Scientific Argument and Explanation: A Necessary Distinction?

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ABSTRACT: In this paper, we argue that there is an emergent confusion in the literature in the use of the terms "argument" and "explanation." Drawing on a range of publications, we point to instances where these terms are either used inappropriately or conflated. We argue that the distinction between these two constructs is, however, important as a lack of clarity of fundamental concepts is problematic for a field. First, a lack of common conception hinders effective communication and, second, it makes defining the nature of the activity we might expect students to engage in more difficult. Drawing on a body of scholarship on argument and explanation, this paper is an attempt to clarify the distinction and to explain why such a distinction might matter. © 2011 Wiley Periodicals, Inc. *Sci Ed* **95:**627–638, 2011

INTRODUCTION

This paper is an attempt to address an emergent confusion in the literature and policy documents between the concept of an argument and the concept of an explanation. Why it might be asked, is this necessary? During the past two decades, the potential role of argument in formal science education for learning has been a significant focus of research (Lee, Wu, & Tsai, 2009) with work conducted within psychology (Asterhan & Schwarz, 2007; Billig, 1996; Howe, Tolmie, & Rodgers, 1992; Kuhn, 1991) and within science education (Bell & Linn, 2000; Clark & Sampson, 2007; Driver, Newton, & Osborne, 2000; Erduran & Jiménex-Aleixandre, 2008; Osborne, Erduran, & Simon, 2004; Zohar & Nemet, 2002). Some of the focus of this work has been not on argument per se but rather on students' ability to construct explanations (McNeill, Lizotte, Krajcik, & Marx, 2006; McNeill & Krajcik, 2008; Sandoval, 2003). Drawing from an examination of these and other papers, our concern is that there exists a lack of clarity around the meaning of

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the word "explanation" and "argument." We wish to argue, moreover, that the failure to distinguish between these two concepts is a weakness in the field. For, if a field lacks clarity about the concept that it seeks to explore and promote as a feature of classroom practice, then it will fail to communicate its meaning and intent to the wider audience of curriculum developers, standards developers, and teachers.

Indeed, we would point to other areas where the lack of a clear construct has led to considerable confusion in practice. For instance, the construct of "scientific literacy" has permeated much of the literature on science education ever since it was first coined by Paul DeHart Hurd (1958). As a notion, it underpinned many of the arguments of the Science, Technology and Society (STS) movement of the 1980s (Aikenhead, 1994). Its goal was "to develop scientifically literate individuals who understand how science, technology, and society influence one another and who are able to use this knowledge in their everyday decision-making" (National Science Teachers Association, 1982). However, the lack of any clear definition of the concept enabled DeBoer (2000) to identify nine differing uses of the term leading him to suggest generously that there are many routes to scientific literacy. A harsher view would be that such diversity of use results in a term that has little meaning other than articulating a broad goal of science education that represents a wide range of the potential needs of the future citizen. Similar arguments could be made about the general use of the term "inquiry" as a pedagogic approach where broad definitions of the term have led to considerable diversity in what is understood by the notion of "teaching science through inquiry"(Abd-El-Khalick et al., 2004).

However, the main need for clarity in the concepts that guide a research field within education comes from the fact that "*assessments operationalize constructs*" [author's emphasis] (Wiliam, 2010). What Wiliam points to is that test items embody the test writer's conception of the skill that satisfactory performance measures. Clearly, if the author of a test item holds only a diffuse conception of the features of argument and/or explanation, it is more likely that its intent will be unclear both to the student who is required to respond *and* to teachers who read assessment items for insight into the true nature of the intended curriculum. Clearly, if test writers hold a flawed or erroneous conception, the situation is even more problematic. Therefore, given the contemporary focus on the role and value of argument in science education (Lee et al., 2009), and its promotion as a valued activity within the science classroom, we would contend that it is vital that, as a field of intellectual endeavor, we have clarity about the concepts of argument and explanation. Moreover, it is the responsibility of the science education community to define the nature of the construct that we would wish to see enacted rather than allowing an inappropriate conception to emerge through the interpretation and efforts of those working in educational assessment. What follows, then, is an attempt to clarify and reify a necessary distinction.

