ABSTRACT: The concept of science as argument, and the view that engaging in scientific argumentation should play a key role in science education, has become widely endorsed. The case is made here that this objective will be enhanced by broad understanding of the nature of argument skills and their directions and patterns of development. A line of research directed to this goal is described. © 2010 Wiley Periodicals, Inc. Sci Ed 94:810–824, 2010

INTRODUCTION

A conception of science as argument has come to be widely advocated as a frame for science education (Berland & Reiser, 2009; Bricker & Bell, 2009; Driver, Newton, & Osborne, 2000; Duschl, 2008; Erduran & Jimenez-Aleixandre, 2008; Kelly, Regev, & Prothero, 2008; Kuhn, 1993; Lehrer, Schrauble, & Lucas, 2008; Lehrer, Schrauble, & Petrosino, 2001; Naylor, Keogh, & Downing, 2007; Nussbaum, Sinatra, & Poliquin, 2008; Osborne, Erduran, & Simon, 2004; Sampson & Clark, 2008; Simon, Erduran, & Osborne, 2006; Zohar & Nemet, 2002). Bricker and Bell (2009) identify argumentation as a “core epistemic practice” of science and accordingly claim that the goal of science education must be not only mastery of scientific concepts but also learning how to engage in scientific discourse. If so, the goal will be attainable only to the extent that we have a well articulated and empirically supported model that identifies the essential characteristics of such discourse and the skills that are needed to partake in it. The work described in this article has had as its goal the establishment of such a model.

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Michaels, O’Connor, and Resnick (2008) portray such a model of skilled discourse as consisting of “accountable talk,” which they define as shared norms of reasoning governing the kinds of discourse in which claims are advanced and debated. Ford (2008) similarly refers to “shared standards of knowing” as needing to become the accepted basis for claims, rather than simply students’ personal experience. What is entailed in students coming to subscribe to such norms and what are the cognitive competencies involved?

Proponents of argumentation as central to science education share the view that this educational mission is complex and multifaceted (Duschl, 2008). Its epistemic component, while foundational, cannot be transmitted to students simply and directly. Efforts to advance students’ typically naïve understandings of the epistemological foundations of science have proven difficult (Duschl, 2008; Sandoval, 2005). We cannot simply inform students that a model of science as the accumulation of certain knowledge is incorrect and convey to them the norms that govern authentic scientific practice and the key role that argumentation plays in these norms. Sandoval (2005) makes a convincing case that students must be engaged in the practice of these epistemologies as the more promising path to advancing their own understanding of the epistemological foundations of authentic science.

Berland and Reiser (2009) emphasize constructing and defending explanations as key, but distinct, components of scientific practice, and they are critical of others who they believe conflate them in a single practice. Constructing explanations—what Windschillit, Thompson, and Braaten (2008), for example, highlight as the central scientific goal of “developing defensible explanations of the way the natural world works”—is certainly central to science and science education, but it is not the only objective. Indeed, as has been shown in both observational (Kuhn, 1991) and experimental (Brem & Rips, 2000; Kuhn & Katz, 2009) research, an emphasis on explanation can undermine attention to evidence and its function in supporting claims. Berland and Reiser (2009) elaborate on the difficulty that students commonly have in distinguishing evidence from explanations and mastering the different roles they play with respect to the two components, constructing and defending. The challenge, they emphasize, is one of recognizing the differing epistemological status of evidence and explanations, a differing status that precludes their serving the same function (Kuhn & Katz, 2009).

In their discussion of the “defending” component of science practice, Berland and Reiser (2009) emphasize what they claim is its neglected social aspect. The goal is to communicate and, most of all, to persuade. Scientific thinking becomes a social activity (Kuhn, 1993). A model that incorporates the various components noted thus far are summarized in the model shown in Figure 1. Each phase of the basic inquiry cycle—inquiry, analysis, inference, and argument—has both a strategic (or procedural) and a metastrategic component that regulates its use. In addition is the declarative knowledge reflected in the epistemological component—understandings of the knowing process more broadly; and finally, deriving from this epistemological component and the practice it informs, is the component of values—the component that most directly supports the shared norms referred to at the outset. Berland and Reiser’s “defending,” or “persuasion,” component parallels the argument component in Figure 1. Although they do not explicitly include epistemological or values components, specifically ones that feed back to the performance components, their acknowledgment of such components is implicit in their suggestion that students’ tendencies to conflate evidence and inference occurs because they do not fully appreciate the goal of persuasion.

