Endorsing and Rejecting Scientific Claims: The Role of Evidence in Scientific Discourse

Leslie J. Atkins

California State University , Chico, U.S.A.

The view of science in the education community is shifting from a "rhetoric of conclusions" to a social process of knowledge construction via scientific argumentation. This emphasis on argument recasts the role of evidence and data in scientific classrooms: rather than being used to demonstrate scientific principles, it is the grounds on which claims are warranted. This understanding of science has launched curricula and research programs that are aimed at improving students' abilities to coordinate theory and evidence in scientific argumentation. In this paper, I examine a transcript of scientific discourse, exploring the rules by which participants in the discourse endorse or reject scientific claims. I appeal for a more nuanced understanding of direct evidence as one of many criteria by which scientific claims are evaluated, and that evidence, at times, is incommensurable with other criteria.

Science is Argument

Our understanding of science over the past decades has shifted to an appreciation of science as a social process of knowledge construction where claims are "grounded through the process of argument – relating the imaginative conjectures of scientists to the evidence available" (Driver, Newton and Osborne, 2000, p. 295). This view of science as argument has led to investigations of the ways in which students provide warrants and backings for claims when engaging in argument (Toulmin, 1958; Kelly & Chen, 1999; Erduran, Simon and Osborne, 2004) and the development of curricula to promote discourse consistent with scientific argumentation (e.g., Bell, 2004; Sandoval, 2003).

This paper reports on the analysis of scientific argumentation in an informal discussion between non-science high school teachers; the question – what causes the seasons – is one posed by the teachers themselves. In analysing the conversation, the interest is in the ways in which the "imaginative conjectures" of the participants in the conversation are evaluated, and, ultimately, endorsed or rejected within the community. What is the role of evidence? What other criteria are at play in evaluating claims?

The attention in this paper is on the ways in which participants evaluate claims and how different criteria – different rules for evaluating and endorsing scientific claims – affect the co-construction of scientific ideas across the conversation. Though this study reports on an informal conversation between non-science teachers, the implications for scientific argument in formal environments will be explored as well.

The Meta-rules of Scientific Discourse: Endorsing and Rejecting Narratives

The transcript, below, is taken from a conversation between non-science faculty at a residential high school in the south-eastern United States. The author, a science teacher at the school, is present and has requested permission to tape. The conversation stems from a question asked by one of the faculty members (Alex): *what causes the seasons?* The initial discussion yielded the following ideas: the tilt of the earth causes light to be reflected off of the atmosphere; the atmosphere filters light that enters; the closer you are to the sun, the warmer you will be; and the angle at which the light strikes the surface of the earth determines the seasons. These are shown in Figure 1.

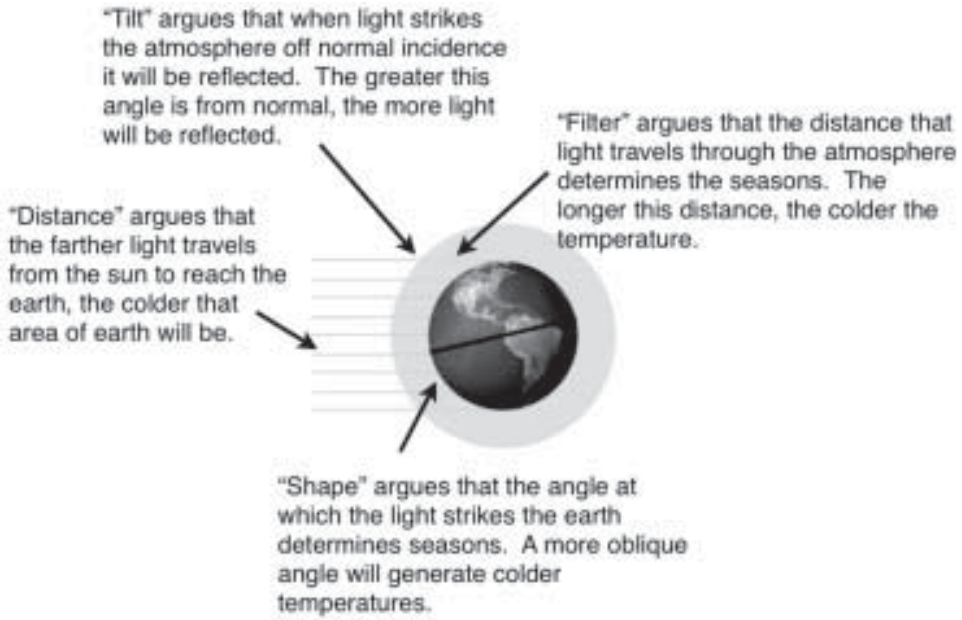

Fig. 1. Explanations for the Earth's seasons.

