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ORIGINAL PAPER

Addressing controversies in science education: a pragmatic approach to evolution education

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Abstract Science education controversies typically prove more intractable than those in scientific research because they involve a wider range of considerations (e.g., epistemic, social, ethical, political, and religious). How can educators acknowledge central issues in a controversy (such as evolution)? How can such problems be addressed in a way that is ethically sensitive *and* intellectually responsible? Drawing in part on pragmatic philosopher John Dewey, our solution is politically proactive, philosophically pragmatic, and grounded in research. Central to our proposal is (1) steps toward creating a philosophical "total attitude" that is democratic, imaginative, and hypothetical; (2) a deeper understanding of how scientific theories can be pragmatically true; and (3) an assessment of differing pedagogical approaches for teaching evolution in the classroom.

Keywords Pragmatic philosophy · Dewey · John · Controversial topics/curriculum · Science education · Evolution education

1 Introduction

Science is often controversial. New scientific ideas are frequently met with disbelief and distrust. Scientific debates may continue for decades, sometimes ending, as Max

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Planck famously observed, only with the deaths of the combatants. In contrast, it is tempting to think that science education is less controversial. And there are good reasons to think this: for example, by the time a scientific theory enters the curriculum, particularly pre-college science education, we would expect it to have gained near universal acceptance by the scientific community. In addition, since science education is typically concerned with foundational introductions to science, we would expect the presence of accepted material in curricula to be largely uncontroversial.

However, these first impressions can be deceiving. As science educators know, science education is not immune to controversy; and while the research establishment of the sciences have procedures and structures designed to resolve controversy (including, but not limited to, peer-reviewed journals such as *Science* and *Nature*, national conferences, and competitive funding), science education lacks a similar set of widely accepted procedures for dealing with controversy.

This paper will consider the nature of controversy in science education from the perspective of pragmatic philosophy, offering several goals and strategies to consider. Then, to illustrate the practical application of the pragmatic ideas, we will examine examples of teachers' classroom choices related to controversy and teaching evolution, especially as the choices apply to a model of classroom interrelationships.

2 Controversy in science education

2.1 Distinguishing the controversy in science education

Controversies in science education are distinguishable in two ways from ordinary scientific controversies. First, science education controversies are more likely to emerge from *outside* the field. While scientific controversies are normally the domain of the scientific community and are raised, discussed, and resolved *within* the community of working scientists, controversies in science education often involve parents, community members, and administrators who themselves are likely to have little scientific background.

A second reason, related to the first, is that science education controversies are more likely to grow directly out of non-scientific considerations. While, at least ideally, scientific controversies can be resolved through additional scientific research, science education controversies can involve a huge range of considerations—social, political, religious, and pedagogical—that make their definition (let alone their resolution) much less clear-cut (Sader 2005). The best current example of such a controversy in science education is, of course, the teaching of evolution. Even though this scientific theory's basic truths have been accepted by virtually all biologists (i.e., it is highly verified and thus, ''uncontroversial''), the teaching of evolution remains a lightening rod for more than a handful of communities around the United States.

Controversies in science education thus pose a distinct set of questions and challenges. These range from whether a controversy is trumped up or genuine, to whether a controversial issue should be taught—and if so, how. Consider, again, the questions raised by teaching evolution:

- Is teaching evolution really as controversial as its opponents claim?
- On what grounds are the objections of parents and school board members ''sufficient'' to contravene the expert judgments made by scientists and educators about the academic merit of that issue?

- How should *genuinely* controversial (scientific) issues be taught?
- Finally, what are the ethical and pedagogical responsibilities of science educators when they *are* drawn in to a controversial issue?

Although these questions are most clear in the case of evolution, they also characterize other controversial issues in science education, including topics in human sexuality, ecology, and climate change.

2.2 Classical pragmatism and controversy in science education

Such issues have an historical precedent. Shortly before the 1925 Scopes trial, the American philosopher and pragmatist John Dewey wrote:

> Many of us imagined that a serious attack upon evolutionary views...was as improbable as an attack upon the astronomy of Galileo, or a wide-spread and influential campaign in behalf of the Ptolemaic system..... Nevertheless, the issue is for the public actual and vital today, in spite of the elapse of a generation in which we prided ourselves...upon the advance of the scientific spirit, and the accommodation of the public mind to the conclusions of scientific inquiries (Dewey 1925/1983, p. 48).

While the controversy had empowered people politically, it had not educated them about the methods of science. "The public," Dewey continued, "has taken an active part [in the Scopes controversy]; but the conditions which have enabled the public actively to intervene have failed in providing an education which would enable the public to discriminate...between opinions untouched by scientific method and attitude and the weight of evidence" (p. 49). Dewey's observation neatly encapsulates our problem today: How should we address controversial scientific issues when the issue is more social than scientific?

Right off the bat, several possible solutions present themselves. One solution, "*teach the controversy*," would suggest describing why a particular issue is controversial and, if taken to the extreme, would offer alternatives. In the case of intelligent design creationism (IDC), the alternatives offered are typically not scientific in their origin; however, the proponents of this solution often argue that students should be entrusted to make up their own minds on controversial issues. A second solution is "*avoidance*," where, for example, teachers may choose to omit controversial topics (or leave them to the end of the school year), thereby limiting students' exposure to the issue and possible conflict over it. A third solution is "*dogmatism*", which would dismiss any controversy out of hand. Proponents of dogmatism can claim that some controversies are best ignored, since doing otherwise may lend more respectability to a controversy than is warranted by the scientific community (which, after all, is the rightful arbiter of scientific educational curricula).