As does the model portrayed in Figure 1, Bricker and Bell (2009) advocate conceptualizing argumentation in a more comprehensive context than science narrowly defined, and they undertake to do so in their treatment of the topic. Russ, Scherr, Hammer, and Mikeska (2008) similarly take this broad view, noting “In fact, it is possible to study abilities for
controlling variables in contexts that are not scientific, and the frameworks for analyzing the structure of argumentation apply to politics or law as much as they do to science” (p. 2). Indeed, contributions to the earlier phases of the inquiry cycle portrayed in Figure 1, as well as the final phase of argumentation, Russ et al. claim, are amenable to analysis in terms of their formal or functional characteristics, independent of their conceptual correctness.

Bricker and Bell (2009) review a wide range of literature on argumentation outside of the science education context and make a case for its relevance to the science educator’s task. How, then, can science educators best go about engaging students in such practice? Bricker and Bell advocate exploiting the roots of argumentation in everyday conversation, an approach others outside the science education mainstream (Billig, 1987; Graff, 2003) have proposed and the one adopted in the work I describe here.

In this work, what needs to develop is conceived in the framework of children’s and adolescents’ cognitive development more broadly, beginning with the question similar to one posed previously with respect to the inquiry, or question-asking, phase of scientific investigation (Kuhn, Iordanou, Pease, & Wirkala, 2008; Kuhn & Pease, 2008, 2009): What are the cognitive challenges that students face with respect to the practice we would like them to become versed in, and what are the skills they need to acquire to successfully confront those challenges? With respect to both inquiry and argument, we have conceived the practice broadly and not confined to science as conventionally regarded. In the case of argument, we have concentrated our initial investigations in social science domains. The rationale is to capitalize on young (as well as older) people’s greater sense of competency in discussing topics in these domains—just about everyone considers themselves qualified to hold positions on social issues—as well as to take advantage of the roots of argumentation in everyday conversation about social topics. The cognitive challenges identified in their argumentative discourse about such topics, we believed, would be highly likely to be salient as well in their discourse within more traditional science domains.
DEVELOPING MIDDLE-SCHOOLERS’ ARGUMENTATION SKILLS

It is not hard to believe that argumentative discourse occasions cognitive overload on the part of young adolescents. Even in the simplest case—the one we have focused on in our research—of dyadic discourse with a single interlocutor, the arguer must simultaneously process the other’s contribution and anticipate his or her own response to it and do so successively over what may become an extended sequence of turn-taking. Moreover, each contribution to the discourse disappears as soon as it is spoken. Any representation of previous contributions must be constructed and maintained by the arguer, posing a further cognitive burden.

This sustained sequence of processing of the other’s input and construction of one’s own responses ideally would be governed by a set of metalevel goals, as well as associated constraints, for the discourse. What does the arguer see as trying to be achieved through this interchange? As well as anticipating developmental differences in execution of the procedural or strategic aspects of discourse, there are also likely to exist developmental differences in this metalevel understanding of goals and purposes. Of a number of theorists who have undertaken to characterize the goals of skilled discourse, one very commonly cited is Walton (1989). He identifies two goals of argumentation. The first is to secure commitments from the opponent that can be used to support one’s own argument. The second is to undermine the opponent’s position by identifying and challenging weaknesses in the opponent’s argument.

Our initial studies of young adolescents engaged in dyadic argumentation with peers on the topic of capital punishment confirmed that they perform poorly in dyadic discourse in terms of Walton’s criteria. Most focus their efforts on exposition of their own position to the neglect of attending to the opponents’ claims and attempting to weaken their force (Felton & Kuhn, 2001; Kuhn, Shaw, & Felton, 1997). Yet, when explicitly instructed to do so, they are able to attend to the opponent’s argument and even generate counterarguments against it (Kuhn & Udell, 2007). When explicitly asked to give a reason against the opposing position, a large majority of sixth and seventh graders were able to do so. When asked simply, however, “What is the best argument to make?” only a minority mention the opposing position and identify weaknesses in it. Thus, at least as important as developing the skill of constructing counterarguments to weaken the opponent’s claims is recognizing the need to do so.

