange between his dad and a member of their congregation. Nathan's father taught biology and environmental science for a rural/suburban school district in Pennsylvania. In making conversation while waiting for a table, the church member inquired about how Nathan's dad circumvented the teaching of evolution in the public school setting. His stark and matter-of-fact response ended the conversation as fast as it began: "I don't. I teach it because it is part of biology." Nathan remembers noticing the abrupt, bristling response from the church member and wondering what the big deal was. The topic of Earth history and evolution was one that Nathan eagerly studied as a child with the aid of his father. From a very young age Nathan was regularly going on fossil-hunting trips and scouring educational books and magazines for information on early humans, extinct species, and long-ago ages of Earth. This was all done with encouragement and loving support from his family. Never once did this information bump up against his church's teachings. For most of his childhood, Nathan saw the topics of Earth's natural history and religion as running parallel, never intersecting until that afternoon while waiting for a table to open at the local diner. From then on, he started to notice and engage in conversations about the confluence of science and religion. What he did not realize at the time was that his dad defused a potentially tense conversation by being up front about the nature of science, an approach Nathan has used through his teaching career in the geosciences and as a high school department chairperson in Mechanicsburg, Pennsylvania, where he and Lindsey work together.

Like several other authors, Lindsey grew up within a fundamentalist tradition and, although she excelled in school, stubbornly clung to a belief that scientists were, at best, wrong and, at worst, in cahoots with the devil to deceive students about the origins of the world and life in it. In choosing a Christian liberal arts college to pursue a biology degree, however, Lindsey was finally exposed to an environment that fostered an exploration of science and religion without setting them up as opposed to each other. She attended church with deacons who doubled as her professors of evolutionary biology, and for her capstone course, she analyzed the history of conflict, as well as nonconflict, between science and religion. As a young teacher, Lindsey was worried about encountering students who would voice their disagreement and protest her lessons as she had done. However, such public defiance never occurred. Instead, Lindsey would only discover her students' discomfort with issues of science and religion when they let slip their beliefs in quiet protest by writing religious explanations for natural phenomena intended to be explained scientifically. Lindsey was often surprised by these instances, but each has helped inform her ever-evolving approach to teaching controversial topics in science class.

Josh's teaching journey is different from the other authors because he teaches in a conservative Christian school in Michigan. His key shift has been his move to an inquiry-centered teaching environment. Josh started as a very traditional teacher, designing his teaching so that he would lecture to his students on what scientific research says about evolution in order to build a strong case. He began to realize, however, that he was designing instruction for himself, not for his students. Josh admits that at the beginning he was not very good at teaching by inquiry, struggling to create solid inquiry experiences for his students. Lee's book was really helpful to Josh, giving him a framework to apply it to his situation and challenging him to turn over the classroom to his students. He and his students began to research questions together, discuss the evidence they discovered, and make claims based on their supporting evidence. Furthermore, Josh's context of an entire population of students resistant to learning about evolution offers wisdom to public school teachers in similar situations. When he teaches evolution, Josh faces the challenge of how to direct a classroom full of students, who are almost all diametrically opposed to the concept, to begin to consider the evidence for it. He consistently works to respect the genuine issues his students have with evolution while still guiding them to ask questions, investigate, argue from evidence, and reflect on their understanding—a process he has found requires a deep commitment to designing backwards (McTighe and Wiggins 2013) from the goal that his students understand, not believe in, evolution.

Lee and Josh met over a decade ago at a National Science Teaching Association conference and have been in conversation about teaching evolution ever since.

OUR APPROACH: UNDERSTANDING EVOLUTION WITHOUT HAVING TO BELIEVE IT

Consider a teaching approach that guides students to understand evolution but not necessarily to believe it. This is the overall approach we want you to consider because it is at the heart of engaging students who resist learning about evolution without threatening their worldview. This approach might be a new idea because you have thought that resolving students' conflicts was the only option.