Here we argue for a different solution which is politically proactive, philosophically pragmatic, and grounded in research. Our approach is proactive in that it neither avoids nor ignores controversy and because it supports a thoughtful, purposeful consideration of the controversy. At the same time, however, it does *not* treat all controversies as *equally deserving* of respect: different controversies require different responses. It is pragmatic particularly insofar as it derives its strategic vision and philosophical instruments from classical pragmatists such as John Dewey and Charles S. Peirce. Particularly relevant to our focus are Dewey's ideas about epistemology: (a) that knowledge is achieved primarily through a process of inquiry that is characterized by its social, experimental, and fallible nature; (b) that inquiry begins for people not with abstract puzzles, but with concrete problematic situations; (c) that because the general inquiry process typical of successful science is also relevant to successful inquiry into other spheres of life, it should be adapted and used to solve pressing moral issues. In this paper, we argue that a pragmatic approach in particular contributes a sorely needed sensitivity given the fact that the central controversy happens *within a science education context*, and to the multiple ethical responsibilities facing science educators entangled in such controversies.

Our approach is informed by the work of John Dewey. Dewey, we find, emphasized the many connections between science education and a vibrant democracy. Not only did he argue for the inclusion of experimental science throughout the elementary and secondary school curriculum, but for the kind of scientific education that would make citizens into more effective participants in the public sphere. Dewey's philosophical work thus offers a coherent account of the importance of science education, the role of controversy in public life, and the democratic means appropriate for resolving such controversies. It is for these reasons that we draw on him here.

3 Pragmatic goals

3.1 Epistemic roots of controversy

While controversies in science education seem like intractable problems, they can be more constructively framed, in Dewey's language, as ''problematic situations.'' As *situations* these controversies involve more than just the scientific or religious issue at their center, and they call out not just for ''answers'' but for what Dewey termed ''inquiry'' in order to effect a resolution. The goal of inquiry is judgment, asserted on the basis of empirical warrant, that describes how participants might take steps to address and resolve the problem (to render the situation ''unproblematic,'' in Dewey's language). The instrumental goal of inquiry's judgments is *warrant*, not truth. This emphasis on warrant is particularly significant given the complex makeup (noted above) of science education's controversies because *warrant* is directly connected to actions and operations relevant to the problem at hand. In other words, one's conclusion to an inquiry is only ''warranted'' insofar as that inquiry's objectives—both normative and epistemic—have been satisfied. After all, most difficult situations demand that we *act,* and so they demand not merely judgments of truth, but judgments of living practice. And very few of us would be satisfied with a resulting practice that conformed only to our epistemic values and not also our moral ones.

In consequence, this means that narrow epistemological solutions will often be insufficient to resolve controversies in science education: it cannot be enough to prove a particular theory is ''true'' or ''verified.'' Consider an example that illustrates this: the proponents of IDC advocate for a ''teach the controversy'' approach to teaching evolution. This pedagogical approach, proponents argue, is necessary because of the scientific community's commitment to ''objectivity'' and ''fairness.'' To exclude some views would amount to the unfair marginalization of an unpopular view. In this antagonism we have, on one side, advocates of IDC arguing that the failure of evolutionary biology to explain certain ‘‘irreducibly complex’’ structures makes necessary the introduction of an ‘‘intelligent designer’’ *as part of the scientific explanation*. These advocates contend that scientists have shunned this explanatory route because of their dogmatic commitment to natural explanations. We also have, on the other side, defenders of evolution who argue that excluding the views of intelligent design creationists is required by science’s methodological rules that a rigorous scientific theory be testable, revisable, and falsifiable. Intelligent design cannot be seriously considered because it cannot be evaluated scientifically.

It is in just this type of antagonism, where the debate has extended to the very correctness of the standards of scientific explanation, that purely epistemic arguments cannot hope to resolve the controversy. For when inquiry is deadlocked at such deep epistemic levels, we *must* address elements of the problem that are *more than epistemic*. We get some clue as to what ‘‘more than epistemic’’ means from Dewey, who wrote that ‘‘All inquiry proceeds *within a cultural matrix which is ultimately determined by the nature of social relations*. The subject matter of physical inquiry at any time falls within a larger social field’’ (Dewey 1938/1991, p. 481). In other words, when epistemic solutions fail we must seek goals that comprise a larger field of common experience.

3.2 Total attitude

We might move toward such common experience by developing what Dewey called a philosophical ‘‘total attitude.’’ This is a response that does more than reiterate philosophical accounts of ‘‘knowledge,’’ ‘‘objective truth,’’ or ‘‘scientific method.’’

> The demand for a ‘‘total’’ attitude arises because there is the need of integration in action of the conflicting various interests in life..... [W]hen the scientific interest conflicts with, say, the religious, or the economic with the scientific or aesthetic, or when the conservative concern for order is at odds with the progressive interest in freedom, or when institutionalism clashes with individuality, there is a stimulus to discover some more comprehensive point of view from which the divergencies may be brought together, and consistency or continuity of experience recovered (Dewey 1916/1985, p. 336).

For example, when we think about creationists and evolutionary biologists it immediately strikes us how differently these groups frame the world, and it seems obvious that their conflict is deeply rooted in their disassociation. However, as Dewey points out, it is a fact for even the most disparate groups that ‘‘in certain fundamental respects the same predicaments of life recur’’ (Dewey 1916/1985, p. 337) and this provides a touchstone for the hope that challenges can be enjoined from the perspective of a single community, despite their many other differences. Our progress toward that ideal, he argues, demands more than just strategic politics; it demands the goal of building of community.

3.3 Achieving total attitude

How can we actually work toward the achieving a ‘‘total attitude’’? We suggest breaking this goal down into four intermediate ones:

The first intermediate goal is to attain an *educated perspective*, which attends to the multiple and particular contexts in which problems emerge so that one can concoct a more nuanced and comprehensive view of the problematic situation. This entails examining controversies as they emerge in their *particular* situations, and not, for example, assuming that a particular type of controversy will automatically manifest itself in the same way in all circumstances. For example, when analyzing the teaching evolution conflict one must avoid the rash conclusion that every such debate is identical. Before ''picking sides'' one must understand the specific forces at play in each individual conflict. So, one might ask: how is science taught *in Ohio*? *In Pennsylvania*? *In Texas*? *Outside of the U.S.?* What are the *specific religions* engaged in these various places? Are their concerns similar or different? In each conflict, what are the relevant economic and political circumstances and how are they ingredients in the case?