The extended argument curriculum for middle schoolers that we describe here has evolved over several iterations, but the goals and broad strategies have remained constant. We undertake to provide dense experience in argumentation, while introducing pedagogical supports that we believe will promote progress along the trajectories of skill and understanding that we have identified. Doing so allows us at the same time to enrich our understanding of these trajectories. We target specific argumentation strategies that our research highlights as key ones that adolescents need to develop skill in. In addition, however, we seek to develop the intellectual values that will enable students to see these strategies as having a productive purpose—as worth the effort they entail.

Our approach rests on the claim underlying microgenetic research (Kuhn, 1995)—that dense exercise of existing strategies over a period of time is often a sufficient condition for change. Two features of this exercise that we believe are critical in all contexts are first, that it be goal directed, i.e., that it have a purpose from the subject’s point of view, and second, that it be designed so as to promote metalevel reflection on the activity, rather than simply its performance. Our initial studies emphasized the first feature and our later ones the second. In current work we have devised a way to incorporate both.
In the program I describe here, assessment of individual skill in dialogic argumentation occurs at the beginning and end of an intervention that continues throughout the academic year. At these assessments, the student engages in one live debate with a classmate, and one electronic debate with another classmate, who hold an opposing view on a social issue. (At present our assessment topics are capital punishment and euthanasia.) Reassessment is based on the same pair arguing the same topic at the later time. Skill assessment focuses on the extent to which the student directly addresses each of the opponent’s claims, attempting to weaken it with a relevant counterargument. We also include measures of individual argumentive essay writing on a separate topic, as well as a recognition measure, involving a choice of which of two counterarguments to an argument is the stronger one (Goldstein, Crowell, & Kuhn, 2009).

The curriculum itself focuses on four topics that students engage over the course of the year, each over a sustained period of twice-weekly class sessions for 7–8 weeks. Students begin with topics close to their own experience and gradually move to social topics of broader scope. Engagement with each topic comprises three phases, which we refer to as the Pregame, the Game, and the Endgame. The first four sessions are devoted to the Pregame and emphasize the goal-directed aspect of the activity. Students meet in small groups of 7–8 who all share the same position on the topic and together form the team for that topic. Their task is to explore, evaluate, and organize arguments to support their position, as well as to anticipate their opponents’ responses.

During the main Game phase, same-side students each work with a partner to engage in electronically conducted dialogs with successive pairs of students from the opposing side. The social collaboration with a partner in constructing responses to the opposition supports metacognitive reflection on the dialogic interchange. Also supporting this reflection are the transcripts of the electronic dialogs that remain visible for students to refer to (in contrast to spoken dialog which disappears as soon as it is uttered). As a further support, the pair of students collaborate on reflection sheets (Figure 2) that give them an opportunity to review and reflect on what has transpired. The idea that evidence is relevant to argument and essential in supporting and refuting claims and building strong arguments is gradually introduced with successive topics and comes to play an increasing role, as students increasingly take charge of identifying and seeking evidence that will strengthen their arguments and counterarguments.

Following the series of 5–7 dialogs with a series of opposing pairs, students move to the Endgame phase, by returning to their same-side small groups and beginning two sessions of preparation for a final “Showdown” full-group verbal debate between the opposing teams. At the showdown, an A and a B team on each side are formed, with A teams presiding during the first half of the showdown and the B teams playing a supportive role of making suggestions. During the second half, A and B teams switch roles. During the showdown students on the presiding team organize themselves, with students taking turns in “Hotseat” interchange with a representative of the opposing side, punctuated by team called “Huddles” to debate strategy. The sequence ends with reflective activities that include viewing a video of the showdown, review of an argument map prepared for them based on the showdown debate, with scoring of strong and weak moves, and a final individual position essay that students write on the topic.

WHAT DEVELOPS?

We have now implemented an argumentation curriculum of the sort described among a number of middle-school groups (Iordanou, in press; Kuhn & Crowell, in preparation; Kuhn, Goh, Iordanou, & Shaenfield, 2008; Shaenfield, 2010). The population from which
our examples here are drawn is an urban public middle-school population of mixed academic ability, ranging from below-average to accelerated, and highly diverse ethnically and socioeconomically, but the method has also proven successful with less able, severely academically disadvantaged populations, including residents in a juvenile detention facility (DeFuccio, Kuhn, Udell, & Callender, 2009). In each case, we have evaluated the outcomes on a number of different dimensions.