THE ESSENTIAL FEATURES OF EXPLANATION AND ARGUMENT

While we recognize that the distinction between argument and explanation might seem subtle to the reader, our intention is to demonstrate that it is not only significant but also important. We begin by sketching the essential difference between these two discursive acts. In developing our argument, we recognize that the issue of how explanation functions is both complex and difficult. For instance, explanation is variously seen as deductive, statistical, causal, linguistic, and even pragmatic or context dependent (Thagard, 2008). The theoretical issues of how explanations work are, however, not the focus of this paper nor would we attempt such an ambitious project. Suffice to say that the particular view adopted here is that the bread and butter explanations of school science are causal, for example, why do things fall, why is matter conserved, or how does photosynthesis happen (Salmon, 1998).

Key to the distinction between explanation and argument is that an explanation should make sense of a phenomenon based on other scientific facts. Thus, explanations begin with a statement of the *explanandum*—the feature or phenomenon to be explained that is often phrased as a question, for example, why did the dinosaurs die out or why do we have seasons? A defining feature of an explanation is that the phenomenon to be explained is not in doubt. Nobody disputes that dinosaurs no longer exist or that seasons occur. Explanations therefore are essentially answers to questions and explanations "explain by describing how the explanandum came to be" (Ohlsson, 2002). From this perspective, explanations consist of a subset of descriptions where new entities or properties are brought into being or invented to provide a causal account. Thus, the dinosaurs became extinct because an enormous meteorite threw a large amount of dust and ash into the atmosphere (a descriptive statement) that caused a sudden temperature drop on the earth's surface (a descriptive statement). As both Wilson and Keil (2002) and Brewer, Chinn, and Samarapungavan (2000) point out, such explanations "work" because they generate a feeling of increased understanding accounting for the genesis of the phenomenon. From a philosophical perspective, they are coherent with the known data. Given that a defining characteristic of school science is the *offering* of well-established explanatory accounts of the material world, one measure of its quality then is the extent to which it achieves this sense of increased understanding.

In an argument, however, there is not so much a feature or behavior to be explained but a claim to be justified—in the case of Wegner's explanation for the shape of the continents—whether the data were consistent with his proposed explanation. Consequently, there is always a substantial degree of tentativeness associated with any argument and, without this element, there would be no necessity for the argument itself. For instance, imagine the dilemma posed for Europeans on first seeing ostriches. "Are these birds?" they would have asked. They have some of the essential features of birds, that is, wings but do not appear to be able to fly. The resolution of this uncertainty requires an argument and not an explanation. Similar arguments have surrounded the question of whether Pluto is, or is not, a planet. Their resolution rests on the definition of what a bird or planet is and not on an explanation. An explanatory hypothesis and the argument for it, however, are distinct entities. Explanations are an attempt to "to make plain or intelligible; to clear of obscurity or difficulty" (Oxford English Dictionary, 1989) and are constructed not out of data and warrants but from models and representations of reality. For instance, Wegner was forced to invent the idea that massive continents were "floating" on the rock beneath and had simply drifted apart. The lack of coherence with the then current geological understanding was the substance of the argument that led to the rejection of his explanation.

Some of the confusion arises because arguments are essential to the process of justifying the validity of any explanation as there are often multiple explanations for any given phenomenon. Some of these explanations are completely false, and others may fail to explain. Explanations are judged, however, by arguments about the extent to which they are coherent, plausible, and comprehensive (Thagard, 2008). The two are, however, not one and the same thing. Rather there are two discursive entities: the explanation that attempts to account for the given phenomenon, and an argument that examines the question of whether the explanation is valid—that is, whether it succeeds in generating understanding and whether it is better than competing accounts. The focus of any argument around an explanation, therefore, is on the claim that Explanation A is in a satisfactory/unsatisfactory explanation, or that Explanation A is a better explanation than Explanation B—and not the explanation itself.