The second intermediate goal is to attain a *communal perspective* which emphasizes common interests that transcend periodic conflicts. Such perspectives are forged in conjoint activities that are consciously shared and communicated. In other words, groups in conflict must do more than ''include'' or ''tolerate'' one another; they must engage each other in ways that include sympathetic appreciation of the other's point of view. Doing so can be achieved by identifying more basic points of agreement.

One way to do this might involve actually working on common problems outside the present conflict. For example, both proponents of evolution and of IDC agree that motivating teen interest and literacy in science poses a common problem. Both groups would presumably agree that a healthy environment requires well-educated scientists. Working on those types of common problems can forge intellectual ground useful for more heated areas of conflict. Some of that ground will be philosophical insofar as it will require devising shared ways of describing, at the most general levels, what it is that science discovers and how science can be made more relevant to life.

The third intermediate goal is to develop *exclusion criteria* useful for criticizing groups who would ''opt out'' of social norms. In other words, there *are* limits to the communal perspective just mentioned: we must leave open the possibility that common ground may, in some cases, be impossible to find just because some groups anchor their very identities *on their differences* with others. In our day, as in Dewey's, insularity remains a fount for group identity. As a result, factionalization increasingly dominates our forms of community. This stands in marked opposition to the democratic ideal, where ''democracy is not an alternative to other principles of associated life...[but] the idea of community life itself'' (Dewey 1927/1988, p. 328). We take a great leap toward a ''total attitude'' when we see that democratic life rests upon the qualitative character of a community's constituent social groups—and when we see what social, economic, and technological conditions are responsible for assaults against social cohesion.

The fourth intermediate goal is the formation of such *democratic ideals* through education and communication. These ideals are not antithetical to science; in many ways, the scientific method is one of our best exemplars of democratic action: an open and public search for evidence, subject to correction and emendation by anyone with a good argument, tested and validated by the experience of the widest possible community, and revised as deemed necessary by the intellectual and moral norms of evolving communities. The formation of such democratic ideals depends upon whether we can train our children to think and communicate in ways that are self-consciously imaginative and hypothetical. When education is made up of pedagogies that place a premium on memorization and conformist outcomes we have found a main source of our factionalization. Instead, modeling responsible inquiry begins with learning how to communicate tentatively and experimentally; that is, in a way that allows us to arrest the dumb flux of human events, examine them for possible significance, and devise strategies for coping with problems. The more impoverished our communication, the less able we are to navigate around incongruent principles and values toward common ground and acts of cooperation.

4 Pragmatic strategies

We have suggested that a pragmatic response to controversies in science education involves the goal of achieving a ‘‘total attitude’’ which can be broken down into four intermediate goals. In this section we will discuss three specific strategies for achieving these intermediate goals. In general, these strategies involve ways of thinking about controversial issues, their truth, and their justification. What follows will necessarily be schematic but will describe pragmatic strategies for addressing controversy in science education.

4.1 (Re)defining pragmatic truth

A scientific theory is, according to its defenders, in some sense a *true* account of a natural phenomenon. But what does this mean? Frequently, it is taken to mean that the theory simply provides an accurate description of the facts; that the theory *corresponds*, in some meaningful way, to how the facts really are. Unfortunately, the devil is in the details and, while there is a grain of truth to this idea, it is difficult to explain exactly what this ‘‘correspondence’’ entails—as shown by the extensive philosophical debate on correspondence theories of truth. As these debates show, a naive correspondence theory is most likely incorrect and more sophisticated versions are by no means *obviously* correct, especially given the many Herculean efforts made on their behalf.[1] For this reason, there is an element of bad faith in anyone treating a theory as ‘‘obviously true,’’ as if it *could* be clear to everyone what this means. At the same time, it would be folly to reject the notion of truth entirely: after all, ‘‘truth’’ (in some sense) is a desirable property of a successful scientific theory. As a result, our first strategy is to *pragmatize the concept of truth*.

To see why, it is important to take a step back and ask what purpose is served in calling a theory ‘‘true.’’ To call a theory ‘‘true’’ is to praise that theory: at the most basic level, to call a theory true is to signal that it *works* in a way that an alternative does not. So, for example, one is warranted in calling the theory of evolution ‘‘true’’ because it has led to *results*; that is, because it is the conceptual core of a well-established experimental research program with a track record for finding reliable answers to pending questions. On the other hand, IDC has been a conspicuous failure in this regard.[2]

To focus on the purpose of ‘‘truth’’ is to pragmatize this concept. To say that a true theory works (in something like the way just mentioned) builds upon C.S.

[1] For representative critiques of the correspondence theory see Künne (2003, pp. 126–145) and Davidson (2005, pp. 33–34). A recent and intricate defense of the correspondence theory can be found in Vision (2004).

[2] See, for example, Pennock (1999) and Shanks (2004).

Peirce's claim that truth should be defined as a property of beliefs that would still be believed at the end of inquiry. More specifically, it is also related to recent proposals by Hilary Putnam (1981), Crispin Wright (1994), and Cheryl Misak (1999) that identify truth with some form of long-term durability. According to Putnam, Wright, and Misak, a true belief is one that would stand up to indefinite scrutiny (though their accounts differ on the details). By requiring that a true belief stand up to further scrutiny, these pragmatic theories salvage an intuition that is at the heart of the correspondence theory: namely, that truth is objective. More importantly, these accounts also preserve the intuition that an important criterion of true theories is their ability to both guide, and stand up to, further inquiry.