The "distance" idea suggests that, as one hemisphere of the earth tilts towards the sun, that hemisphere is closer to the sun and therefore warmer. After some discussion on the elliptical path of the Earth around the sun, one participant in the discussion comments that sun is at one focus of the ellipse rather than at the center – which requires that one hemisphere have a warmer winter than the other (since it tilts towards the sun when its orbit brings it closer to the sun). John and Alex then use this information to rule out the "distance" theory:

1 John: I think this whole, 'if the sun is not at the center of the ellipse but is one of the foci of the ellipse' [Leslie: Which is true.] I think this whole business thing...

2 *Alex:* Is all about the atmosphere filtering.

3 *Ben:* Un-unless you-unless we could measure and dis cover that one hemsphere's average temperature *is* dif ferent than the other's.

4 *Jeremy:* Well but the earth is much fatter in the middle than on, you know what I mean? So the part that's that's facing the sun, the closest part to the sun the one that's getting the most direct rays is al ways the equator. Be- cause that's the way it works. And that's the nature of the angle of of the...

5 *Ben:* That that's 'shape'?

6 *Julie:* Mmm hmm has to be, that's what makes the equator.

7 *Neil:* The equator's not always the closest part to the sun.

8 *Ben:* Right but it's always getting the most direct sun.

9 *Neil:* Not always.

10 *Ben:* No no, it's true.

11 *Neil:* That's what the tropics are about.

12 *John:* Yeah that would only be true if...

13 *Alex:* That's that's... it's some sort of area between Capricorn...

14 *Ben:* Right, right. I see.

15 *Julie:* You're right, but still that area- the belt. The fat-belt. [pause]

16 *Leslie:* So why does the tilt matter?

17 *Alex:* Well they think it's 'cause the [laughter] – well here's the thing, now I have a problem for all you people you and your filter [laughter] is that that's fine... I'll accept your filter if you can explain to me why even when the earth is demonstrably further from the sun we don't have any differences in temperature between north and south pole?

18 *John:* Why does angle matter more than distance?

19 *Nick:* Or why is distance irrelevant?

20 *Alex:* Right. How can distance be irrelevant?

Several narratives take place in this passage, that is, "a description of objects, or of relations between objects… that is subject to endorsement or rejection, that is, to being labeled as true or false" (Sfard, 2007, p. 572). These include: (2) the seasons are "all about the atmosphere filtering," (7) the equator is not always the closest part to the sun, and (8) the equator is getting the most direct sun.

These last two narratives are endorsed and rejected ("Not always." "Right right I see." "You're right…") without enough of the rationale given to access the rules by which Neil, Julie and Ben decide to endorse and reject those narratives. But there are several statements made that suggest particular routines ("well-defined repetitive patterns in interlocutors' actions… [such as] the process of creating and substantiating narratives" (Sfard, 2007, p. 572)) for endorsing or rejecting the first narrative:

Line 3: "Unless we could measure…" points to a rule employed by Ben for the endorsement of narratives: scientific narratives are subject to confirmation or refutation by direct evidence. This will be referred to as the ***direct evidence*** meta-rule.

Line 17: Alex's final comment above, "I'll accept your filter if you can explain why…" suggests a rule he employs for endorsing narratives: it is not enough to explain why tilt is responsible for the seasons, but it is also necessary to explain why the alternative explanations are not responsible. This meta-rule and its associated routines I will refer to as ***refutation of alternative explanations***.

Line 17: Notice, too, that Alex is not asking the group for *evidence* that distance does not matter. Indeed, evidence has already been offered earlier in the conversation: the northern and southern poles have equivalent seasons (though the veracity of this claim has been called into question). Rather, as we will see later, he is requiring a particular kind of explanation for why distance does not matter – one that includes a causal explanation that accounts for the claim. The routine employed in developing this explanation, as we will see in a later section, is a mechanistic one (Russ, et al, 2008) and I will refer to this meta-rule for endorsing explanations as ***mechanism***.

Line 20: While Nick seems to understand and employ Alex's rule (rephrasing it as "Why is distance irrelevant?" with Alex echoing this question), it is not clear that John does. John rephrases Alex by saying: "Why does angle matter *more than* distance," suggesting, perhaps, that both can be reasonable means of accounting for the seasons, it's just a matter of figuring out which one is better, rather than which one is wrong. This is a ***ranking of claims***, in which the best claim is endorsed (again, this ranking is subject to particular rules, and may employ evidence or mechanistic rules for ranking).

