Lessons from Galileo in Framing Socio-scientific Conflicts

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Introduction

Why should science be trusted? In a post-modern world where traditional sources of authority and expertise are increasingly questioned, how can we maintain and rebuild support for science? How do we deal with the seeming growth of socio-scientific conflicts over evolution, climate change, vaccinations and the light while avoiding the charge that science is an elitist, oppressive endeavor?

These are not new issues. Socio-scientific controversies have existed from the beginnings of modern science and even influenced its development. The value and legitimacy of a scientific knowledge as opposed to other types of knowledge have been hotly debated for centuries. Perhaps the most famous of these historical socio-scientific conflicts was the controversy surrounding Galileo's *Dialogue Concerning the Two Chief World Systems* (Galileo, 2001). While that conflict has long been portrayed as "science versus religion," (White, 1896) it was actually a much more complex conflict with religious leaders and scientific arguments on both sides (Graney, 2015; Sobel, 2000).

Galileo's *Dialogue* contains not only evidence and arguments for a helio-centric model of the universe, but also an empirical approach to natural philosophy that emphasized evidence-based models of natural phenomena that would develop into modern science. In part due to its structure of a debate between two persons defending two different positions, it provided one of the clearest presentations of the contrast between the medieval scholastic approach to natural philosophy and the beginnings of natural science in the seventeenth century. Furthermore, as Galileo was (covertly) arguing against the established position, he was forced to build a convincing argument without appeals to authority, for example claiming, "most scientists agree that …."

For this reason, Galileo's *Dialogue* can serve as a good model for understanding socio-scientific conflicts and effectively developing arguments for a scientific position while avoiding approaches that can be interpreted as elitist or even oppressive. This is an approach I have adopted in an upper-level interdisciplinary college level course I developed and teach where the goal is to develop in students the intellectual tools to understand the dynamics of contested socio-scientific issues and be able to effectively communicate across the differences in positions. The *Dialogue* itself is a long, sophisticated argument that is a rich trove of examples to follow (and a few to avoid); to carefully examine every aspect of Galileo's example would far exceed the scope of a journal article. Strikingly, Galileo does not even begin treating the main topic of the book until the second of the four days of the fictional dialogue, using the first day to establish the cultural and philosophical framework for the discussion, something that is easily overlooked in debates over socio-scientific issues, often leading to communication breakdown. Therefore, in the rest of this paper I would like to identify and discuss a number of valuable lessons that can be drawn from Day 1 of Galileo's *Dialogue* with respect to framing discussions over socio-scientific issues.

Lessons from the *Dialogue*

Respectfully acknowledge the different paradigms involved

The *Dialogue* begins with the character of Salviati (Galileo's mouthpiece) outlining the scope of the discussion to be a comparison of the Aristotelian/Ptolemaic paradigm with that of Copernicus. In the process, he acknowledges that position each has its own community of adherents, assumptions and arguments—two different paradigms in the Kuhnian sense (Kuhn, 1996). This is in sharp contrast to the attitude that if someone rejects the mainstream scientific knowledge that person is "ignorant, stupid or insane" (Dawkins, 1989), which is rooted in a deficit model of cultural differences (Agar, 1994) and which will tend to make those on the other side defensive and impede open communication. At the end of his seminal work on the history of American religious fundamentalism, including the significant role of opposition to biological evolution, historian George Marsden observes, "cultural conflicts are not simply products of the machinations of the warped minds of one's opponents, but rather reflect deeply embedded cultural patterns" (Marsden, 2006). Galileo avoids immediately putting a skeptical reader on the defensive by opening the *Dialogue* with a respectful acknowledgement of the existence of different socio-scientific paradigms while still maintaining that one might be better than the other. Theologian-biologist Denis Lamoureux frequently begins presentations to potentially skeptical religious audiences by outlining five different paradigms on evolutionary biology and religious faith (Lamoureux, 2008) which he finds often grants him a hearing for his arguments for the compatibility of the two (Lamoureux, personal communication, 2013).