EXAMPLES OF THE CONFLATION OF ARGUMENT AND EXPLANATION IN SCIENCE EDUCATION

In our work, we have identified several instances of the conflation of these terms. For instance, McNeil and Krajcik (2008) in their work on characterizing and evaluating teachers' instructional practices with scientific explanations state explicitly that they have chosen to use the word "explanation" for the discursive actions they examine. They do so to align their work with the national and state science standards that their teachers need to address and state that their goal is "to help students construct scientific explanations about phenomena where they justify their *claims* using appropriate evidence and scientific principles" (p. 54) (emphasis added). Such statements would appear to conflate the notion of a claim—which is a feature of an argument—with the features of explanation such as scientific principles. Later, these authors characterize a scientific explanation as a linguistic construct, which contains three elements (emphasis added): "a *claim* (a conclusion about a problem); evidence (*data* that supports the claim); and reasoning (a *justification*, built from scientific principles, for why the evidence supports the claim)." Similarly, Ruiz-Primo, Li, Tsai, and Schneider (2010), drawing on the work of McNeill and Krajick, argue that "scientific explanations should connect patterns of *data* with *claims* about what the data mean" (p. 586). However, "claims," "data," and "justifications" are the elements of an argument (as defined by Toulmin, 1958) and not those of an explanation (see Figure 1)—a distinction on which we will elaborate later.

Other examples where such conflation can be found are in the new College Based Science Standards (College Board, 2009), which define a scientific explanation as "a statement that is composed of the following: at least one claim, the evidence that is related to the claim, and the reasoning that makes clear the nature of the relationship between them" (2009, p. 6). Once again, we would contend that these are the elements of an argument rather than an explanation and that such definitions misconstrue the nature of explanation. Berland and Reiser (2008) do at least recognize that there is a distinction between argument and explanation seeing these as complementary elements arguing that a school science should provide opportunities to construct and defend explanations. Later in the paper they conflate the two, however, when they state that the claim ("some birds survived because they ate a specific plant") is an explanation as "the three components of claim, evidence, and reasoning are clearly identifiable in this presentation." While we would agree that this statement is an explanation, it is not because it contains these elements, as "some birds survived" is a statement of fact and not a "claim." Likewise, the statement that "they ate a specific plant" is not so much "data" as essentially a descriptive statement, which provides a reason why some birds could survive.

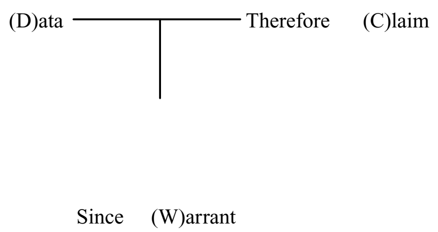

Figure 1. Diagrammatic representation of argument.

THE DIFFERENCE BETWEEN ARGUMENT AND EXPLANATION

The Nature of Explanation

Scientific explanations attempt to answer three questions: what we know (the ontological question), why it happens (the causal question), and how we know (the epistemic question) (Ogborn, 1988).[1] The first of these questions is largely amenable to descriptive answers at the macroscopic level. At the microscopic level, however, teachers of science are forced to construct macroscopic models and use metaphor and analogy to realize new objects such as cells, atoms, and molecules that are demanded by explanations (Harré, 1986; Ogborn, Kress, Martins, & McGillicuddy, 1996; Treagust, Harrison, & Venville, 1996). Conversely, such resources are also required for phenomena that are too large to conceive of such as the age of the Universe, which is commonly conceived of as a 24-hour clock with humanity only present in the last minute. As for the third of these questions, research would suggest that little space is commonly devoted to any explanation of how we know what we know within formal science education (Newton, Driver, & Osborne, 1999). Rather, the predominant focus of classroom discourse is on the second question, constructing causal accounts of phenomena.

What is to be explained, however, is an a priori given—in the case of the example drawn from Berland and Reiser's work, the phenomenon in need of explanation is the fact that "some birds survived." To put it simply—explanations are driven not by the need to persuade or to advance a claim to knowledge but by the desire to answer the question "Why?" (e.g., Why is the sky blue?). Driving the need for explanation is the presupposition that the phenomenon occurred (e.g., that some birds survived, the sky is blue, or that it rained yesterday)—none of which are statements in need of evidence to establish their validity. The fact that the sky is blue is, after all, beyond doubt. Explanations answer such questions by invoking an ontological zoo or cast of imagined entities—what Ogborn et al. (1996) consider to be "protagonists," which enact a series of events—in the case of Berland and Reiser's example the protagonist is "specific plants which enable eating." Such features are considered linguistically to be the "explanans"—the element that makes plain. In the case of why the sky is blue, the explanans are the notion that light is a wave, that the air consists of molecules, and that molecules scatter light, etc.