Neil, meanwhile, does not recognize Alex's comment to be a meta-rule for endorsing or rejecting a particular narrative. Instead, he interprets Alex's comment as an implicit rejection of the "angle" narrative:

41 *Neil:* So are you saying... are you all saying that the angle doesn't matter?

42 *Alex:* No, I'm just saying that if – if we don't think dis tance does matter then we have to be able to explain why distance doesn't matter. And why...

43 *Julie:* He's tough, that Alex, he doesn't let you get away with anything.

44 *Alex:* ... even though the earth is much further from the sun at some points in its orbit the average summer temperature in northern and southern hemisphere maybe is not [different].

Alex clarifies that he has not rejected the "angle" idea, rather that, for him to endorse that idea, he also needs to know what is wrong with his explanation of distance.

Alex's comment, "I'll accept your filter if you can explain why…," is an explicit statement of what Sfard (2007) refers to as a meta-level rule: "if formulated, they would take the form of metalevel narratives – propositions about the discourse rather than about its objects." The rule (refutation of alternative explanations) also brings with it a routine—one that, as Hammer and van Zee (2006) have noted, is characteristic of scientific discourse: "In science, when you think you know the answer, you need to go through all the competing arguments and try to explain why they don't work" (p 26).

Note that this is a different kind of rule from what is often considered necessary (and frequently treated as sufficient) to endorse a scientific idea – direct evidence. Ben's statement ("Unless we could measure") is consistent with this meta-rule, one that is featured prominently in the National Science Education Standards (NRC, 1996): "Scientific explanations must meet certain criteria. First and foremost, they must be consistent with experimental and observational evidence about nature...".

Incommensurable Meta-rules

Faced with these various meta-rules for endorsing and rejecting ideas in scientific discourse, one option is to decide that all must play a role in endorsing scientific claims: claims must be consistent with evidence, they must have mecha-

nistic explanations, and you must also account for competing claims – either explaining why they are incorrect (refutation) or less satisfactory (ranking). However, I will argue that these rules – in particular, the rule employed by Alex, who consistently seeks evidence for endorsing scientific claims, and Ben (and later, Nick), who seek a mechanism for endorsing a scientific claim – are incommensurable. Furthermore, each interlocutor's use of distinct rules takes the conversation to an impasse.

As the conversation proceeds, the participants wonder how objects in space heat up, and why they do not heat up indefinitely.

227 *Leslie:* Does [the object in sunlight] keep warming up indefinitely?

228 *Alex:* Right.

229 *Ben:* No because there's finite amount of... he would reach a stable point.

230 *Leslie:* Why?

231 *Nick:* Yeah – why? There's no way for you to give off that heat... there's no way for you to radiate that heat.

232 *Ben:* No but you do – but you do radiate the heat.

233 *John:* You don't heat up indefinitely...

234 *Ben:* Because all matter would evaporate.

When employing a mechanistic rule for endorsing or refuting narratives, Ben's rejections – "he would reach a stable point" and "because all matter would evaporate" – are unsatisfactory. But from an evidence rule for endorsing narratives – that is, data that confirms that David will not warm up indefinitely – Ben's is an appropriate, scientific argument: David does not warm up indefinitely because if he did, that would mean that all matter evaporates, which clearly has not happened.

However, not everyone in the conversation is applying this evidence rule for endorsing scientific claims, and Ben's rationale for rejecting the idea that this object will keep heating (a statue, referred to as "he") are met with dismissal:

253 *Ben:* He does radiate heat. He does radiate heat.

254 *Anna:* But only for a while, right? Is he radiating it as fast as he gets it?

255 *Ben:* Once he reaches a stable point—

256 *Julie:* **You can't play that card.**

257 *Ben: Why?*

A similar rejection of Ben's narrative comes later in the conversation from Alex:

470 *Ben:* He does. He absorbs it and he heats up. He goes from some temperature to a higher temperature.

471 *Alex:* What's to stop him from heating?

472 *Ben:* He heats to the point that he heats.

473 *Alex*: **That's teleological.**

474 *Ben:* No – but it happens.

Ben argues that there is a stable point (an equilibrium temperature) at which the statue radiates heat "as fast as he gets it." Plenty of evidence that such a point exists has been offered: "Pluto is, like, frozen solid," "the moon, so far, has not exploded," and "you don't heat up indefinitely…because all matter would evaporate." But the mechanism by which that happens – a causal account of how objects absorb radiation up to a point and then radiate energy as quickly as they receive it – has not been established. When Julie tells Ben that he "can't play that card," and when Alex rejects his narrative as "teleological," they are making statements about the kind of routines they are expecting in generating scientific narratives and the rules they apply in endorsing those narratives: scientific narratives require mechanism to be endorsed. Operating with a different set of rules, Ben is puzzled and tries to explain (again) why the statue must re-radiate that heat:

396 *Ben:* What you're saying is the sun is hitting it and it's constantly accelerating because it's constantly getting new energy, right? Tick – tick – tick-tktktktktk! Pow! Right- that's not what's happening. It's just tick, and some energy comes in just as it's about to slow down it gets new energy so it – it's that energy that keeps it at that constant rate.