You probably know the resolution approach, even if you have never heard that term. It demands that beliefs about supernatural and scientific understandings have to be resolved. If scientific evidence conflicts with what religion teaches, then one of them is wrong, and teachers have to show students which one is in error. Unless you jumped straight into this chapter when you picked up this book, you know now that focusing on resolution is not a good idea. In our approach, teachers open up the classroom by allowing students to examine the scientific evidence for evolution, and how scientists explain that evidence, through intentionally designing learning activities to diffuse the pressure that students feel to resolve the conflict. Some highly resistant students might not accept any of the evidence or explanations they encounter, and some may accept portions only. The evolution unit can still be successful, though, because its instructional goal should be for all students to understand, not believe in, evolution.

In this approach, students consistently hear their teachers say, "I expect you to understand evolution, but I do not expect you necessarily to believe it." Teachers affirm the value and beauty of students' personal beliefs while also guiding them to examine the evidence for evolution and its place as a powerful scientific explanation. Teachers support students in the hard intellectual work of encountering the support for and implications of evolutionary theory, but the teachers also recognize that for many students, this can be threatening. At the bottom line, teachers do not seek to overturn students' religious beliefs.

This approach requires us to honor our students' beliefs. Religion is not something to be stamped out of the science classroom, but that agenda is what the resolution approach often communicates. If children hear us say, "We're not going to talk about faith; we're going to stick to the science," they may hear us saying, "Your faith is not important." That may be the furthest thing from our minds, but because secondary school students are sensitive to rejection, they typically sense their faith being denigrated if we refuse to acknowledge how their understandings about evolution and their religious beliefs can be intertwined.

TEACHING STRATEGIES FOR UNDERSTANDING, NOT BELIEVING

Our overall approach of teaching evolution for understanding, not believing, gives the big picture of what teaching evolution to resistant students looks like. Next, we provide you with several practical strategies that we have worked out in our own teaching. Nathan and Lindsey developed many of these strategies to lower the threat level in their biology and Earth science classrooms and to foster a tentative willingness on the part of such students to question and learn. Josh developed other strategies as he was implementing the general ideas from Lee's book. Taken as a whole, these strategies seek to avoid triggering students' fears of being asked to choose between their faith and learning science, while planting the seeds of scientific thinking in hopes that acceptance of science will bloom alongside students' intellectual maturity, bearing fruit in their adult lives that they may not be ready for in high school. At the end of this chapter, we include a list of resources you can tap to help implement these strategies in your classroom.

Strategy 1: Emphasize Stories From the History of Science

As the amount of scientific knowledge has expanded over the years, the challenge to cover all the science standards has intensified and lessons surrounding the history of science have tended to diminish. Lindsey and Nathan find great value, however, in sharing the stories of scientific discoveries (see Chapter 2 for additional information), particularly those fostering empathy for people whose discoveries seemed to contradict their prior notions of the world. These stories humanize the process of science and model for students the ways scientists operate without yet having it all figured out. These anecdotes do not have to take too much time away from other content. They can serve as bell-ringer reading assignments, short discussion points during direct instruction, student jigsaw activities, or even as background material for assessment prompts.

A classic example from biology is Charles Darwin's hesitance to publish his work on natural selection, which can be structured into a classroom discussion of his motives for both the delay and his ultimate decision to publish. In Earth science, it is helpful to teach students about the steady-state notion of the universe and the famous thinkers who subscribed to it, including Robert Wilson, discoverer of cosmic background radiation, and Albert Einstein with his cosmological constant. An anecdote does not need to rely on such a dramatic challenge to worldview, however, to be helpful. Biology students can empathize with Gregor Mendel when given the opportunity to contemplate what would motivate a monk to count so many peas and whether his discoveries might have challenged his ideas about the role of God in nature. Earth science students can empathize with early efforts to calculate the age of the Earth. Students can use these historical examples to illustrate the scientific approach to problem solving and identify where bias, assumptions, or lack of information limited the accuracy of their results, as was the case for Lord Kelvin's estimation of the age of the Earth calculated before the discovery of radioactivity. And middle school teachers can carefully select stories to connect with their students' unique developmental needs.