A notable characteristic of explanations then is that the entities invoked to explain have less certainty than the "explanandum"—the fact to be explained. The explanandum is generally presumed to be true, and facts derived either from observables, laws, or theories are provided as the premises of the reasoning that makes plain what is being explained. Thus in seeking, for instance, to explain how living things reproduce, the function of the heart, or why it rained today what is not in dispute is that living things *do* reproduce, that mammals *do* have hearts, or that it *did* rain today. Here, the explained statement has more certainty than the statements used to explain it (Govier, 1987). Explaining why it rained today requires the invocation of features such as low pressure, cold fronts, and the effects that occur at boundary layers between air masses to provide a causal account, and to make explicit the reasoning to an audience.

It is the presence of these features that makes the statement advanced by the students in Berland and Reiser's (2008) study an explanation. The statement does not contain a claim (in that it is tentative) nor data. Hence, it is not an argument. Rather, the argument to be had

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[1] It is perhaps worth noting that explanations in science also address what might be considered the technological question "what can we do with such knowledge?" as well as the linguistic question of "how do we talk about these ideas?"

is the issue of whether the explanation offered by the students in Berland and Reiser's study is a valid explanation—an argument that must be judged by criteria that are transcendent to the statement itself such as whether there is a more plausible explanation or one that is more comprehensive. For instance, historically, the reason the Copernican account replaced the Ptolemaic account was not so much that it provided a better fit with the data, as initially it did not. It is rather that Copernicus' account met a basic requirement of parsimony doing away with the need to invent the additional element of epicycles required to explain the retrograde motion of planets (a feature not required by the Copernican explanation). While the invention of epicycles might account well for retrograde motion, the problem for Ptolemy's adherents was answering the question of why they existed. In short, the Ptolemaic system violated the notion of parsimony embodied in Occam's Razor and was seen to be inferior.

Govier (1987), for instance, offers the following example of the distinction between argument and explanation with the following syllogism:

1. Doctor Smith has predicted that Susan will catch the measles.
2. Doctors are almost always correct when they predict that children will catch the measles. Therefore,
3. Susan will catch the measles.

Statement 3 is a logical deduction from the premise provided by Statement 2. As such, most would concur it is a valid argument as the data on which it draws are not readily contested. However, this argument does not provide any explanation as to why Susan will catch the measles. As Govier points out, "even if we wanted to explain why Susan will probably get the measles, the expertise of doctors would not be the right sort of factor to refer to—exposure to others, or failure to get vaccinated would" (1987, p. 165). Indeed to fully explain the occurrence of measles, we are forced to imagine a tiny self-replicating organism called a virus, which enters the human body, which in turn produces a unique immune reaction. Such an explanation does not require an argument unless we are called on to provide the evidence that might justify either the entities or the process invoked.

Providing Explanations and Constructing Explanations

Providing explanations is the bread and butter of the science teacher's existence. The explanations that teachers offer their students are not tentative claims about the world but rather an account that, within the scientific community, is beyond doubt. Ultimately, all explanation bottom out at a point beyond which there is no point in asking repeated questions of "Why?"—a point achieved because we are satisfied that we have perceived the essential nature of things and where further elaboration would add nothing. As Cartwright (1983) and Ogborn (1992) argue, this ultimately makes explanation viciously circular—things are as they are because that is how they are. A case in point is the explanation of why things fall. To explain this commonplace event, we have invented a mysterious attractive force of gravity that acts between all objects in the Universe. In one sense, this explains but only if you are content not to ask why does the force of gravity exist, why is it only attractive, and how is it propagated? Even if these questions are pursued, there comes a point at which no new information is added.