A pragmatic theory of truth is self-consciously tentative and fallibilistic. To assert that a theory is true, in the pragmatic sense, is to make a prediction about its continued success. It is possible that this prediction will not come true. However, because the concept of truth is here understood in terms of ongoing inquiry, and not in terms of an a priori ''correspondence'' relationship (as Jim Garrison has written in these pages, ''pragmatists generally reject representative realism and any epistemology that describes truth as correspondence to reality'' (1997, p. 544)), a true theory is one that invites further testing and scrutiny. In other words, claiming that a theory is true, in the pragmatic sense, is not the end of the story but rather the beginning: for it to be true it must continue to work, and it is possible that under new conditions a given theory will no longer function successfully. It is important likewise to remember that, unlike beliefs, which can only change so much before becoming a *different* belief, theories can evolve over time while retaining their identity. Thus, a theory can be modified in response to new evidence and, in the process, become increasingly durable. Pragmatically, calling a theory true is to indicate that it is durable and to invite tests of its durability: it is definitely *not* to claim that it is absolutely durable. It would be foolhardy, therefore, to assume that any given theory is *absolutely* durable, or *absolutely* true. To do that would flout the Peircean requirement that true theories be capable of further testing and inquiry.

Understanding and employing a pragmatic account of truth in science education represents one strategy for achieving the third goal mentioned above: having a justifiable means for criticizing groups who opt out of the social norms which have shaped good curricula. A pragmatic theory of truth sets a baseline for what we expect a true theory to be capable of doing. Pragmatically, a true theory must withstand scrutiny and this means, in the present context, that a true *scientific* theory must withstand further *scientific* scrutiny. Theories which evade scrutiny because they are empirically untestable, for instance, or because they cannot be given public scrutiny, thus fail to meet the baseline requirements for being considered candidates for truth. In this way the norm of truth is a necessary condition for communication, investigation, and dialogue: when this norm is not shared by competing parties, further discussion and inquiry is pointless. Thus, proponents of theories which resist scrutiny may be justifiably criticized for lacking the commitment to truth which is a necessary condition for inquiry to take place. In fact, we can justifiably conclude that such proponents are arguing in bad faith; insofar as a purpose of science education is to impart truth, theories that evade or resist scrutiny undermine this very purpose.

While we would hope that most controversies would be resolved through further inquiry, communication, and debate, it is also important to recognize that these efforts have their limits. A pragmatic account of truth offers one strategy for justifiably setting such limits.

4.2 Contextualizing justification as contextual, problem-oriented process

Our second strategy is to contextualize the process of justification. This is because controversies in science education center on *justification*: that is, on the body of evidence and reasons that justify a particular theory as being true. Commonly, a scientific theory is taken to be justified when it is sufficiently well supported by empirical evidence and *only* by empirical evidence. This leads to a foundational picture of science, where high level theories are ultimately supported by low level empirical data which are, themselves, foundational in the sense of needing no further justification. This picture, often associated with positivist models of science (though not all positivists would agree with it), has, of course, been widely questioned by philosophers and other scholars of science. So, once again, it is problematic to claim that a theory is (simply) empirically justified, as if this were the end of it.[3]

To take an example, proponents of IDC have drawn on the science studies literature in order to point out ways in which science is a contingent, value-laden enterprise; in other words, they suggest that scientists, like any other interest group, approach their work with biases built right into their initial assumptions. They point out that scientists' theories are, after all, underdetermined by their evidence and so the choice of theory rests, finally, on their inexplicit biases. In the case of evolution, proponents of IDC use this underdetermination to make room for *their* alternative: if the evidence would support IDC just as well as evolution, they argue, then it seems only fair and honest to give the challenger a shot. In particular, proponents of IDC accuse evolutionary biologists of stacking the deck in favor of naturalistic explanations. This, they argue, is a merely philosophical presumption that arbitrarily excludes non-natural explanations for the origin and development of life. Significantly, they argue, naturalism cannot itself be justified foundationally by appealing to empirical evidence (see, e.g., Johnson 2000).

But naturalism is not merely a presumption, and the arguments in its support are not merely philosophical as opposed to scientific. Rather, a commitment to naturalism is a direct consequence of viewing science as a problem-solving activity. Real, visible problems require real, visible solutions, and naturalism is the requirement that the solutions to scientific problems be describable in terms that appeal to publicly accessible phenomena. Solutions that cannot be empirically confirmed, or that rely on entities whose natures transcend empirical confirmation, are not *scientific* solutions. For these reasons, naturalism is a crucial condition for the scientific legitimacy—and success. This success, in turn, provides justification for naturalism.

Once again, this emphasizes a pragmatic dimension to scientific practice. Treating science as fundamentally a matter of solving problems leads us to emphasize those features responsible for its practical success. In addition, this highlights the contextual nature of scientific practice: that what counts as a real problem will depend on the situation, as will what counts as an adequate solution. In contrast with the usual foundational model of scientific justification, this pragmatic account recognizes a range of factors that may contribute to the solution of a problem. While these factors include the empirical evidence, they also may include a range of additional normative commitments.

Viewing justification as a contextual, problem-oriented process is a strategy for achieving two of the intermediate goals discussed in Sect. 3.3: the goals of achieving an

[3] The classic source of these questions is, of course, the work of Thomas Kuhn (1996).

educated and *communal* perspective. Most obviously, viewing justification in this way furthers the goal of analyzing particular contextual differences between different instances of controversial science. However, in addition, this strategy also provides a basis for discovering common ground that may be used to solve problems, diminish controversy, and achieve consensus. As noted earlier, it is in everyone's interest that science education be as rigorous as possible. But this is justified for contextual reasons: if science were not so crucial in helping us resolve common problems, we could well take a less serious attitude toward it. Instead, it is because of the practical importance of science education—a point on which nearly all can agree—that we should be able to use this as a basis for achieving consensus on those scientific theories which best serve these practical needs. In this respect it is important to remember that proponents of IDC (many of whom, such as the biochemist Michael Behe, have scientific credentials) do not question the importance or practicality of evolutionary theory: in fact, they generally recognize the importance of evolutionary theory to such fields as immunology. Their objection, instead, is to naturalism as the philosophical foundation of evolutionary theory. Our point here, as a result, is that it is a mistake, for both proponents and critics of evolutionary theory, to view naturalism as a philosophical foundation, as if it were a body of *theory*, rather than as crucial condition for a particular kind of scientific problem solving or *practice*.