Know the other side's arguments

Salviati quickly moves into examining foundations for the Aristotelian/Ptolemaic arguments for the immovability of the earth, in particular claim that celestial and terrestrial matter belong to two distinct categories. In doing such Galileo through Salviati demonstrates a sophisticated understanding of the position he is arguing against, something that he continues to demonstrate throughout the rest of the *Dialogue*. On one level it is obvious that for one to effectively argue against a position, one needs to understand the arguments that one is arguing against, both to construct effective arguments and to retain the respect of those listening. Later in the *Dialogue* Salviati ridicules and dismisses a contemporary anti-Copernican tract, the *Mathematical Disquisitions* of Johann Locher (Graney, 2017), by highlighting some of its arguments against the helio-centric model that were based on a misunderstanding of the Copernican claims, effectively nullifying other, valid arguments it contained. When my students examine the public debate over creationism between Bill Nye and Ken Ham, they largely agree that Ken Ham did a better job presenting his arguments for the the creationist paradigm than Bill Nye did for mainstream science. An important part of that was how Ken Ham anticipated and proactively countered many of Nye's arguments. For example, Bill Nye's closing appeal that acceptance of mainstream biology and geology was critical "so the United States can continue to innovate and continue to be a world leader" (Ham & Nye, 2014) had been effectively undermined by Ham presenting a series of videos in which scientists and technology leaders identified with the creationist paradigm.

Explicitly address epistemological foundations

The first foundation that Salviati and Simplicio (the defender of the Aristotelian/Ptolemaic paradigm) argue over involves the number of physical dimensions. They both agree there are three dimensions; the discussion is over one what basis one knows that. Salviarti explicitly rejects rhetorical arguments that Aristotle had put forth, such as "all things are determined by three—beginning, middle and end—

which is the number of the Whole" and that three items is the smallest number for which the word "all" (as opposed to "both") is used. Instead, Salviarti provides a series of geometric constructions to show that all paths through space can be reduced to a combination of motions along three orthogonal axes. Through this discussion, Galileo zeros in and draws a sharp distinction between the epistemological foundations of the two paradigms. In contrast to the medieval scholastic tradition, with great reverence for the authority of Aristotle, theoretical arguments, and beliefs in logical necessities (Grant, 1997), Salviati puts for a case for logical arguments based on mathematical analysis of empirical data and observation as the best way to understand the physical world.

Unaddressed difference in epistemological beliefs can provide insurmountable barriers to effective communication across differences. A foundational assumption in fundamental Christianity is that the Bible is *inerrant*, i.e. without error, including historical and scientific ones (Marsden, 2006). In such an epistemological framework anything that comes into conflict with the understood meaning of the Bible would be viewed as necessarily incorrect. For example, presenting geological evidence for the age of the earth would likely result in decreasing trust in geology, a backfire effect that explicitly addressing epistemological issues can help avert (Fackler, 2021).

Deal with alternative conceptions

The discussion between Salviati and Simplicio leads to discussing the nature of motion. Galileo's goal is to expose fallacies about the Aristotelian distinction between "natural" or "simple" motion and other types, i.e. that every body had an intrinsic form of motion—up, down, or circling the center of the universe, depending of what it was composed of—while all other types of motion required a force to be applied. Instead, Salviati argues that straight-line motion is the most basic type of motion and that being at rest is a natural state of a body. While this move could at first glance seem like it is quibbling over minor issues, it is of fundamental importance for the ensuing discussion. While motion may seem like a simple concept for physics experts, it is a topic that took two millennia to develop a through, rigorous understanding and one that most students struggle with at some level (Arons, 1997), in part to the presence of "common-sense misconceptions" that mislead student reasoning (Halloun & Hestenes, 1985). It is necessary for an effective teacher to explicitly deal with these "alternative concepts" in order for students to develop a solid grasp of the material (Knight, 2002).

Establishing that both sides are using words to mean the same concept instead of subtle but significant differences for meaningful communication. Locher's argument on Day 2 that Galileo particularly singles out for ridicule is that Copernicus inverts the entire order of the universe by making towards the sun "down" such that "Christ the Lord ascended to Hell. He descended to heaven (for he approached the sun)" (Graney, 2017) due to the idea that "up" and "down" are intrinsic, absolute directions in the universe rather than relative to the speaker. "Common sense misconceptions" about natural selection in biological evolution (Brumby, 1984; Greene, 1990) and confounding "climate" with "weather" can lead to communication breakdowns when discussing socio-scientific issues.