Strategy 2: Tap Into the Power of Effective Questioning

Josh and Lee both consistently tap into the power of questions to help engage their students. Josh begins the evolution unit with a question that Lee developed: "Why can't we just skip evolution?" He finds this a powerful question because of his students' viewpoint of evolution as a completely invalid perspective on the world. They easily disengage from this core piece of the scientific worldview, especially when taught with traditional pedagogy. This question places the focus back on Josh's students, allowing them to develop the ideas necessary to answer the question.

After Josh poses the question, he gives students time to develop their first thoughts individually and then to share those with partners, groups, and the class. This allows him to get a sense of student thinking as the unit begins. This process also starts creating the key classroom environmental piece of students both responding to questions and asking their own. He takes time to lead students in listing things they already think they know about evolution and to develop questions they need to answer if the class is going to understand, but not believe in, evolution. He usually gets very specific questions about different parts of evolution such as timelines, dinosaurs, and apes.

Next, Josh finds it helpful to organize the questions and to direct the class to the first major question they are going to investigate. Most students know some things about evolution, which allows him to introduce another question that Lee developed: "What does evolution actually say?" Students then write their responses in their journals. This is very important because at the end of the unit he will ask them the same question again. Students then see the changes in their own thinking, a powerful metacognitive activity that we highly recommend.

Strategy 3: Value Questions Over Answers

Nathan and Lindsey extend the emphasis on questioning to placing value on questions that students raise on their own. Too frequently the science curriculum is pruned to only discoveries leading to the successful theories of today, but Nathan and Lindsey find great value in sharing the dead ends of scientific thinking that have occurred along the way. Science is not a linear path of right answers, but a web of discoveries and insights that have survived despite the limitations and biases of the people doing the science.

Students feeling their religious beliefs threatened can find some tension eased when their teachers shift the focus away from having answers and toward having questions. Science and religion are often presented as different ways of knowing, but students can still struggle if the things they know based on their religion seem to be at odds with the things they know based on what they learn in science class. They can sense that they will eventually be forced to choose which "truth" is right. When teachers speak of science as a way of knowing, they may miss an opportunity to present science as a process of questioning, testing, and discovering. Teachers should emphasize that, while science classes require students to gain the background in what is currently known in science, this is a mere jumping-off point for the real work of science, namely asking the next question and devising a way to go about finding out even more.

Teachers who hope to nurture an environment open to questioning must themselves be willing and unafraid to be questioned and must resist the temptation to pretend to have all of the answers. Middle school teachers are well aware of the challenging and even heart-wrenching questions their students can raise as they face the challenges of early adolescence and of the comfort that teachers can bring as they guide their students in courageously facing tough questions. In Mechanicsburg, Pennsylvania, Lindsey and Nathan encounter a significant number of students attending public school for the first time in ninth grade. These students have grown accustomed to having their curiosity answered with "because God …" in their parochial education. These students find it discomforting, but also enticing, to instead have their questions praised and even met with still other questions they have not yet considered.

Strategy 4: Directly Contrast the Vocabulary of Science With Everyday Language

Students learning about evolution are often confused by the language scientists use to describe their process of thinking. Almost all students come to science class with common-language understandings of words such as *theory*, *law*, and *fact* not matching the way these words are used in the more formal context of science. Unfortunately, scientists are also ordinary people who use these terms in a common-language fashion from time to time, and the lack of consistency can perpetuate confusion. *Theory* is certainly the most misunderstood of these terms, signifying to most students merely an idea or a hunch. To suggest that evolution, Big Bang, or molecular genetics are merely theories in that sense is one of the most common defense mechanisms against science. These words must be clarified early in a course and repeatedly reinforced throughout the year (see the nature of science discussion in Chapter 1).