4.3 Recognizing real controversy

Our third strategy is to recognize that *controversies are real*. This strategy involves frankly recognizing the range of considerations—epistemic, social, ethical, political, and religious—that, as a matter of empirical fact, contribute to making a topic controversial. This strategy is set against the temptation to treat these considerations as irrelevant in resolving the controversy. In other words, we would caution against the assumption that controversies in science education can be easily dissolved because they are not *real* controversies.

For example, some defenders of evolution have argued that evolution, properly understood, poses no threat to religious belief (e.g., Gould 1997). Unsurprisingly, these arguments have not convinced those for whom evolution poses a clear and distinct threat to deeply held religious beliefs. To suggest otherwise, or to suggest that evolution requires only minor modifications to one's religious beliefs, can thus appear patronizing.[4]

Earlier we claimed that the theory of evolution is true in the sense that, in its essentials, it is highly likely that it will withstand any further inquiry. If evolution is true, this does not mean that religiosity is impossible. But it does mean that *some* religious beliefs become more difficult to maintain in light of current science—or at least require additional subtlety and argument on their behalf. More generally, this suggests that science and religion are not, as Stephen Jay Gould (1997) put it, completely ''non-overlapping magisteria'' (though Gould also admitted that ''the two magisteria bump right up against each other, inter-digitating in wondrously complex ways along their joint border''). Our point is simply this: *pace* Gould, for many people the ''net of religion'' does not extend only to ''questions of moral meaning and value.'' For many people, religion also extends to questions of empirical fact, such as the origin of the human species. For them, science *will* pose a

[4] John Dupré (2005, esp chap 4) also argues that evolution poses a challenge to theism in general.

threat to their deeply held religious beliefs, even if scientists and academics tell them it should not.[5] It is simply a fact that many religions *do* make empirical claims, and these claims are a central part of many religions' identity. Without these empirical claims a particular religion would be unrecognizable to many of its adherents.

If religion makes empirical claims then this would suggest that science might have ethical implications—and that it is appropriate that it do so. This is, in fact, the conclusion drawn by philosophers who question whether there is a sharp distinction between facts and values (Elgin 1996). As the distinguished philosopher Hilary Putnam (2004) has argued, facts and values are ''entangled.'' Putnam writes:

> Recognizing that our judgments claim objective validity and recognizing that they are shaped by a particular culture and by a particular problematic situation are not incompatible. And this is true of scientific questions as well as ethical ones. The solution is neither to give up on the very possibility of rational discussion nor to seek an Archimedean point, an ''absolute conception'' outside of all contexts and problematic situations, but—as Dewey taught his whole life long—to investigate and discuss and try things out cooperatively, democratically, and above all *fallibilistically* (2004, p. 45, emphasis in original).[6]

As Dewey recognized (1939/1991) science is guided by value judgments (e.g., that cancer is bad and therefore worth curing) and our value judgments are informed by our scientific understanding of the world (e.g., the legality and morality of lethal injection depends partly on a scientific assessment of the pain involved). The connection between science and values is a result of treating science as a problem-solving activity (see the second strategy, above). According to Dewey, there are no restrictions to the kinds of problems that science, broadly construed, can tackle—and it is desperately important that we tackle social problems with the resources and intelligence of science. As he wrote:

> Science through its physical technological consequences is now determining the relations which human beings, severally and in groups, sustain to one another. If is incapable of developing moral techniques which will also determine these relations, the split in modern culture goes so deep that not only democracy by all civilized values are doomed (1939/1991, p. 172).

It is important to emphasize that this does *not* mean that science automatically trumps other sources of values, such as religion. Other values, such as considerations of justice or fairness, may take precedence in certain situations over scientific values of accuracy or explanatory power. (For example, IRB's are required to balance the

[5] In this regard it is worth noting that Gould first presented his theory of ''non-overlapping magisteria'' in response to a statement by Pope John Paul II affirming the compatibility of evolution with Catholic doctrine. While Gould's (and John Paul's) argument may hold for Catholics, it does not address the continuing tension between religion and science that is still present for many non-Catholic Protestants. Even Gould, in his original 1979 piece, blurred the difference writing, ''John Paul...adds that additional data and theory have places the factuality of evolution beyond reasonable doubt. Sincere Christians must now accept evolution no merely as a plausible possibility but also as an effectively proven fact.'' Obviously many sincere non-Catholic Christians would bridle at the thought that John Paul's words should determine their acceptance of evolution.

[6] Earlier Putnam writes that: ''the point of view concerning the relation between 'facts' and 'values' that I shall be defending in this book is one that John Dewey defended throughout virtually all of his long and exemplary career'' (2004, p. 9).

epistemic goals of clinicians against the moral claims of experimental subjects.) The important point, rather, is that it is possible to study, to inquire into, the disputes that arise between science and religion without claiming, in advance, that these disputes can be straightened out by simply marking the difference between facts and values. Requiring that facts be separated from values is to demand the impossible and, as a result, can be a conversation-stopper that blocks further attempts to bring the problematic situation to resolution.

Recognizing this is an important strategy for achieving the fourth goal mentioned in Sect. 3.3: achieving the democratic ideals of wide understanding and communication. Resolving a controversial issue may require a sophisticated understanding of why it is controversial, and of the fact that there may be no easy resolution. Returning to our evolution example, this does *not* mean that evolution is a genuinely controversial theory: it is, after all, almost universally accepted by working scientists; but even if evolution *itself* is not controversial, there *is* a genuine controversy over its teaching and *this* fact demands understanding (rather than a denial that there is a real controversy in the first place). It is not easy to anticipate how this controversy will be resolved, but it is counterproductive to assume that there is no tension between evolution and some people's religious beliefs. Only by frankly recognizing this tension can it be adequately addressed.