Be cognizant of metaphysical differences

The discussion then turns to the Aristotelian belief that the heavens (the moon and beyond) are perfect and changeless, while the Earth (the sublunar region) is imperfect and changeable. The metaphysical idea that there exist two completely distinct categories of substances that obey distinct laws was part of the underpinning of Aristotle's model of the cosmos and needed to be brought into question before proceeding with the argument that the moon and planets are so unlike the Earth. Like epistemological foundations, it is easy to not recognize metaphysical differences between different positions because they frequently exist as unstated starting assumptions underlying thinking about a topic. It is common in modern thought to assert that science and religion deal with distinct non-overlapping magisteria with the former dealing with objective, empirical reality and the latter with subjective spiritual and moral values (Gould, 1997). That distinction, however, comes into direct conflict with the creationist assertion that God is objectively real and the direct cause of the world's existence and various forms of life. Furthermore, the perception that modern science—especially biological evolution—serves to promote this modernist distinction that makes God and religious belief merely a subjective experience is a driving force behind the opposition to biological evolution (Marsden, 2006). While Salviati's attacks on Aristotle's sharp distinction between celestial and terrestrial realms do not change Simplicio's mind, they do open up space for the subsequent examination of evidence that might have otherwise been dismissed out of hand.

Expose logical fallacies

During the discussion about whether the celestial sphere is composed of different substances than the terrestrial, Simplicio brings up Aristotle's argument that we have never seen any changes or alterations in the heavens. Salviati challenges that, asking if the lands in China and the Americas are static and unchanging, since Simplicio has never seen alterations in those lands. When Simplicio protests that one can believe in changes an alterations in distant lands because of reports from there, Salviati counters by asking him what reports he has from the moon or the stars, explaining, "From your not seeing alterations in heaven (where if any occurred you would not be able to see them by reason of the distance, and from whence no news is to be had), you cannot deduce that there are none" (Galileo, 2001). In this way, Salviati exposes the logical fallacy that underpinned this argument for unchanging heavens, that absence of evidence does not necessarily imply evidence of absence. Importantly, Salviati does not do this in a triumphal, accusatory way the way that Locher did in his previously discussed flawed argument against the Copernican system. Salviati's skilled leading Simplicio to pretty much articulate the contradiction himself both helps ensure that it is a real logical fallacy (and not due to misunderstanding the other side's claims) and makes it much harder for Simplicio to wiggle out from it. This, of course, requires knowing the opponent's arguments well enough to identify and expose their flaws.

Utilize multiple lines of evidence

Salviati continues to press his argument against the idea that the heavens are fundamentally different from the earth by bringing in a number of different recent astronomical observations. He brings up the supernovas that had been observed in the previous sixty years, sunspots on the sun, and multiple observations about the moon. While each of these alone is in principle sufficient to undermine the Aristotelian argument, combined they bring much more force to bear. After all, Simplicio has counter arguments to each of them that when taken individually might at first glance seem sufficiently strong to counter Salviati's claims. However, Salviati brings them all together in a mutually reinforcing way while Simplicio is force to try to counter each with individual, unrelated arguments, demonstrating that Salviati's theory is simpler and more productive in its ability to explain a variety of phenomena, which is to be preferred in scientific theories. Tellingly, at this point Salviati refuses to get bogged down in the details of the disputes over the supernova observations (they return to that in Day 3), but rather pivots to bring up more evidence. Providing a big picture with multiple lines is important for arguing for mainstream scientific understanding on issues such as origins or climate change; as those involve large, complex systems many of the specific observations are not airtight in isolation. A common approach of young-earth creationists or climate change deniers is to focus on one specific observation, such as issues with a specific radiometric dating method (Snelling, 2019), raising doubts about that claim just as Simplicio attempted to do against Salviati. This strategy exploits the fact that science depends to a large degree on inductive reasoning, where general principles are deduced from multiple, individual observations, which means that one can never absolutely prove a claim but rather provide only a certain *degree-of-support* for it, so that it is important to consider the total body of true evidence when assessing the strength of an inductive argument (Hawthorne, 2021). This of course goes against the way that scientists generally interact with professional colleagues during periods of 'normal science' focusing on specific, narrow problems (Kuhn, 1996) and a cognitive bias among human beings towards drawing definitive conclusions from a small body of evidence (Kahneman, 2013).