397 *Alex:* **I don't buy equilibrium.**

398 *Nick:* Uh uh.

399 *Alex:* I reject that. I reject the assumption of equilib rium.

It's a very peculiar game that Alex is playing – a strange set of rules for discourse – that allow him to reject equilibrium. And it is different from the game Ben plays, because for Ben equilibrium is not an assumption; it's data. If equilibrium does not happen then "Pow!" and "that's not what's happening."

This difference in rules that Alex and Ben apply to the argument is characteristic of what Sfard (2007) terms

commognitive conflict: "a situation in which communication is hindered by the fact that different discursants are acting according to different meta-rules" (p. 574). Furthermore, "commognitive conflicts are mistaken for factual disagreements," and so, too, with Alex and Ben. Ben's continued descriptions of an empirically true narrative continue to be rejected because they do not meet Alex and Nick's criteria for endorsing narratives – in this case, mechanism. Ben, in a later description of the argument, described the conflict as a disagreement over whether or not the statue "will radiate sunlight as heat" – which was never the contention. Similarly, others – including myself – failed to recognize that Ben was making a claim endorsed by evidence rather than offering poor or teleological explanations for a mechanistic argument.

Shortly after the exchange above, the conversation becomes very heated. Alex comments that "there's a really different tone from … before…I feel like I'm involved in some sort of heated argument and I'm not actually enjoying it very much." At this, Ben leaves, and the group decides to put the conversation on hold. They never resumed the discussion.

The Role of Evidence in Argumentation

This incommensurability poses a challenge for science education: we wish for students to engage in argumentation, using the full range of epistemic practices of science – in particular, seeking confirmation via evidence and developing mechanistic explanations for phenomena. However, evidence is not the sole arbiter of scientific claims – in fact, it is not uncommon for theories to yield experimental predictions that cannot be tested with the technology of the day (examples from physics include Bose-Einstein condensate, neutrinos, and extra dimensions). Furthermore, it has been argued (Hammer & Elby, 2003, Russ, et al., 2008) that the meta-rules that Alex employs (refuting alternative explanations and using mechanistic explanations to warrant claims) are deeply scientific—they are the meta-rules that drive scientific inquiry in the physical sciences, pointing us toward ideas for which we might then seek evidence.

There is, then, a need for a more nuanced view of the role of evidence and data in scientific argumentation. Not only is it one of many criteria by which we evaluate scientific claims, it can distract us from the goal of scientific inquiry—the "pursuit of coherent, mechanistic accounts of natural phenomena" (Hammer and van Zee, 2006).

References

Bell, P. (2004). Promoting students' argument construction and collaborative debate in the science classroom. In Linn, M.C., Davis, E.A., Bell, P. (Ed.), *Internet environments for science education* (pp. 155-143). Mahwah, NJ: Lawrence Erlbaum Associates.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, 84, 287-312.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the use of Toulmin's Argument Pattern in studying science discourse. *Science Education*, 88(6), 915-933.

Hammer, D., & Elby, A. (2003). Tapping students' epistemological resources. *Journal of the Learning Sciences*, 12, 53-91.

Hammer, D., & van Zee, E. H. (2006). *Seeing the science in children's thinking: Case studies of student inquiry in physical science*. (Book and DVD). Portsmouth, NH: Heinemann.

Kelly, G. J., & Chen, C. (1999). The sound of music: Constructing science as sociocultural practices through oral and written discourse. *Journal of Research in Science Teaching*, 36, 883–915.

National Research Council (NRC). (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

Russ, R. S., Scherr, R. E., Hammer, D., & Mikeska, J. (2008). Recognizing mechanistic reasoning in student scientific inquiry: a framework for discourse analysis developed from philosophy of science. *Science Education,* 92(3), 499-525.

Sandoval, W. A. (2003). Conceptual and epistemic aspects of students' scientific explanations. *Journal of the Learning Sciences*, 12(1), 5-51.

Sfard, A. (2007). When the rules of discourse change, but nobody tells you - making sense of mathematics learning from commognitive standpoint. *Journal of Learning Sciences*, 16(4), 567–615.

Toulmin, S. (1958). The uses of argument. Cambridge, England: Cambridge University Press.