5 Pragmatic approaches to evolution education

Secondary science teachers likely recognize their responsibility to encourage all children to become scientifically literate, but they are not usually aware of the goals which situate that literacy in a democratic ''total attitude.'' The arguments presented earlier in this article provide structure for thinking about instructional and curricular decisions that are informed by the pragmatic ideals of community and democracy. To illustrate the practical application of these goals and strategies, we will discuss some of the choices made by secondary school science teachers in relation to controversy.

As stated previously, human sexuality, cloning, global climate change, and other science topics carry controversial profiles, but one particular topic, biological evolution, has been credited as the most contentious issue to surface in the American public science classroom (Cracraft and Donoghue 2004). For that reason, as well as others, evolution is an appropriate topic to select as a basis for discussion of controversial issues. The controversy historically applied to evolution stands in ironic contrast to evolution's relatively unquestioned acceptance by scientists as the cornerstone of biology, and a unifying theme that marries the domains of science (American Association for the Advancement of Science 1990, 1993, 2002; National Research Council 1996; National Science Teachers Association 2003).

This odd juxtaposition—hotly controversial, socially, yet scientifically essential—makes biological evolution a particularly challenging science theme to plan into classroom curriculum and instruction. Classrooms, unlike the working environments of practicing scientists, represent the intersection of science and society. Teachers must, therefore, plan with, around, or through the controversy that will potentially surface in the classroom.

5.1 Nature of science, controversy, and classroom relationships

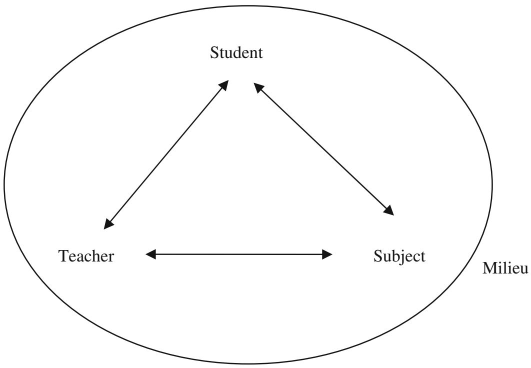
Science education researchers agree that the best way to teach evolution specifically, and science broadly conceived, is to incorporate the nature of science (NOS) into the curriculum (Abd-El-Khalick and Lederman 2000). By explicitly, and integratively, bringing NOS into science teaching, students will come to understand and situate science in its scientific as well as its societal contexts, both of which are required for a sophisticated understanding of the controversy associated with evolution (Khishfe and Lederman 2006). Specifically defined, NOS instruction helps students to come to know science as

> tentative (subject to change); empirically based (based on and/or derived from observations of the natural world); subjective (influenced by scientists' background, experiences, and biases); partly the product of human imagination and creativity (involves the invention of explanations); and socially and culturally embedded (Khishfe and Lederman 2006, p. 396).

These NOS qualifiers are well aligned with the pragmatic strategies toward "total attitude" which involve close consideration of the meaning of scientific truth, means of justification, and context-bound nature of problem solving.

Not surprisingly, science teachers may be wary of controversial issues but will, inevitably, come to some decision regarding how, or if, they will teach controversial topics (Sadler et al. 2006). Certainly, anyone who becomes a biology teacher will face the question, "How will I teach evolution?" A complete answer to this question emerges only from making an allowance for all of the complex layers involved in classroom decision-making. The most proximal of these layers is the teacher's own personal beliefs and understanding of evolution. Previous studies of pre-college evolution education indicate that the primary factors influencing a teacher's decision to emphasize evolution are personal religious beliefs and knowledge of evolution (Aguillard 1999; Ellis 1983; Fahrenwald 1999; Osif 1997; Shankar and Skoog 1993; Tatina 1989; Zimmerman 1987). The next layer of consideration includes contextual factors, such as the teacher's perception of the students', parents', and community's beliefs and the degree of support that they have from their school administrators and peers (Bilica 2001; Bilica and Skoog 2004). The teacher must also acknowledge and act upon the learning needs, beliefs, and attitudes of the students. Planning for a classroom that maintains positive social relationships as well as connects the learner to the subject matter can be especially challenging when controversial topics surface.

Fig. 1 Schwab commonplaces model of curriculum (1973, 1983)



Schwab's (1973, 1983) conceptualization of classrooms as dynamic systems consisting of the teacher, student, subject matter, and the contextual milieu constitutes our theoretic structure for examining the relationships within the science classroom (see Fig. 1). This diagram shows that the three proximal classroom components are the student, teacher, and subject matter all of which are affected by the contextual milieu. These commonplaces, as Schwab called them, are equally important and inextricably linked so that decisions that influence any single component will impact the other components. We discuss the controversy associated with teaching evolution as a *science education* issue—because the controversy exists as an example of the impact of the milieu on the classroom environment. The controversy directly and indirectly influences teachers' instructional and curricular decisions.

The Schwab Commonplaces model permits us to study the manner in which teachers' decisions about curriculum and instruction impact the inter-dynamics of the classroom. For example, the model offers a way to visualize secondary students' perceptions of their science teacher and science as a subject matter. Relationships at the secondary level of education are unique in that secondary students tend to view their teacher as the embodiment of their particular subject matter, and for a many students, their conceptions of, say, chemistry, will be inextricably linked to their feelings about their high school chemistry teacher. Because of this association, teachers must carefully and tactfully manage relationships with students and content, especially when incorporating potentially controversial topics into the curriculum. Conflict that occurs as a result of a controversial topic, especially a planned lesson on a controversial idea, can sometimes be perceived by students as resulting from the teacher's personal belief system or ''agenda.'' The close relationship between teacher and content can also place teachers in a situation to feel as though they may be under attack or must personally defend particular scientific ideas.