Compare alternative theories

As Galileo's characters discuss sunspots and the moon, they introduce and compare alternate explanations for the observed phenomena. For the former they compare the idea that sunspots arise from a collection of many small planets inside the orbit of Mercury that just happen to come together in clumps as with the idea that they are in fact some sort of blemishes moving across the face of the sun. For the latter the compare the claims that the moon is self-illuminating vs. reflects sunlight, whether it is smoothly polished or relatively rough, and whether the faint illumination of the dark areas in the moon is due to it being slightly translucent vs. due to reflected light from the earth. In all of these comparisons they evaluate which theory is more consistent with the observed evidence about sunspots and the moon.

It is valuable to take the time to bring up and compare how different claims stack up against the evidence when discussing controversial topics. First, that is how science works; a key part of Thomas Kuhn's insight was that scientific paradigms do not change merely because discrepancies and anomalies arise but only when there exists an alternative paradigm that the community judges to be better (Kuhn, 1996). Second, this recognition integrates/requires many of the preceding points. In order to effectively compare alternative theories, one must first recognize that there are different perspectives/ paradigms involved, then understand the other side's arguments. Comparing theories can help expose and deal with alternative conceptions and reveal faulty reasoning. Third, a useful approach in managing conflict is to disassociate the ideas from the person; setting up two or more alternatives "side by side" for comparison can facilitate more objective evaluation than if perceived as "my idea vs. yours." Fourth, as previously mentioned, a common technique of those who seek to dispute scientific claims is to raise doubts about them while not defending a concrete alternative theory, a kind of intellectual guerilla warfare. The is possible because in its very nature scientific knowledge has a degree of tentativeness such that perfect, absolute truth is not possible. However, the standard for accepting a scientific theory is not absolute proof but that it is better than the alternatives. Insisting on comparing theories instead of just defending one's own is a way to counter this.

Be humble

Galileo has his characters end the first day's discussion decrying the "vain presumption of understanding everything" that some people exhibit which they attribute to "never understanding anything." On the contrary, the assert that the more one knows, the more one recognizes how much one doesn't know (Galileo, 2001). They bring up the example of Socrates, who claimed to know nothing although he had been proclaimed by the Oracle of Delphi to be the wisest of all men. They conclude this is only a seeming contradiction because Socrates could have known more than other men but still have known almost nothing compared to the sum total of all knowledge. They then associate the latter with unlimited, perfect divine knowledge which they contrast with the limited, imperfect human kind (Galileo, 2001).

While the examples of Socrates and divine understanding might not carry so much weight today, the final point of Day 1 is even more relevant. The sum total of human knowledge and information has exploded in the last four hundred years, so that while it may be possible for each of us to be an expert in one narrow field, there are vastly more fields of knowledge where our individual understanding is next to nothing. This recognition is especially critical when dealing with socio-scientific issues such as origins, climate change and others where there are complex interactions between scientific understanding, social identity, cultural history, religious belief, economic and political conflict, philosophical underpinnings, cognitive biases and more (Sadler et al., 2016; Sismondo, 2009). No single person can be an expert in all facets of a socio-scientific issue; making progress on resolving those requires a degree of cooperation and avoiding a triumphalist "I have all the answers" attitude.

This recognition is also important to help counter some of the post-modern critiques of science in which it is portrayed as elitist, anti-democratic, imposing cultural hegemony on a multi-cultural world (Mackenzie et al., 2014). It is not difficult to find examples where scientists have held themselves up as superior to non-scientists (physicists like myself are particularly notorious). It is not difficult to find examples where "science" was used to advance the economic or political interests of those in power or exploit socially or economical vulnerable groups. It is not difficult to find examples where science and technology were imposed on people groups will little understanding or respect for their culture. But it is also possible to find examples of the opposite happening. Keeping a humble attitude, recognizing that none of us knows everything and that we can potentially learn from each other is a valuable aid in avoiding the actions and behaviors that post-modernist critiques of science have rightly called out.