In ninth-grade Earth science classes, Lindsey and Nathan have students first complete a self-assessment of their understanding of these terms. Students are given their scores but not told which questions they answered incorrectly. Confronting their misconceptions at the start helps prevent student overconfidence and their tuning out the lesson. Students then complete a jigsaw activity in which they learn about both the common and scientific uses of five tricky words: *hypothesis*, *theory*, *law*, *belief*, and *fact*. Students complete an organizer comparing and contrasting the two styles of usage of one of these terms and prepare to teach a group of their peers how to correctly use their term in the scientific context. After the jigsaw, groups work together to find examples online of individuals misusing one of the words as well as an example of the word being used in the scientific sense. Students discuss how everyday citizens could be confused about the significance of a scientific idea and then brainstorm ways that scientists, the media, and even teachers could help make communication clearer. Because the word *theory* seems to cause the most trouble in high school science classes, the lesson concludes with an overview of some of the less controversial, and more familiar, theories in science—such as germ theory of disease, cell theory, plate tectonic theory, atomic theory, and general relativity—before considering evolutionary theory or Big Bang theory.

While such a lesson early in the year goes a long way to clarifying the confidence scientists have in various ideas, Nathan and Lindsey have found misconceptions to be stubborn things. They must reinforce the meaning and correct usage of these words frequently during any science class in order for students to transfer the information to future experiences. They have to take time whenever they present a new hypothesis, theory, or law to reassess and, if necessary, reteach the scientific uses of such terms. If someone in a video clip or reading passage uses one of these terms, students do a quick evaluation on whether the word was used in the common-language or scientific sense. Nathan and Lindsey emphasize in each case that nothing is wrong with using these words casually, but that in science class they will ask students to strive to do so scientifically at all times to be clear.

Strategy 5: Respect Students' Journeys in Assignments and Tests

Just as students are asked to use words precisely in the scientific context during class, teachers must also select language that is clear and respectful of the potential struggle students might be having with the material. Words have power and students who may seem to be faring well with what for them is a controversial bit of science may hit their limit when asked to write their thoughts down or to speak in public about a subject. When asked how the Moon formed, for example, students feeling a conflict between their religious ideas and the science they have been learning may see this as a test of faith. Teachers who ask questions in this way are probably not trying to prompt a choice between students' faith and their grades, but they may be unaware they have put the student in a bind until they see for themselves a disconcerting answer explaining what the Bible or other religious texts have taught them.

> ***"Ultimately, when students are allowed to walk between both worlds, they stand a much greater chance of understanding and accepting scientific ways of thinking."***

Lindsey and Nathan have created and revised assignments and assessments that specifically avoid triggering the need for students to sacrifice their grade in order to remain faithful and that still assess students' understanding of the content. A typical assessment on the Big Bang might ask students, "How did the universe begin and change over time? Include three lines of evidence that support your answer." Instead, it is better to ask, "Scientists draw on three lines of evidence to explain the formation and early evolution of the universe. Name and describe each, including its role in developing Big Bang theory." The shift in these questions is subtle and many students would not notice it. The first version asks students to state how the universe began for which they might have two answers, one known from religion and the other from science class. The second version specifically asks about the evidence that scientists use and avoids forcing the student to choose a religious belief in that moment. A student who fervently believes the universe began in a supernatural way can still truthfully answer the question and demonstrate his or her learning.

Even with carefully constructed questions, Lindsey and Nathan have had occasions when a student answered in a religious sense. They use these as opportunities to have a conversation with the student to clarify how they do not intend to force students to choose between their beliefs and learning science. They point out the intentional wording of assignment and test questions to the student as an example of their commitment to honoring students' journeys as learners and a sign of respect that they deserve the space and freedom to learn new science without being required to discard or compromise articles of their faith. Similar conversations have helped concerned parents feel more at ease with this approach to science instruction, even when it seems to conflict with their views. Ultimately, when students are allowed to walk between both worlds, they stand a much greater chance of understanding and accepting scientific ways of thinking.

Strategy 6: Engage Students With Actual Evidence for Species Evolution

Josh has developed a series of lessons on whale evolution, which he calls the poster child for evolution, because he has seen the power of engaging his students with actual evidence. Josh's goals with this strategy are to direct his students to locate scientific evidence, to describe it in both graphical and textual ways, and, finally, to be able to answer from a scientific worldview, "What does evolution actually say about whales?" His students typically respond well to this strategy. They often exit the unit not accepting evolution, but they do come to understand evolution because of the way the lessons are designed with an inquiry approach placing a priority on students' learning and presenting actual scientific evidence.