5.2 Teaching evolution: choices and consequences

In an attempt to negotiate controversy, teachers make instructional choices that can potentially, often inadvertently, perpetuate controversy, becoming part of the problem rather than a solution. Scharmann and Harris (1992) identified several ways in which teachers manage classroom controversy—including teaching evolution without mentioning ''evolution'' specifically, teaching evolution as dogma without the opportunity to learn about the controversy, or even avoiding evolution altogether. These instructional decisions have the short-term effect of reducing the heat of controversy in the classroom, but in the long-term, they also render learning ineffectual.

By examining teachers' responses to controversy surrounding the teaching of evolution (and the introduction of IDC to curricula; Bilica and Skoog 2004), four distinct types of instructional approaches have been identified. These include (1) avoidant approaches, (2) corrosive (dogmatic or passive) approaches, (3) teaching about controversy, and (4) proactive, pro-social approaches.

5.2.1 Avoidant approaches to teaching evolution

Avoidant approaches include both direct and indirect attempts to strategize around controversy. For example, teachers can avoid introducing controversy into the classroom if they omit evolution from their biology curriculum; leave evolution until the end of the year, when time may limit students' exposure; or teach only the non-controversial topics within evolution, thus avoiding the potential conflict that may arise by teaching about human evolution or origins of life. In the short-term, avoidant strategies effectively deflect conflict because the teacher carefully controls the content that is permitted into the curriculum; however, according to a pragmatic examination of this strategy, it does not meet the educational aim to prepare students for participation in a democratic society. By avoiding particular topics, especially topics that are as fundamental to understanding science, the teacher has controlled a student's exposure to controversy for *now*, but not for the future. Students leave the avoidant science classroom undereducated. As Moore (2001) states, avoiding evolution in the biology classroom is equivalent to committing educational malpractice.

Of the four approaches identified, the avoidant approach is possibly the most detrimental, as it denies a student the opportunity to learn science, not by their own choice, but by the choice of the teacher. Such decisions are not likely made out of malice on part of the teacher. If the teacher made a choice to avoid evolution because of personal beliefs—that evolution is against the teacher's personal religious beliefs—then this would be an illegal act. If the decision was based on a rationale that by avoiding evolution, the teacher consequently avoids conflict, the teacher permitted classroom management to trump science literacy. A fortunate indirect effect of the accountability movement, though, has been to encourage teachers to include evolution in the curriculum, as it is often present in state standards and therefore state examinations (Skoog and Bilica 2001). Avoidance approaches are not applied as frequently as they might have been prior to the standards movement of the late 1980s.

5.2.2 Corrosive approaches to teaching evolution

Teachers who teach evolution as dogma, or, conversely, tell students that they don't have to "believe" evolution, are using corrosive instructional approaches. Corrosive strategies have the net effect of corroding either the student–teacher relationship or the student–science relationship. These relationships are represented by the connective arrows between the student and teacher or the student and subject matter on the Schwab Commonplaces model in Fig. 1. To further illustrate, a particular classroom approach has the potential to position one relational dyad (student–teacher) against another (student–subject matter), thus shifting the relationship in the classroom.

In a dogmatic-corrosive classroom, teachers will tend to teach evolution as "absolute truth," regardless of the possibility that some students may perceive scientific truth as existing in opposition to their personal religious truth. Teachers who employ dogmatic-corrosive methods will not just avoid controversy, as with the avoidant approach, but will *deny the existence of controversy* entirely. Dogmatism (as well as avoidance) is wrapped in issues of control and power (Farber 2003). Avoidance attempts to control behavior by altering content; dogmatism attempts to control ideas by advancing a narrowly defined conception of truth. Dogmatism, in particular, has the unfortunate effect of polarizing a classroom and degrading the student–teacher relationship. Dogmatic teachers can become targets of conflict related to controversial issues.

The second type of corrosive approach, passive-corrosive, also denigrates relationships, but in this case, it corrodes the student–subject matter relationship. When teachers tell students that they ''have to know evolution but don't have to believe it,'' they have, inadvertently or not, reduced the role of biological evolution from a central, unifying theme and cornerstone of biology to a sound-bite of non-essential information to store away. This passive-corrosive approach implies to students that science is an unsound way to inquire into the natural world.

Smith and Siegel (2004) address the role of belief and understanding in teaching science through a philosophic deliberation on the meaning of these concepts and their alignment with the goals of science education. One conclusion from their deliberation was that the goal of science education is scientific understanding, not belief. From this, one might extrapolate and say that a teacher's ''don't have to believe'' statement is perfectly appropriate in the context of controversy.

Interestingly, the results of our analysis of passive-corrosive approaches are not in conflict with the Smith and Siegel conclusion. What differs between their study and our examination is the teacher's *attributed rationale* for using the statement, ''You don't have to believe evolution....'' If the teacher extends the statement by offering a lesson that introduces students to the role of belief in scientific discovery, the teacher would be using a NOS strategy, not a passive-corrosive approach.

However, there is another possible rationale for a teacher to tell students that they don't have to believe: to diffuse potential classroom problems that may emanate from a conflict between evolution and students' religious beliefs. Used in this way, the ''don't have to believe'' statement ceases to be educative and becomes, instead, a disclaimer not unlike the disclaimer attached to textbooks in Cobb County, Georgia. This demeans the scientific value of evolution (and science as a whole) and builds ideological obstacles for students who hold a naïve understanding of the NOS. The passive-corrosive approach can potentially undermine the value of science as a way of knowing and can be seen as a conspiratorial tie between teachers and students, at the expense of scientific literacy.

5.2.3 Teaching about controversy

A third approach, teaching about controversy, has some support from professional science educators (Scharmann 1994, 2005; Staver 2003) and has been effectively employed in some non-public or religious institutions as well as in college-level science and science teaching courses. This approach should not be confused with the ''teach the controversy'' tactics employed by proponents of IDC. This IDC strategy challenges naturalism in science, leveraging for a place in the secondary science curriculum to teach intelligent design. The aim of the IDC-derived approach is to sabotage evolution and incorporate non-scientific ideas into the science curriculum.