Ohlsson (2002) argues that the foundation of all explanations is generative relations, which attribute the existence of the explanandum to a set of factors that produced the phenomenon. Thus, objects are said to fall because of gravity, the weather was bad because the air pressure was low, and the plant died for lack of water. These relations can be expressed diagrammatically in the following form where the arrow is equivalent to “can be attributed to”:

Gravity → Falling
Bad weather → Low pressure
Plants dying → Lack of water

Complex explanations are dependent on multiple generative relations. That is, the generative relations that form the explanations are themselves dependent on prior explanations, which are seen as being “primitive” with respect to the explanation itself. Thus, the relation *lack of water causes death* is a primitive for most people. Or the notion of “collisions causing damage” forms the primitive, which explains why the Titanic sank when it hit an iceberg and can be represented diagrammatically as

Titanic sinking → Collision with an iceberg → Collisions cause damage

Some of the confusion surrounding argument and explanation is a consequence of the fact that scientists are in the business of constructing explanations. Likewise, teaching science through a process of inquiry will also require students to engage in some form of approximation to this process. Undoubtedly, the process of *constructing* new explanations is distinct from that of offering well-established explanations. In constructing an explanation, it is necessary for scientists (and students) to draw on prior knowledge and existing primitives to assemble an explanatory hypothesis. Such elements might be seen by some as the data and warrants of an argument. However, this would be to confuse the goal of an argument—to justify a claim to knowledge—with the goal of an explanation to account for a consensually agreed fact or phenomenon to be explained—the explanandum. Thus, the essential difference between the two linguistic acts—argument and explanation—lies in their epistemic function. One, explanation, seeks to make plain, to generate that sense of increased understanding, whereas the other, argument, seeks to justify a claim to knowledge or to persuade.

The Nature of Arguments

Arguments attempt to justify conclusions that are equivocal or uncertain with a claim that is supported by the data, which act as the premises for the claim. The warrant acts as a linking phrase that elucidates how the data support the claim. Drawing on the notion of argument as a form of informal reasoning, Toulmin[2] (1958) provided a useful analytical model of argument:

> Whereas the goal of scientific explanation is to provide a causal account of events in the material world, argument seeks to use data and warrants to justify belief. Having different goals, the two linguistic structures have different criteria for their evaluation.

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[2] While we recognize that there exist other approaches to the analysis of argument, e.g., Walton (1996), Toulmin’s model of informal reasoning is the predominant model that has been used in science education (e.g., Driver et al., 2000; Jiménez-Aleixandre et al., 2000; Erduran et al., 2004; Berland & Reiser, 2009). More specifically, it is the model used in the articles where we note the original conflation (Sandoval, 2003; McNeill et al., 2006; Krajcik et al., 2008). Other approaches such as the pragma-dialectical theory of Van Eemeren and Grootendorst place an emphasis on the process (argumentation) rather than the product (the argument), which is the focus of this article (Van Eemeren & Grootendorst, 1984).

In argument, we attempt to reason from the data to a conclusion using appropriate warrants. Taken together, the data and the warrants form the substance of the evidence for the validity of our claim. Thus, an argument is a statement where the premises are stated as a means of proving or justifying a conclusion (Govier, 1987). With arguments, the most certainty lies within the premises that provide a justification for a less certain conclusion. According to Brockriede and Ehninger (1960), the characteristic of an argument then is a diminishing degree of certainty from "accepted data through a warrant to a claim." The goal of the arguer, then, is to provide incontrovertible warrants that support the claim and to show that it is a justified belief. For instance, Darwin's observations of the diversity of the form of the beaks of finches on the Galapagos are unquestioned. From these, he constructed an explanatory hypothesis—that of evolution by natural selection. The elaborate argument that he used to justify this hypothesis in his book *The Origin of Species,* is that this explanation is more coherent with the data—an argument that remains controversial to this day. Darwin essentially used well-accepted data to support his argument that his tentative explanatory hypothesis was the best possible explanation for the multitude of forms of life on the earth.

Because the pragmatic direction is from premise(s) to tentative conclusion(s), arguments have a sense of directionality. The more unequivocal and unquestioned the premises of an argument, the stronger the sense of directionality and the more likely it is to persuade. In contrast, in an explanation, the explained statement is often more certain than the explaining statements. For instance, no young child doubts that there is a phenomenon of day and night or that its existence is worthy of explanation. The notion that it is caused by an Earth that rotates once every day is, however, considerably less certain—particularly when it conflicts with their perception that it is the Sun that moves (Baxter, 1989) or that we live on a flat Earth (Nussbaum, 1979). Another way of putting this is that in an argument well-established premises are used to support a less-than-certain conclusion, whereas in an explanation a well-established fact is accounted for by a less-than-certain explanation.