Josh begins the lessons with a video clip, "Great Transformations," from the Public Broadcasting System's (PBS; 2018) *Evolution* series. As his students watch the first 16 minutes, he asks them to write down the pieces of evidence Dr. Phil Gingerich used to develop his theory of whale evolution. Josh then leads a classroom discussion on what students think so far, which is a good opportunity to check in and invite student questions about the claims that were made. After Josh has established a baseline understanding about whale evolution, he has students gather evidence on the variety of different whales mentioned in the video through a timeline activity. Most of his students have not heard of these different types of whales. He gives each student group one copy of the Whale Evolution Data Table Worksheet, a blank graphic organizer found on the same PBS website, and they work together to collect information and to complete the table.

Josh then does two additional activities to help them see both the order of whale evolution and the reason for that order. The first one is a simple presentation in which each group must claim a slide in a Google Slides presentation and present on a specific organism in the whale lineage. This creates an opportunity for the students to own the evidence and reasoning as well as gives Josh a formative assessment opportunity on their research. Students are assessed on how they show the evidence for where in the whale lineage their assigned organism should be placed, what features this organism has that are different or new, and why the organism should be considered a link in whale evolution. Josh's students are now ready for a fuller layout of the whale evolution story line. Next, he has them watch a section of "Fossils, Genes, and Mousetraps," a lecture by Dr. Ken Miller (Howard Hughes Medical Institute 2018) on whale evolution, so they see and hear the evidence they have been deciphering on their own. Josh then guides his students to develop a complete whale evolution timeline, and he has done this several different ways: He has given them paper and pencils to draw it, they have used computers to research pictures that they printed out and glued onto paper, and they have used web-based timeline generators.

At this point, Josh's students have a solid informational base on what scientific evidence says for whale evolution. He ends the lesson series by guiding his students to revisit their original journal entries with the question, "What do you think now?" He enjoys seeing their growth in making statements supported by scientific evidence and he really likes to hear his students making statements along the lines of "I used to think this … but now I think this." Josh encourages them to write down new questions or things they are wondering about. He may not have class time to investigate all of their questions, but some can be answered with additional readings or video clips.

Strategy 7: Weave Controversial Topics Throughout the Entire Course

A single exposure to any concept is rarely enough for students to gain mastery or total understanding. The same is true for potentially upsetting concepts such as evolution and origins, whether it be the origins of life, the Earth, or the entire universe. In too many biology and life science classrooms, evolution is taught as a stand-alone unit with few connections to the rest of the curriculum. Teaching in this way gives the wrong impression of evolution's place within biology and suggests it could be removed from the course entirely without affecting the rest, like some sort of tumor. When evolution is taught in this way, students are more likely to dread the start of the unit or even prepare themselves to resist accepting anything during those lessons. Students' defenses are up; they are prepared for battle. For some, the battle may be silently enduring the lessons, while others may feel compelled to publicly challenge the teacher, boycott activities or tests, or otherwise cause disruption.

Besides causing these students undue stress and unhappiness, this approach to teaching biology neglects the elegance of evolutionary theory's role throughout the entire field of biology. There should certainly be a unit in the biology course in which evolution is explained, including its discovery, mechanisms, and predictions. This must not, however, be the students' first exposure to these ideas. Instead, Lindsey and Nathan have found the power in seizing every opportunity to mention evolution's role. In a unit on cell structure, for example, the endosymbiotic theory for the origin of organelles such as chloroplasts and mitochondria provides a small dose of how evolution works. Later, teachers can revisit these ideas in a unit on cellular energetics and guide students to compare the functions of mitochondria and chloroplasts in cellular respiration and photosynthesis to the strategies that unicellular organisms use to make or acquire their energy. During a unit on DNA, teachers can continue to develop these ideas as students learn how the genetic material of their mitochondria is fundamentally different than that of their cell nuclei, yet in many ways similar to that of bacteria. Units on cellular reproduction and genetics provide students the mechanisms for genetic diversity and the introduction of novel traits via mutations.