There are growing concerns about public understanding and trust of science, in part due to science skepticism and socio-scientific conflicts (Editors of Science & Education, n.d.; Naomi Oreskes, 2019). However, these are not new phenomena. They have existed since the beginnings of modern science, even before science itself was recognized as a separate discipline. The controversy surrounding Galileo's *Dialogue Concerning the Two Chief World Systems* and his subsequent trial represents a classic socio-scientific controversy, far more complex that the popular perception of it simply as a case of "science vs. religion," and can serve as a valuable prototype for better understanding the dynamics of socio-scientific controversies. In particular, Galileo's *Dialogue* provides for us a number of lessons on both effective and problematic ways of addressing socio-scientific conflicts. Following the example of others (Schvartzer et al., 2021), this paper will examine Galileo's *Dialogue* in order to highlight a number of lessons that can be learned from his example in constructing arguments seeking to persuade those with skeptical and pseudo-scientific views, both those to emulate and those to avoid.

The empirical, data-driven approach to understanding the natural world that characterizes modern science was in its nascent stages when Galileo wrote his *Dialogue*. Furthermore, "Science" had no social clout that could be appealed to as an authority; that which we today call "Science" was still understood by Galileo and contemporaries to fall within the field of natural philosophy alongside the positions he opposed. Early in his career Galileo himself had followed medieval impetus theory in describing motion (Grant, 1997) and as a professor of mathematics would have taught the Ptolemaic model of the universe (Sobel, 2000). Thus, as someone advocating a minority position with no social clout and someone who personally had converted from the position he was arguing against, Galileo was far more cognizant than many scientists today of where adherents of the other position were coming from and the need to construct arguments that had the potential to connect with and persuade them. In these times when "Science" is no longer is an unchallenged source of authority in our society (Mackenzie et al., 2014), we would do well to relearn the art of constructing arguments that argue for the scientific approach to understanding the natural world that understand the paradigm out of which those holding alternative positions are operating out of in order to expose its weaknesses and inconsistencies and help them modify their beliefs. Reflecting Galileo's background as both an educator and a public debater, his *Dialogue* provides an excellent example of doing just that.

Galileo's *Dialogue* was published in 1632, eight years after an audience with the then newly elected Pope Urban VIII, who had been an admirer of Galileo. During their meeting Galileo sought and believed he had obtained permission to publish a book on the Copernican model of the universe as long as it was treated "hypothetically" and not as actual fact, which would represent a softening of the Catholic Church's 1616 edict against teaching the Copernican model. In order to comply with that expectation, Galileo wrote the *Dialogue* such that it nominally concluded that the argument for the Copernican model was inconclusive, and furthermore he arranged for the book to be personally reviewed and approved by the Pope's right-hand man who was in charge of the licensing of books in Rome. Nevertheless, within a year various people close the Pope—including some with whom Galileo had a long-standing professional rivalry—convinced the former that Galileo had in fact violated the edict and had in the process personally insulted the Pope. Already under considerable political pressure stemming from the Thirty Years War, the Pope ordered a committee of the inquisition to investigate. Seeking to mollify the committee, an elderly Galileo confessed to "inadvertently" violating the edict, had his works banned by the inquisition, and was effectively placed under house arrest for the rest of his life (Sobel, 2000).

The body of Galileo's *Dialogue* is constructed as a discussion between three Italian gentlemen: Salviarti (Galileo's mouthpiece) who argues for the Copernican model, Simplicio (his foil) who seeks to defend the medieval Aristotelian cosmic model, and Sagredo (the host) who is nominally neutral on the subject and who the other two seek to persuade. Their discussion of a wide range of topics including epistemology, falling bodies, experimental design, astronomical data, reference frames, the cause of tides and more supposedly takes place over four days, which form the principle divisions of the text. The text nominally adheres to the stipulation to comply with the 1616 edict of not promoting the Copernican argument as fact: Salviarti repeatedly claims he is taking the Copernican side simply for argument sake and doesn't really hold that position and the at the end Sagredo declares himself not persuaded by the heliocentric arguments. However, the arguments Galileo put in the mouth of Salviarti are far stronger and coherent than the rebuttals offered by Simplicio, making it fairly obvious where Galileo's sympathies truly lay (Galileo, 2001). In the rest of this paper I will highlight various examples from Galileo's argument, discuss the reasons behind his doing that, and then show how that could apply to current socio-scientific controversies.