The nature of that asymmetry is that in argument we reason from what we believe are secure premises to a *tentative conclusion*. The goal is an attempt to persuade the listener of the validity of the conclusions. The basic assumption here is that the premises are sound, whereas the conclusion is less certain. In contrast, in constructing an explanation, what is to be explained is not in doubt and we reason from a *tentative premise* to a definitive conclusion. For example, Copernicus, Galileo, and others reasoned from the tentative (and controversial) idea that we live on a sphere that rotates once every 24 hours, to explain the well-known fact that the Sun orbits the Earth once every 24 hours. Likewise, Darwin reasoned from a tentative premise that natural variation in species would lead to new life forms, some of which would be better adapted to their habitat to explain the well-known fact that there is an enormous diversity of life on Earth.

Moreover, the goal of explanation is not to persuade but to provide an account that offers a plausible causal mechanism. The questions we must resolve through argument are whether the proposed explanation accounts for all the known facts. Whether it does it better than others. And all things being equal whether one explanation is simpler than another. Whether the explanation "some birds die because they ate a specific plant" is the most likely explanation requires an argument that is constructed from the data set of all competing explanations and elements that are transcendental to the statement itself. Thus, we would concur with Govier (1987) that

> No account of reasoning and discourse which dispenses with the distinction between argument and explanation is going to be plausible, because there are many arguments that are not explanations and there are many explanations that are not arguments. Furthermore, an examination of cases shows that different criteria of appraisal must be at work. There

> are good arguments that would be non-starters as explanations and good explanations that would be non-starters as arguments. (p. 167)

WHERE ARGUMENT AND EXPLANATION OVERLAP

Granted, there are occasions when the boundaries may appear blurred or indistinct. Take, for instance, the debate surrounding the issue of climate change—where the environmentalists argue that it is a product of human activity on the planet as opposed to their critics who regard it as a product of natural variation. What the debate is about is not the explanation per se but rather the validity of competing explanations for an agreed fact (at least within the scientific community)—that global average temperatures are rising. Climate change refusers use two counterarguments, suggesting that a better explanation is that it is a product of natural variation. A more fundamental strategy is to disagree that there is any consensus about the existence of climate change arguing that scientists have selectively manipulated the data to suggest an effect that is at most a product of natural variation in the climate, or alternatively, nonexistent (Oreskes & Conway, 2010). Their goal here is to suggest that the explanandum is false and that there is nothing to be explained. In this instance, as the explanatory hypotheses offered are for a prospective event—the possibility of climate change, the issue of whether one explanation is better than another cannot simply be judged on criteria of coherence, parsimony, and completeness. Rather, the debate about the validity of an explanation has also become an argument about the validity of the explanandum (climate change is happening) and, in so doing, denying the very need for any explanation.

Some of the confusion may be attributed to the fact that explanations emerge initially as a hypothesis that *might* explain. Any such hypothesis must then be evaluated in the light of competing or alternative explanatory hypotheses and be argued for. Its epistemological status is only transformed to that of an explanation when it has resisted various arguments to demonstrate its falsity. As Hacking (1983) suggests, entities come into being because

> "We regularly set out to build, and often enough succeed in building—new kinds of device that use various well-understood causal properties of electrons" not only do such entities exist but their properties and nature are confirmed time and time again.

Thus, establishing explanatory hypotheses is dependent on a process of argument. And, it is only after this process—which occurs over time—that a hypothesis becomes transformed into what scientists would commonly recognize as an explanation. The transformation requires both a temporal element and a social community. The social community is necessary to subject the explanatory hypothesis to critical evaluation and only when it survives repeated critiques, each of which is shown to be defeasible, does it attain the status of consensually agreed knowledge (Longino, 1990), and hence, become a commonly accepted explanation. This is one of the reasons why critique is so fundamental to science and the act of knowledge construction (Ford, 2008).