The approach for middle school teachers is similar even though middle school standards focus more on natural selection than on evolution of species. During a unit on ecosystems, teachers can point to natural selection as a powerful way to understand interdependent relationships and a pattern of interactions. In a unit on growth and reproduction of organisms, middle school teachers can help their students see how natural selection is an elegant way to develop arguments and scientific reasoning for reproduction and genetics.

With this strategy, students will have already begun to build a foundation of understanding of evolution that stands a better chance of developing further during an evolution unit than if the theory had been avoided and then taught in isolation. Teaching biology in this way reinforces how evolution is not merely a topic within biology, but one of its principle components—a thread that cannot be removed without unraveling the whole.

Strategy 8: Create Department Policy Regarding the Teaching of Controversial Topics

As Nathan began his teaching career at Mechanicsburg Area Senior High School in Mechanicsburg, he found himself just a few miles away from Dover, Pennsylvania, a district and community embroiled in the landmark *Kitzmiller et al. v. Dover Area School District* (2005) trial dealing with the issue of intelligent design in the science classroom (see Chapters 2, 3, and 5 for more detail). He quickly found the local community and district educators to be abuzz about the trial. He worked with his mentor and department chair at the time, Michael Floreck, to draft a position statement on intelligent design that could be used by department teachers and school administrators if parents and students inquired about the topic. A few years later, Nathan became the science department chair and used an updated position statement on reasons not to include intelligent design or other nonscientific explanations in Mechanicsburg's curriculum. He used this position statement to educate families, administrators, and colleagues on the differences between valid, empirically based science research and faith-based explanations.

Science teachers and administrators need to be on the same page with respect to what is and is not appropriate for the science classroom. Position statements like the one used in Mechanicsburg are an excellent tool for establishing a baseline in communicating with parents and the public. We provide the statement here (see Figure 7.1) so that you can review it as you begin to consider what a similar policy might look like in your school district.

Figure 7.1. Mechanicsburg Area Senior High School science department position statement

Science is the search for natural explanations to the phenomena we encounter in our daily lives; it is accomplished by applying the scientific method to such problems. When science is implemented correctly, a researcher never allows his or her own biases to influence their results. A continuum of certainty exists within science and the word "theory" holds a very specific meaning. While a person may use the word "theory" in common speech to mean a hunch, or a guess, this is much closer to our definition of a hypothesis. Scientific problem solving begins by offering an educated guess, the so-called hypothesis, and attempting to test it against a control. If the hypothesis, in addition to many other similar hypotheses, becomes validated, the idea begins to build toward the status of a scientific theory. These theories are the pinnacle of scientific understanding with regard to how a system or phenomenon in nature works. Darwin's initial theory was published over 150 years ago. Since then, evolution has withstood repeated scrutiny by both the scientific community and the public. While our modern understanding of genetics and cell biology show the mechanics of evolution in a way that Darwin did not know, the observation and accuracy of the theory of evolution hold true and are bolstered by these discoveries. Evolutionary theory has accomplished this increasing level of certainty for the past century and is a widely accepted fundamental theory of biological science.

While many people disagree with the implications of evolutionary theory, it is still a sound theory, and one that is a central theme in biological science. Intelligent design (ID) does not meet the qualifications necessary to be considered a scientific theory; it is in fact, much more like a hypothesis. While it does offer some very difficult challenges to Darwinian natural selection, scientists have responded by continuing to find answers to those questions. In turn, ID does not produce a testable hypothesis, but merely asserts that a designer must have been present to aid the process. The Mechanicsburg science staff feels very strongly that Darwinian *natural selection is the only valid scientific explanation for the trends seen in the fossil record and in the genetic code of Earth's diverse forms of life. The theory has not been damaged by arguments (such as irreducible complexity) proposed by ID advocates in such a way as to become prohibitive. Until ID begins to produce a verifiable hypothesis, it is not a scientific theory, and will not be addressed as such in our science classrooms. Since the topic is likely to come up, we are willing to discuss its shortcomings as a scientific theory, and the obvious agenda of its proponents, but will not offer it as a viable alternative to Darwin's theory.*