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STRATEGIC DEVELOPMENT: ADDRESSING THE OTHER’S ARGUMENT

The first and most crucial development we look for is an increase in students’ ability and willingness to attend critically to the other’s argument. Until this happens, no genuine argumentation has occurred. We have observed two phases in this evolution. The first and most fundamental is recognizing the need to attend to the other’s argument and investing the cognitive effort in doing so. Students at the beginning of the intervention often focus entirely on their own arguments, using their turns in the dialog exclusively for this purpose. Once they begin to listen to what the opponents have to say, the second challenge becomes constructing a counterargument that successfully weakens the force of the other’s argument. Not all counterarguments have this characteristic. Students’ early counterargument efforts very often consist of disagreement with the opponent’s statement but then followed not by a critique of it but rather by an alternative argument against the opponent’s position (rather than against the opponent’s argument) that leaves the opponent’s argument unaddressed. For example, in his first dialog on the initial topic (Should a misbehaving student be expelled from school?), one boy was confronted with his opponent’s statement, “They shouldn’t be expelled because they deserve another chance.” His reply ignored his peer’s “another chance” concept and instead introduced a new, perfectly sound argument against the opponent’s position, but one that leaves the opponent’s argument intact: “Yes but they have been acting up for awhile and their behavior has not gotten better and it’s not fair to the other kids who are trying to learn.”

Near the end of the year, in a dialog on the fourth topic (Should sale of human organs be allowed?), the same boy exhibited greater skill in genuine counterargument. His opponent argued, “[They] shouldn’t be allowed to because it is part of their body,” and this time he directly addressed and undertook to weaken his opponent’s argument: “But if people are willing to give up their own body parts and be so generous to the people who need kidneys why should we stop them...?”

These gains are reflected in the significant changes we have observed on year-end assessments in the proportions of students’ discourse utterances coded as direct counterarguments to the opponent’s immediately preceding claim. Gains also appear in sustaining sequences of counterarguments, i.e., rebuttals (counterarguments to counterarguments); these sequences become longer over time (Kuhn & Crowell, in preparation; Kuhn, Goh, et al., 2008). These gains represent a transition from focus on one’s own position and supporting arguments to a focus on the other’s position and supporting arguments and how these can be addressed. Once this important transition is underway, students are ready to address another fundamental component of skilled argumentation—evidence.

INTEGRATING EVIDENCE INTO ARGUMENT

Initially we do not explicitly identify for students the entity of evidence as one for them to be concerned about. Our rationale is to let students draw on their own knowledge base as they see fit and to focus their efforts on developing the practice of authentic discourse with a peer, one in which the other’s contributions are attended to and addressed. After they have done so during the first year of the curriculum, at the end of the first and beginning of the second year, we begin to introduce evidence related to the topic they are discussing. We do so casually, mentioning that we have gathered some information that we are making available to them and that may be of use to them in their argumentation. This information takes the form of a set of questions (about 8–10), each printed on the outside of an envelope, inside of which is printed a 2–3 sentence factual answer to the question. The set

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of envelopes is centrally located in the classroom, and students must go through a simple procedure of checking out and returning any envelope they wish to access.

The questions and answers are carefully chosen to reflect a range of relations to the two opposing positions being debated. A few fairly directly support one position and a few the other, but others do not clearly do either and might be invoked in connection with more than one primary or secondary claim. For the animal rights topic, for example, two of the questions are “How humanely are animals treated in laboratories?” and “Has animal testing led to cures for any human diseases?”

Initially, students show only slight interest in these evidence envelopes, but with time they access them more frequently, and we begin to see the appearance of the information they contain in students’ discourse. At the same time, an even more interesting phenomenon gathers steam: One or two students ask whether they can submit their own questions that they would like to have answered. This request is accepted, other students get interested in this possibility and begin to participate, and student-submitted questions and answers become part of the evidence base available for student use. Over subsequent topics, student-generated questions become so plentiful that the need for researcher-generated questions becomes minimal, and these are reduced to one or two introduced at the beginning to get the process started. A final phase of this process occurs when students take over for themselves not only question generation but generation of answers to their own questions. This is a phase that we are just beginning to experiment with, although it is clearly the desired endpoint in terms of an idealized practice.