Take, for instance, Watson and Crick's paper, which advanced a model for the structure of DNA (Watson & Crick, 1953). What it offered was an explanation of how the genetic information is transmitted from generation to generation (the explanandum). To explain this fact, Crick and Watson proposed that the genetic information was carried by DNA in the nucleus, which consisted of a double-helical structure. The double helix would explain how the protein could unfold and create a replica of itself from other available molecules so passing on the information encoded within [the explanation]. Establishing that this was correct required, however, an argument demonstrating how this structure would account for the known data about the ratio of the base pairs, the amount of water per nucleotide, and, most importantly, the data obtained by Rosalind Franklin. Part of the paper consists of an argument elaborating why the structure proposed by Pauling and Corey is wrong. The essential substance of the paper, therefore, is an argument for an explanatory model that takes the form of "If the structure of DNA was this, then it would explain how the genetic information is transmitted from generation to generation" [an explanation]. Their argument that this model was correct was that this structure accounts for all the data we have about DNA better than any other model [the argument]. Thus, the paper contains two distinct linguistic structures—an argument for the validity of their model and an explanation of how it would explain a known fact.

Likewise, when working in science classrooms with students to construct explanations, we are asking for them to invent an explanation—an explanatory hypothesis—that would explain all their observations. It is the observations that drive the need for explanations but explanations are only valid to the extent that they account for the known data. Advancing the claim that they do so requires the construction of an argument about the fit between the known data and the explanatory account but the argument that they do is not the explanation of the phenomenon itself—the two are not one and the same thing. As Walton (2006) points out,

> the purpose of explaining or an explanatory hypothesis is not to give a reason for the other party to accept a proposition as true. The purpose is to take this proposition that the explainee does not understand and clarify it, relating it to other propositions that the explainee is familiar with and can comprehend. (p. 77)

Thus, explanations, including tentative explanations or explanatory hypotheses, are "different because each has a different purpose in dialogue." The goal of the explanation itself is not to convince or persuade but to make the unfamiliar, familiar or more readily comprehended.

IMPLICATIONS

Some may ask whether this simply the argument of pedants—an exercise in intellectual sophistry—a tale full of sound and fury signifying nothing. We would contend otherwise. For just as understanding how science works provides a deeper understanding of science as a practice, likewise showing students how to identify and resolve linguistic structures helps students to construct their own arguments and explanations and identify the features of others. When two linguistic features are conflated, the outcome is confusion in the mind of the teacher and student. Lacking a well-defined intellectual construct students are in danger of confusing the goals of argument and explanation, omitting vital elements of both, or unable to identify these in the arguments of others. As many, an individual will attest, if something is hard to grasp in theory or, as in this case, has been made harder to grasp by the elision of the two, then it is even more difficult to apply in practice.

A more subtle, but nevertheless important value of the distinction lies in the goal to which argument and explanation contribute. Explanations and the construction of explanations are essential to the creation of new knowledge. The pedagogic value of argumentation, however, lies in its value for exploring the justification of belief and promoting a dialectic between construction and critique (Ford, 2008). In short, being able to identify why one explanation is wrong matters as much as being able to explain why another is right. As Kuhn (1992) argued, "only by considering alternatives—by seeking to identify what is not—can one begin to achieve any certainty about what is" (p. 64). Engaging in argumentation is what fosters the critical disposition that is the hallmark of the practicing scientist and what develops a deeper understanding of the epistemic criteria that any explanation must satisfy. Whereas the goal of producing explanations is to engage in the construction of knowledge, only the practice of argumentation enables students to engage in the critical evaluation of claims to knowledge. To conflate, the two concepts raise the possibility that, yet again, the construction of knowledge may be prioritized by those who see them to be synonymous and the important pedagogic role and value of argument neglected.

Undoubtedly, teachers may be reluctant to use the term "argument" with their students for fear that its colloquial sense of "argument as war" (Cohen, 1995) carries a pejorative meaning. The function of education, however, is to defend the value and use of forms of knowledge and discourse that have proved immensely valuable as forms of intellectual resources and cultural capital. The construction of argument and counterargument are essential aspects of higher order thinking, providing an arena that demands the use of the skills of analysis, synthesis, and evaluation. Developing such skills requires not only opportunities to practice their use but also a knowledge of the metalinguistic feature of their essential elements and the ability to resolve key differences. Thus, making argument central to the practice and pedagogy of science education will not be helped by masking it in the cloak of explanation. Rather, if the function of education is to bring out and develop student understanding it requires us to rehabilitate the notion of argument, to explain what its purpose and function is, and to distinguish it from explanation.

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