It must also be said that we do not believe that evolutionary theory and religion are mutually exclusive; in other words, belief in one does not prohibit belief in the other. We feel that it is necessary to teach our students the current scientific consensus and allow them to decide for themselves based upon the scientific evidence presented. Since we have limited time available to discuss this topic and those issues related to it, we will not plan on discussing every point of contention made by the ID proponents. However, if students or their parents are interested in having a point-by-point discussion on the merits of evolutionary theory and modern research as well as the accusations that are part of ID thought, questions can be directed toward the teacher and/or department coordinator and time can be made after school hours to discuss these issues. Students will need to rely upon influences outside of science class to foster an understanding of those ideas not considered within the domain of science.

We recommend that your science department, at a minimum, consider building a statement like this for any topics you find potentially controversial. Mechanicsburg is currently developing a broader document to include climate science, deep time, origins of life, and origins of the universe, as well as evolution. The discussions within the department alone are worth the effort. Being able to vet ideas, construct common language, share stories, and commiserate builds unity and understanding with colleagues and is in itself a most valuable endeavor.

CONCLUSION

Teaching evolution does not have to create a war in the classroom. Science teachers truly can do both: teach science well, evolution in particular, and respect the religious beliefs of their students, even those whose faith creates conflict for them. Our overall approach gives science teachers a way to move beyond conflict and toward a classroom honoring both science and students' cultural and religious backgrounds. The strategies we have developed offer practical applications in line with our overall approach and examples you can follow in developing your own strategies for engaging resistant students in learning evolution and other scientific concepts.

In recent years, we are seeing some changes in the landscape of evolution education in American schools. Nathan and Lindsey have noticed a shift in the climate of their classrooms. Students no longer seem to arrive in August primed for a fight, and it has been years since either of them has seen a student write a religious explanation for a scientific phenomenon on an assignment or test. At the same time, both have experienced an increase in the number of students mentioning their religion in a nonconfrontational way. More students come in and talk about their background and ask questions out of curiosity and with trust that they will receive honest and compassionate answers and conversation in return. Lee is seeing at a national level a real decrease in the number of teachers who advocate a check-your-religion-at-the-door approach to teaching evolution, and maybe even a rising tide of science teachers and science educators who want to see confrontation removed from evolution education.

The strategies above will certainly need to evolve as the population and culture of teenagers shift, but the core approach of teaching controversial science topics for understanding, not belief, will remain effective. An emphasis on decreasing conflict while increasing thinking, understanding, and empathy will make the teaching of evolution, deep time, and even climate change something that all students and teachers can approach without fear.

REFERENCES

Howard Hughes Medical Institute. 2018. Fossils, genes, and mousetraps. *www.hhmi.org/biointeractive/fossils-genes-and-mousetraps*.

Kitzmiller et al. v. Dover Area School District, 400 F. Supp. 2d 707 (M.D. Pa. 2005).

McTighe, J., and G. Wiggins 2013. *Essential questions: Opening doors to student understanding.* Alexandria, VA: ASCD.

Meadows, L. 2009. *The missing link: An inquiry approach for teaching all students about evolution.* Portsmouth, NH: Heinemann.

Public Broadcasting System (PBS). 2018. Evolution lab. *www.pbs.org/wgbh/nova/labs/lab/evolution*.

RESOURCES

"Big History Project," *https://school.bighistoryproject.com*

"Classroom Resources," *www.hhmi.org/biointeractive/evolution-collection*

"Evolution Resources," *www.nas.edu/evolution*

"Teaching Evolution Through Human Examples," *http://humanorigins.si.edu/education/teaching-evolution-through-human-examples*

Index

MAKING SENSE OF

SCIENCE AND RELIGION

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"A thoughtful and thorough guide to navigating the interface between science and faith, *Making Sense of Science and Religion* combines the elements of a legal handbook and a how-to manual to create a common-sense guidebook for holding respectful conversations on this controversial topic. It's a must-read for scholars, educators, and anyone interested in the impact of science on religious thought."

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