The ''teaching *about* controversy'' approach, entirely unlike the IDC strategy, is research-derived and intended to engage students in an exploration of their personal feelings, thoughts, and beliefs in relationship to the controversy associated with biological evolution. Putting the controversy at the forefront will, according to its supporters, manage social relationships, provide a safe space for students to learn, and acknowledge the social context of the controversy in explicit ways (Scharmann 2005). For example, as part of a ''teach about controversy'' lesson, students respond to questions such as:

1. Consider what you have read or been taught about evolution and summarize your understanding.
2. Are you personally aware of any explanation(s) that may differ with evolution theory in interpreting the present diversity that we see in nature?
3. Is there anything about evolution theory that causes you personal concern? (Scharmann 2005, p. 14)

A "teach about controversy" approach does not deny the value of science as a means of understanding and exploring the natural world, but it caters to the social controversy that students have likely encountered.

This approach *seems* proactive in that it acknowledges the existence of controversy and gives students the chance to voice their opinions on the matter; however, this approach has a strong potential to backfire on good instructional intentions. By taking classroom time to introduce non-scientific ideas into the science classroom, such as would likely be the case with the questions presented above, the teacher has created an environment where science and non-science ideas are placed into a form of competition, not unlike the debate-style lessons which have been discouraged as well (Bybee 2000). The typical science classroom is full of restrictions—lack of time, too much content, increasing testing pressures—and does not offer sufficient opportunity to explore, compare, and come to understand the deep meaningfulness of the controversy. Further, one must ask if secondary students taking a biology course, often freshman or sophomores in high school, have the capacity for abstract thinking required to understand the nuances of the controversy.

One potential positive outcome of a short-term unit on controversy and evolution may be that students will be engaged and motivated and may remember the lesson later in life. But will the learning outcome also be achieved? Will the student have the sophistication to discern science from non-science as a result of this unit? And when asked to develop an opinion about matters related to science, such as the intelligent design debate, will these individuals perceive science and non-scientific ideas as carrying equal scientific merit because they were both "taught" in the science classroom?

The net effect of a "teach about controversy" approach could be what we currently see in contemporary society—a dichotomization of science and religion. Debates and lessons intended to "teach about controversy" may perpetuate conflict between these two domains of knowing. Further, since the 1987 *Edwards v. Aguillard* Supreme Court Decision, creationism could no longer be presented as a viable scientific explanation for life's origins in public classrooms (Matsumura 2001; National Science Teachers Association 2003). A "teach about controversy" approach, while seemingly a student-centered choice, could perpetuate student misconceptions and even lead to situations in which a teacher's professional credentials are questioned.

5.2.4 Proactive, pro-social management

A fourth approach, promoted by professional organizations in science and science education, is proactive, pro-social management (American Association for the Advancement of Science 1990, 1993; National Research Council 1996; National Science Teachers Association 2003). Proactive approaches take place when the teacher is aware and acknowledges the social controversy as part of the curricular and instructional *planning*, but does not actually *teach* the controversy as part of the classroom experience. Instead, the teacher purposefully designs the curriculum so that it places a special focus upon the special qualities of science, not in opposition to other ways of knowing, but in a manner that helps students to discern scientific and non-scientific methods of inquiry and questioning. The proactive approach encourages an ongoing, long-term distinguishing between natural and supernatural explanations. The goal is to help students to understand science by studying what makes science unique as a field of research. It does not advocate any exploration of non-scientific ideas beyond highlighting the fact that there are many ways of knowing, but that science is the way that we study the natural world. This approach is in close alignment with the NOS recommendations for improved science literacy (Abd-El-Khalick and Lederman 2000).

Within the long-term, academic year curriculum plan, the teacher who uses a proactive approach will take every opportunity to highlight the activity of science—and the value of using scientific methodologies to explore the world (Staver 2003; Scharmann and Harris 1992). At the same time, the teacher will also encourage students to identify the types of questions that can be answered by science, thus distinguishing science from other ways of knowing (McComas 2004).

A proactive approach does not deny the value, import, or usefulness of other ways to explore the world (philosophically, theologically, aesthetically, historically), but it does assist the student to develop an appreciation for all types of knowing (Nord 1999). It is beyond the scope of the science classroom to deeply engage students in religion, art, philosophy, history—but proactive teachers can represent the democratic ‘‘total attitude’’ about living in society, as discussed in Sect. 3.3. Communities of understanding—scientific and non-scientific—make up the communal society, representing the second pragmatic goal (Sect. 3.3)—transcendent, community values. Additionally, alternate ways of knowing becomes the exclusion criteria, identifying non-scientific ideas as important, but not the domain of science (the third pragmatic goal). The ‘‘total attitude’’ does not have to deny or trump other ways of knowing (necessarily), but can augment or complement the growth of students in holistic, meaningful ways (McComas 2004).

The phrase, ‘‘proactive management’’ has been applied to approaches that we would classify as ‘‘teaching about controversy’’ (Scharmann 2005; Scharmann et al. 2005; Smith and Scharmann 2006). These well-researched approaches do, indeed, share the common aim to encourage teachers to make educated and communal decisions about controversies. They also both encourage a strong focus upon NOS as integral to science learning. The two approach types diverge, though, in what counts as *exclusion criteria*. The study of personal, non-scientific beliefs is acceptable, even encouraged, in the ‘‘teach about controversy’’ approach; whereas, the proactive approach described here would highlight science and its limitations by positioning science as one among many ways of knowing, but special in its ability to know the natural world.

To conclude, pragmatic approaches to highly controversial ideas are situated and intentional, often challenging us to negotiate in the context of the secondary classroom. Decisions that classroom teachers make about their approach to science issues—controversial or not—can be predicated on the greater goal of helping young people prepare for the complexities of interacting in a culturally diverse global community. Democratic goals for science teaching and learning are not so different from the goals of other subject areas, but science education is our opportunity to showcase the value of science—as a way of knowing and inquiring into the natural world—and to help students to find a niche for science in their own lives.

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