Lessons from the *Dialogue*

Pay attention to metaphysical beliefs

The remainder of the First Day of the discussion primarily revolves around Salviati raising questions and debunking key elements of Aristotle's metaphysics. He questions and points out logical inconsistencies with Aristotle's division of motions into *natural* and *forced*. In Aristotle's physics all objects were understood to intrinsically possess one of the three natural motions, with those being up (linear away from the center of the earth/universe), down (linear toward the center) and circular around the center while all other motion required an active agent exerting a force on it. This then sets up a challenge to Aristotle's assertion that there is one intrinsic center of the universe towards which heavy matter intrinsically moves, thereby forming the earth at the center of the universe around which all celestial objects must rotate. This is followed by a discussion of heavenly bodies and Galileo's own observations of sunspots, phases of Venus, moons around Jupiter and long discussion about the moon and light reflected from it. The primary aim of this discussion is to undermine Aristotle's assertion that the celestial realm (orbit of the moon and beyond) is composed of matter that is entirely different from that of the sublunar realm in that it is perfect, incorruptible (unchanging), lighter than air and fire and moves in perfect circles.

Throughout this discussion, Galileo is seeking not only to overthrow the foundational concepts in Aristotle's physics but the metaphysical framework behind them, such as the distinction between natural and forced motion, the idea that some places in space (e.g. the center of the earth/universe) are intrinsically different than others, and that the celestial realm is governed by different laws of physics than the sublunar one. Implicit in this he is also challenging the Aristotelian idea that the cosmos must necessarily have certain characteristics that can be determined through pure reason which reinforces the empirical epistemology that he had already argued for. It was important for Galileo to explicitly challenge these metaphysical assumptions because some key parts of Aristotle's physics are the logical outcome if these assumptions are accepted and left un challenged.

While not all socio-scientific conflicts involve irreconcilable metaphysical assumptions, they can still cause different groups to draw different conclusions from the same data. Most scientists operate out of a methodological if not fully ontological materialism, i.e. all things (at least in science) are to be explained in terms of physical objects and forces between them. One manifestation of this shows up in periodic efforts to develop scientific theories to explain religious behaviors [citation needed]. However, for a young-earth creationist God is just as much an ontological reality as atoms, if not even "more real" due to being the creator of everything else. Thus, while claims of a divine supernatural intervention in some situation raises red flags for many scientists due to its violation of a materialistic metaphysics, it would be unobjectionable as par for the course in a theistic metaphysics. In many cases one may not need to directly challenge the metaphysical framework of those on the other side, since a theistic metaphysics does not intrinsically interfere with doing and discussing science itself. After all, modern science developed out of a culture dominated by a theistic worldview (Grant, 1997). Even so, metaphysical differences can affect related issues such as types of arguments one finds persuasive.

Provide social identity bridges

Day Two of Galileo's *Dialogue* also begins with a seeming diversion from the main focus of the book. Salviati and Sagrado engage in a series of attacks on the arguments of some of the scholastic philosophers who dogmatically defended positions attributed to Aristotle in the face of empirical evidence, associating them with alchemist and astrologers. However, at the same time they defend Aristotle himself, claiming that those scholastic philosophers disgraced him and that he would alter his views if he would have access to empirical data available to the discussants (Galileo, 2001). There are two things going on here. First, they are reinforcing the empirical epistemology promoted at the beginning of the first day through exposing and even mocking the scholastic methodology. Second, they are seeking to drive a social identity wedge between Simplicio and scholastic natural philosophers. In his preface Galileo had described Simplicio as someone "whose greatest obstacle in apprehending the truth seemed to be the reputation he had acquired by his interpretations of Aristotle" (Galileo, 2001). In attacking contemporary scholastic philosophers as a disgrace to Aristotle yet praising the later as someone who would correct his teaching based on new evidence, Galileo was putting forth an argument that a true disciple of Aristotle would change their position based on the evidence.