In Table 1 appear many of the wide array of questions that one group of seventh-grade students participating in the second year of the curriculum generated as they addressed the topic of whether the newly elected president should focus his effort on domestic or international issues. These questions and answers came to figure strongly in their argumentation. We see this evolution toward evidence seeking and incorporation into argument as significant on multiple grounds. At a strategic level, clearly argumentation is enriched. But at least as important is the epistemological advancement that this evolution represents. These were all questions that students themselves identified as ones they wanted the answers to, because they believed that answers to them would facilitate their argumentation. Their recognition of their importance signifies two kinds of epistemological advance—one with respect to strategy and the other content. With respect to strategy, these students have begun to appreciate the role of evidence in argument. With respect to content, they have begun to appreciate the complexity of and subtleties involved in the issues they are discussing, a development we say more about shortly.

We are now studying how students make use of evidence in their argumentation and how their strategies in coordinating claims and evidence evolve with practice. The two core strategies we observe are the support strategy (using the evidence to support one’s own claim) and the challenge strategy (using the evidence to challenge the other’s claim). Also, however, we begin to see additional types of talk about the evidence and its functions. These are particularly important because they entail metalevel statements about evidence (and implicitly at least, its status in relation to a claim). The simplest is a defensive statement supporting the validity of the evidence that has been used as support for one’s own claim: “We know this from one of our evidence cards.” Although the relation is most often not explicitly stated, such statements occur in conjunction with a claim and it is implicit that the evidence, if accepted, will serve to bolster the claim. What we see much less frequently is a parallel invocation of evidence with the goal of weakening the other’s claim—a strategy we have reason to think may be a more challenging and cognitively advanced achievement. What we do see, however, are attempts to discredit evidence the other has introduced—“That doesn’t prove anything,” or, quite often, to criticize the lack of evidence. “You don’t
TABLE 1
Student-Initiated Questions During Argumentation on the President Topic

<table>
<thead>
<tr>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>How much does the US spend on the Iraq war?</td>
</tr>
<tr>
<td>How many Americans have lost their jobs?</td>
</tr>
<tr>
<td>How many people have gone homeless because of America's [economic] crisis?</td>
</tr>
<tr>
<td>In the past how have economic crises been solved?</td>
</tr>
<tr>
<td>How have other presidents dealt with these issues?</td>
</tr>
<tr>
<td>How many economic crises have we had before?</td>
</tr>
<tr>
<td>How many Americans have died in the Iraq war?</td>
</tr>
<tr>
<td>What is the UN? What is their main job?</td>
</tr>
<tr>
<td>What is the US or Obama doing about the economy; for example, how are they making money literally?</td>
</tr>
<tr>
<td>If any, what other countries are trying to help the US out of its economic crisis?</td>
</tr>
<tr>
<td>Approximately how long will it take to bring home the military to America?</td>
</tr>
<tr>
<td>Why and how did the economy problem start?</td>
</tr>
<tr>
<td>What other serious international issues are there?</td>
</tr>
<tr>
<td>What else can we be spending the money on that we are spending on the war?</td>
</tr>
<tr>
<td>How much debt are we in with all the countries?</td>
</tr>
<tr>
<td>How much money does the US have? Do we have more than 3 trillion dollars?</td>
</tr>
<tr>
<td>How much money does the US spend each day/week?</td>
</tr>
<tr>
<td>How long was the great depression?</td>
</tr>
<tr>
<td>How did we get out of the great depression?</td>
</tr>
<tr>
<td>What kinds of extreme things can happen when people lose their job?</td>
</tr>
<tr>
<td>What [private] foundations are there that help with the economy?</td>
</tr>
<tr>
<td>Which issue is taking up the most money in our budget?</td>
</tr>
<tr>
<td>What is water pollution doing to the people and animals that live/eat/drink it?</td>
</tr>
<tr>
<td>How much did George Bush focus on global warming?</td>
</tr>
<tr>
<td>How much money will it take Obama to fix the economic crisis?</td>
</tr>
<tr>
<td>Compared to other countries, how bad is the economic condition in the US?</td>
</tr>
<tr>
<td>How do problems in the US directly affect other countries?</td>
</tr>
<tr>
<td>Did the US ever make a promise to always help other countries?</td>
</tr>
<tr>
<td>How many alliances does US have with other countries; what are those countries?</td>
</tr>
<tr>
<td>Will helping other countries help us gather alliances?</td>
</tr>
<tr>
<td>How can alliances help us to fix the problems of the nation?</td>
</tr>
</tbody>
</table>

have any proof,” becomes a common refrain. Or, “You would know this if you looked at the evidence.” Or, more charitably, evidence may be solicited: “Do you have evidence to prove that?” These are all of course from an epistemological perspective extremely important contributions to the discourse, in as much as they reflect a recognition and endorsement of shared norms of discourse.