In doing such, Galileo showed that he clearly grasped the principles of social identity theory long before it was fully articulated in modern times. All human beings possess a variety of formal and informal social identities such as those involving race and gender, community and familiar relationships, religious and political affiliations, and characteristics such as 'attractive' or 'intelligent.' Some social identities are salient in that they provide the person with a sense of belonging and self-esteem (Stets & Burke, 2014) and therefore can be powerful sources of motivation to act or behave in a certain way (Maslow, 1970) in order to project and maintain a desired social identity (Cupach & Metts, 1994). One of the driving factors behind attacks on mainstream science and promotion of alternative views is the protection of social identity {citation needed}. Conservative Christians have for over a century now viewed mainstream biological evolution as incompatible with a fundamental belief in the divine inspiration of the Bible (Marsden, 2006), so there is formal and informal pressure to hold such beliefs and exclude alternative viewpoints, such that those who express divergent viewpoints may be asked to leave[1], be publicly attacked, or lose their job. {citations needed}

In attacking contemporary scholastic philosophers while praising Aristotle as someone who would follow the evidence, Galileo is seeking to build a social identity bridge that would allow someone to switch their position on the model of the cosmos while maintaining a salient social identity as a follower of Aristotle. Pathways that enable people to accept certain ideas in mainstream science while allowing them to maintain salient social identities are potentially far less socially and psychologically costly than those that would require them to change social identities, and therefore potentially more effective. An example of doing that is the BioLogos organization that promotes the position that biological evolution is compatible with Christian beliefs {biologos citation].

Don't attack religious or political identities

This is really a corollary of the previous point, but it is an important point to emphasize. Although the conflict over Galileo's *Dialogue* has long been portrayed as science vs. religion (White, 1896), an examination of the text itself and the historical context shows that Galileo did not believe that there was an inherent conflict between science and religion and went out of his way to try to avoid it being characterized as such. As already mentioned, Galileo—who was a life-long Catholic and had steered both of his daughters into becoming nuns—both sought permission from the Pope himself for the book and had the Pope's close advisor personally review, request changes and finally approve the modified

[1] The author personally experienced this after respectfully requesting his former pastor to explain the justification for a particular statement in a recently adopted statement of faith.

text. Galileo had previously devoted significant effort into writing his *Letter to Grand Duchess Cristina* (the very devout mother of his patron) in which he used scripture and the writings of important theologians to argue that the Copernican world view did not contradict the Bible or Catholic theology, though it would not be published until after the affair and then in Holland, far away from the Catholic Church censors (Sobel, 2000). Then in his forward "To the Discerning Reader," Galileo both praises the church edict against teaching the Copernican worldview as fact and tries to cast his book as a defense of the Catholic Church, in order "to show to foreign nations [i.e. Protestant countries] that as much is understood of this matter" and that "everything was brought before the attention of the Roman censorship" when the ban was enacted (Galileo, 2001). While Galileo's sincerity in that claim would certainly be open for debate in view of his subsequent dismantling of the arguments against the Copernican worldview, in the main text of *Dialogue* he completely avoids mentioning scripture and religious beliefs with the exception of a few passing references.

Religious and political beliefs are important social identities for many people, something seen clearly in the rise of identity politics in the United States. Because of that, arguments that are perceived to attack those identities tend to be rejected out of hand, often attributed to nefarious motivations of the other side, such as the common trope among young earth creationists that biological evolution is a Trojan Horse to promote a modern, secular worldview or that climate change is a hoax invented by liberals.

Gently explain models and address "common sense" misconceptions

After the attempt at weaning Simplicio away from the scholastic social identity, Salviati introduces a key model for addressing the subsequent discussion. He uses the analogy of a merchant ship sailing in a straight line on a smooth sea (the *Dialogue* was set in Venice) to introduce the concept of what we call today inertial reference frames. It is an analogy he comes back to multiple times, making various points that a person (or butterfly) in one of the ship's cabins would not necessarily be aware of the ship's motion and that motion of an object in the cabin can be thought about in terms of motion relative to the ship and motion with the ship. This is presented in a respectful, easy-to-follow manner that doesn't assume that the concept of relative reference frames is obvious to Simplicio (or a skeptical reader).

Developing and explaining this theory of relative reference frames is key for the upcoming discussion over the motion of terrestrial objects. An entire class of Aristotelian objections to the rotation of the earth were rooted in the "common sense" belief {Halluen&Hestenes} of there being a single, privileged reference frame such that objects were either moving or at rest in an absolute sense. Salviati's upcoming arguments against those depended on recognizing the less intuitive but physically more accurate understanding that objects could be at rest in one reference frame but moving in a different one. It is notable that at no point in this discussion does Salviati imply that Simplicio is stupid or ignorant for not understanding that, but rather uses a bridging analogy to build the concept of relative reference frames by refining existing intuition {elby}.

Identifying and effectively addressing underlying incorrect "common sense" is important to be able to effectively communicate across differences. One source of these difficulties is rooted in such "common sense" misconceptions that are not necessarily obvious to those on other side. A number of the common objections given to biological evolution are rooted in incorrect "common sense" of what "evolution" means in a biological context. Although in a biological context "evolution" does not refer to the development of an individual organism, that is exactly what it means in a Pokémon game and that misconception is potentially reinforced by oft repeated argument for biological evolution based on a supposed passing of embryos through stages representing different stages of evolution. The conflation of weather and climate in climate change debates and the idea that if the earth is getting warmer it will be a uniform effect are additional examples of “common sense” misconceptions that are incorrect but seemingly plausible to someone not well versed in the science of the field. Galileo provides for us a good example of recognizing problematic misconceptions and respectfully drawing upon the other’s knowledge and intuition to develop a more accurate understanding of the world.

Know the opponent’s arguments

After laying the groundwork with the concept of relative reference frames, Salviati turns to the Aristotelian arguments against the motion of the earth. With Simplicio’s permission, Salviati himself summarizes a series of arguments against his own position, eliciting agreement from Simplicio that Salviati had articulated them well. Of course, Simplicio’s enthusiastic approval of Salviati’s articulation of them is short-lived as the latter proceeds to systematically undercut everyone of those arguments by exposing the errors in them, many based on a faulty understanding of relative motion. By having Salviati summarize the arguments against the Copernican worldview before demolishing them, Galileo first demonstrates that he knows those arguments well and gets Simplicio (and potentially a skeptical reader) to commit to a position that Salviati proceeds to expose as flawed.

It is not true that if someone has objections to science, that necessarily means that in established socio-scientific controversies, each side has reasons upon which they believe they are right. As Galileo through Salviati shows, not all reasons are equally valid; some under careful scrutiny can be exposed to be based on faulty assumptions, to conflict with evidence, to be logically inconsistent, and so on. Galileo knew not only the arguments in support of the Copernican model but those against it, and those sufficiently well that he could identify and expose the flaws in the latter.

To be able to construct potentially persuasive arguments against positions skeptical of science, it is not enough to know our own position but to also have an understanding of where the other side is coming from. A poignant example is in the Ken Ham vs. Bill Nye debate over evolution; in class discussion my students largely agree that Ken Ham was more effective in presenting his argument (even when rejecting it) than Bill Nye did. A significant reason was that in his presentation Ken Ham proactively sought to undermine typical arguments against a young-earth creationist position, while there was much less evidence that Bill Nye was familiar with common young-earth creationist arguments

Lessons

- Address foundational epistemological and meta-physical beliefs
- Explain construction of models and frameworks
- Role of social identity
- Don’t attack religion
- Deal with data, uncertainty and outliers
- Be aware of cognitive bias
- Don’t belittle or demonstrate contempt for opponents (bad example)
- Don’t construct false dichotomies/attack strawmen (bad example)
- Limited power of political/judiciary actions to end conflicts

Framing as socio-scientific paradigm, explanation of what that is

- Critical realism
- Philosophical foundations, social identity, cultural history, economic/political conflict, scientific investigation