TRANSFER TO INDIVIDUAL EXPOSITORY ARGUMENT

Another highly desirable outcome of our argument curriculum would be to witness students applying these argumentation skills in their individual writing, which, as noted earlier and following Graff (2003), can be regarded as interiorized dialog. Students show a considerable lack of skill in individual written argument when assessed by standardized tests (Greenwald, Persky, Campbell, & Mazzeo, 1999), despite the fact that the ability to write a persuasive essay is widely endorsed as an important educational outcome. Graff
(2003) posits that argumentative writing gains purpose and clarity when the writer accesses an internal argumentative discourse with an imagined interlocutor who the writer then attempts to convince in his or her writing. We believe that practicing argumentation with a peer, as students do in our program, promotes this process in two ways. First, the practice students get in anticipating, attending to, and countering the opponent’s arguments implicitly strengthens an internal interlocutor as the agent to whom the written argument is directed. Second, by coming to recognize the importance of directly countering one’s opponent in discourse, the writer will eventually achieve this same recognition in the written mode.

There is indication that such transfer is indeed occurring. At the end of a second year of the curriculum, students’ individual written essays on a pretest and posttest (nonintervention) topic were superior on multiple dimensions, compared to a group who had participated in a more traditional whole-group discussion class covering many of the same topics over an equivalent period of time (Kuhn, Crowell, & Yanklowitz, submitted).

**EPISTEMOLOGICAL ACHIEVEMENTS**

What explicit knowledge do students who participate in our curriculum gain about argumentation? A sample of their responses, when we asked them directly what they had learned in the class, is presented in Table 2. As these responses reflect, students’ awareness of gains covers a broad spectrum. They include learning to contain emotion, to listen, to think, to provide reasons to support claims, and to respond directly to what the other has said. All of these reflect shared intellectual values that are every bit as important as the skills needed to practice them. Explicit awareness of skills (“I’ve learned to listen to what other people are saying and then really counter it”) is particularly important as it is a necessary first step.

**TABLE 2**

Students’ Reflections on the Value of Argumentation

<table>
<thead>
<tr>
<th>WHAT HAVE YOU LEARNED THIS YEAR?</th>
</tr>
</thead>
<tbody>
<tr>
<td>How to argue without getting mad or frustrated.</td>
</tr>
<tr>
<td>I’ve learned how to argue without screaming and fighting with someone. I’ve learned that by screaming and shouting you don’t get your point across because you are making the person concentrate on your anger; but by speaking they can understand you and analyze your idea.</td>
</tr>
<tr>
<td>I’ve learned to listen to what other people are saying and then really counter it.</td>
</tr>
<tr>
<td>I’ve learned to make strong arguments and be sure to use evidence.</td>
</tr>
<tr>
<td>Somebody is a lot more willing to listen and to agree with what you have to say if you back it up with reasons.</td>
</tr>
<tr>
<td>We should think a little more before we respond so that we can have better constructed responses.</td>
</tr>
<tr>
<td>We should learn to clarify our statements so our opponents don’t get confused.</td>
</tr>
<tr>
<td>I’ve learned you need to have backup and good reasoning to win... to weaken their argument.</td>
</tr>
<tr>
<td>One skill I’ve learned is counter, which is when you counter back to what the person said, not getting off topic. Another is to listen to what the person is saying &amp; arguing straight to the argument, weakening the counter that was said to you.</td>
</tr>
<tr>
<td>I’ve learned that when you assume something will happen but you are not exactly sure if it will or not, it is called an unwarranted assumption.</td>
</tr>
<tr>
<td>To counter reasons that people have and to give a good reason back. This is a good method in your daily life to use when you are in a crisis.</td>
</tr>
<tr>
<td>Having a skill to argue for something effectively is important because it helps you be able to write better essays (which are basically just arguments in writing).</td>
</tr>
</tbody>
</table>

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step toward metalevel management and regulation of their use. The responses in Table 2 also suggest an encouraging developing awareness of where and when these skills will be useful.

A further very encouraging indication of epistemological achievement has to do with the content of students’ claims. In eliciting their positions on topics, we also asked how certain they were that their position was the correct one. Students in both intervention and comparison groups tended to express high certainty in initial assessments. Among the intervention group, however, this certainty—on the very same topic—declined. In the comparison (nonintervention) group, by contrast, it increased slightly.

ARGUMENTATION IN THE SCIENCE DOMAIN

Is the knowledge gained in the research described here of use to the science education community concerned with strengthening students’ argumentation skills within the context of science learning? To gain evidence bearing on this question, Iordanou (in press) conducted a study in which the method described was implemented in both science and nonscience domains. The goal was twofold, the first being to examine the generality of observed skill development across domain—an extremely important goal in its own right in terms of identifying the extent to which such development is context bound and hence precisely what it is that is developing. The second goal was to compare the efficacy of the interventions within a science and a nonscience domain, on skill mastery within each of the domains. Putting the question more specifically, is the development of argument skills in science contexts most effective, or possibly only effective, when it takes place within a scientific content domain?

In this study, 40 sixth graders engaged in electronic discourse on a controversial topic; for half, the topic was a choice between two rival theories to account for the extinction of dinosaurs (the science topic) and for the other half the topic was whether parents should be allowed to home school their children (the social topic). A sheet containing a list of several “Possibly Relevant Facts,” each a sentence or two in length, was provided, for either the science or social topic depending on condition, and remained available throughout the series of IM discussions. Over 13 sessions, students collaborated with a partner in conducting arguments electronically with a succession of pairs of classmates who held an opposing view on the topic. In addition, each pair engaged in reflective activities of the sort that have been described here, and each student participated in an individual assessment of dialogic argument skill before and after the intervention. A control group participated only in these pre- and postintervention assessments.

The results indicated that argumentation skills in scientific domains are amenable to development in similar directions and in a similar way as are skills in social domains. Compared to students in the control condition, from initial to final assessment students exhibited increased frequency of usage of skilled (counterargument and rebuttal) argument strategies and decreased frequency of less advanced (simple exposition, ignoring the other’s position) strategies. The intervention also proved to be successful in producing transfer of argument skills across domains in both directions. However, a difference in the magnitude of transfer was observed, with only participants in the science topic condition able to transfer their achievements in argumentation skill to the nonintervention (social) topic to the same degree that these skills were mastered in the science topic. Intervention gains in the social-topic condition transferred less well to the science topic. Similarly in the epistemological realm, the science condition was more effective than the social condition in effecting advance from an absolutist and toward an evaluativist level of epistemological understanding within the science domain (Iordanou, in press; Kuhn, 2009). At least part of the explanation of the patterns of transfer observed may lie at the metalevel. As metalevel
understanding of argumentation develops, as reflected in Figure 1, it supports the execution of argument skills at the procedural level, an outcome that extends across domains of application.

If so, the implications for science education are several. First, these results suggest that students’ limited argument skills in the science domain reported in several studies (Driver et al., 2000) are not due to constraints imposed by the nature of the science domain itself. Second, the findings also indicate that direct attention to the development of argumentation skill (and its associated epistemological understanding) within science domains is warranted, even though these skills extend beyond the domain of science itself. Argument skill in the science domain is amenable to the same development as argument skill in the social domain has been shown to be; still, specific engagement and practice within the science domain is warranted for optimum development of such skill. The policy recommendation supported by Iordanou’s findings—engagement and practice in argumentation within the context of authentic science topics—is consistent with much recent thought in the field (Duschl, 2008; National Research Council, 2007).

ARE THERE COGNITIVE CHALLENGES SPECIFIC TO SCIENCE?

The conclusions just drawn should not lead us to ignore the asymmetry in Iordanou’s (in press) findings with respect to transfer. Why was transfer more difficult to achieve to the science domain than from it? A growing psychology and sociology of science (Bazerman & Paradis, 1991; Dunbar, 1995; Feist, 2008) have begun to tell us a great deal more than was previously known about the practice of authentic science. This work does not directly inform us as to the cognitive challenges that engaging in authentic scientific thinking poses to students. But it is helpful in keeping us attuned to the significant differences between professional science and the kinds of activities students undertake in science classrooms or in a study such as Iordanou’s.

In science classrooms, if students examine scientific arguments at all, they tend to consist of a simple opposition between two conflicting points of view. Doing so is arguably the appropriate entry point for engaging science as argument. But authentic science commonly goes beyond such simple oppositions, to encompass what philosophers have referred to as “coalescent argumentation” (Gilbert, 1997) and social scientists as “knowledge construction” (Bereiter, 2002) and “model building” (Lehrer & Schauble, 2006). Such entities include simple oppositions but go beyond them, and hence they need to be recognized as educational objectives that are an important part of a developmental progression.

It is in the epistemological realm, however, that the differences between argumentation in social and scientific domains may be most significant. Specifically, the role of human interpretation poses somewhat different challenges in scientific and social domains. In the science domain, the entry of human interpretation into what was previously regarded in absolutist terms as direct perception of a single reality is to be understood in positive terms: Science comes to be appreciated as a human construction and interpretation as an essential resource for knowing. The “filter” that human minds represent empowers the scientific endeavor.

In the social domain, in contrast, when human subjectivity first impinges on the absolutist realm of objective fact, it is typically regarded in negative terms, as the intrusion of human “bias”—a necessary evil to be acknowledged and accommodated. The lingering absolutist often looks for a way to get beyond this bias to uncover the “true facts.” But the danger is one of a permanent stall in the multiplist’s embrace of radical relativism (Moshman, 2008; Muis, Bendixen, & Haerle, 2006), with the evil of subjectivity seen as overpowering the quest for any knowledge beyond subjective opinion—“there’s no way of knowing anything
because everyone sees it their own way” (a position difficult to maintain in the domain of science). In the social domain, then, the major challenge is to conquer the view that human interpretation plays an unmanageable, overpowering role. In the science domain, the major challenge is to recognize that human interpretation plays any role at all.

A recent study by Kuhn, Iordanou, et al. (2008) supports this interpretation of the distinction between the two. We presented sixth graders with scenarios in the two domains and asked them the same key questions regarding the certainty of knowledge: Could anyone ever be certain about what happened in the (fictitious) Fifth Livian War? And, in another scenario, about why dinosaurs became extinct? And what would help us become more certain? Previous literature leads to a prediction of greater willingness to relinquish the absolutist idea of certain knowledge in the social domain and greater resistance to doing so in the science domain (Hallett, Chandler, & Krettenauer, 2002; Kuhn, Cheney, & Weinstock, 2000). The goal in the Kuhn, Iordanou, et al. (2008) study was to identify a problem in the science domain that would facilitate willingness to loosen the absolutist’s commitment to knowledge as objective fact (and thereby foster developmental advance), to a degree that would equal or exceed that observed in the social domain. Because dinosaur phenomena are situated in a prehuman era, the firsthand observation by humans that an absolutist conception requires is precluded. As a result, the potential negative influence of human subjectivity (the “biased” observation that is a dominant concern in the social domain) is minimized. In the dinosaur problem, then, the only way in which knowledge can advance is by means of the positive, constructive role of human theorizing and its coordination with various forms of indirect evidence. We therefore predicted it would facilitate the transition from absolutism. A comparison of performance across the two problems supported this prediction.

CONCLUSIONS

The approach to identifying and developing argumentation skills that has been described here is controversial in two respects. It would appear to be counter to a widely held view that intellectual skills can only be identified and/or nurtured in contexts in which students are engaged in the acquisition of rich and authentic subject matter, a view that has been particularly strong among science educators (Metz, 2004; Sandoval, 2005). In the contexts described here, the content of students’ discussions is typically rich and varied. They typically come to realize that the issues they are discussing are more complex than they first appear and they gain in understanding of factors that bear on them. But we are not at the same time undertaking to impart to students a particular body of factual or conceptual understanding. The objective of developing the skills in question seems an important and challenging enough goal to warrant attention in its own right. An added bonus afforded to us as researchers is the potential to observe and better understand the nature and components of this skill development. Skills, as much as conceptual knowledge, have their own learning progressions (Corcoran, Mosher, & Rogat, 2009), and we need to understand what they are. Yet Iordanou’s (in press) research described above suggests that the subject matter in which we contextualize this skill development is not irrelevant—that is, entirely substitutable. Outcomes and transfer of skills may vary across subject matter.

If the view is accepted that the development of argumentation skills warrants pedagogical investment, the approach described here is controversial in a second respect, with some researchers making a case for direct, explicit instruction in argument as the preferred instructional method (Larson, Britt, & Kurby, 2009; Schworm & Renkl, 2007), rather than the experiential approach we have described. Only more extensive research will resolve these pedagogical questions definitively. The claim being put forward here is simply that the skills of argument are fundamental intellectual skills, worthy of attention in their own right.
Knowing more about their nature and development can only enrich the models and methods that guide science education.

REFERENCES


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