Chapter 8
Quality Argumentation and Epistemic Criteria

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The language of science is not exclusively the enunciation of terms and concepts, facts and laws, principles and hypotheses. The language of science is closely related to the restructuring character of scientific claims about method, goals, and explanations, a character firmly established in the history, philosophy and sociology of science (Duschl, 1994; Duschl & Hamilton, 1997; Hodson, 1985). Language of science is a discourse that critically examines and evaluates the numerous and at times iterative transformations of evidence into explanations (Duschl & Grandy, 2007). Thus, as this edited volume on argumentation demonstrates, educational researchers are focusing on ways to understanding the language of science and to support dialogic argumentation in science classrooms.

Shifting the dominant focus of teaching from what we know (e.g., terms and concepts) to a foci that emphasizes how we know what we know and why we believe what we know (e.g., using criteria to evaluate claims) requires a different classroom culture and discourse environment. Consider for a moment what's involved when science teaching and learning are formatted around argumentation practices. First, scientific knowledge claims include information about theory (what knowledge is important), method (what strategies for obtaining and analyzing data are appropriate), and goals (what outcomes are sought and how can we determine if the outcome has been attained). A curriculum, instruction, and assessment design challenge is providing teachers and students with tools that help them build on nascent forms of argumentation to develop more sophisticated and rational scientific knowledge claims. Equally important, as Siegel (1995) argues, is the need to address the development of criteria students employ to determine the "goodness", the normative status, or epistemic forcefulness of reasons for belief, judgment and action.

Engagement in argumentation discourse also requires appropriation of criteria and of evidence for the evaluation of arguments (Kuhn, 1993). Driver et al., (1996), White and Fredericksen (1998) and Duschl (2000) each point to the importance of students seeing scientific inquiry as epistemological and social processes in which knowledge claims can be shaped, modified, restructured, and at times, abandoned. Thus, learners need to have opportunities to discuss, evaluate, and debate the processes, contexts, and products of inquiry. Such discussions and debates expose the members of the community to each others' ideas, opinions, sources of evidence,

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and reasoning. These discourse processes also make thinking visible to participants. Such visibility can, in turn, provide a powerful mediation or formative assessment opportunity. Herein lies the importance of locating robust argumentation frameworks that will provide the appropriate level of details for guiding the development of students' argumentation practices. The feedback on thinking can come from the students themselves as well as the teacher. But it is the teacher that sets the agenda for mediating the learning environment that can support formative assessments on pupils' scientific thinking and reasoning. The challenge of teaching higher level thinking for teachers is fundamentally one of managing the ideas and information that are generated by students (see Zohar, this book).

The adoption and development of argumentation frameworks has gained in importance over the last two decades as researchers and curriculum developers seek ways to either nurture dialogic discourse in classrooms or to analyze the development of students' reasoning with evidence and theory. When looking across the various available options for argumentation frameworks one sees that there are issues regarding the "grain size" of information being sought and used (Sampson & Clark, 2006; Duschl & Osborne, 2002). Toulmin (1958), for example, distinguished between field-dependent and field-independent forms of argumentation with the latter focusing on the general patterns of arguments involving claims, warrants, backings, rebuttals, qualifiers and conclusions. The question asked by Sampson and Clark (2006) in a review of 5 different frameworks for examining rhetorical argumentation is "How does any framework inform us about the quality of students' argumentation?" This is an important question and one that is taken up in this chapter. Specifically, argumentation while common among many cultures and communities, when played out in science argumentation discourse has particular rules for "what counts" for knowledge building. Such knowledge building rules represent the epistemic demands (Sampson & Clark, 2006), epistemic resources (Hammer & Elby, 2003), epistemic actions (Pontecorvo & Girardet, 1993) and the practices of epistemic communities (Duschl & Grandy, 2007). Thus, as stated above, when thinking about argumentation discourse in classrooms, there is a need to have tools that can support or scaffold students' participation in argumentation discourse and, importantly, teachers' assessment of the students' argumentation.

Sampson and Clark (2006) review 5 frameworks used for the assessment of argument:

- Toulmin's Argument Pattern in science education research (Erduran et al., 2004; Jiménez-Aleixandre et al., 2000; Kelly et al., 1998);
- Zohar and Nemet's modification of Toulmin (Zohar & Nemet, 2002);
- Kelly and Takao's framework examining the epistemic status of propositions (Kelly & Takao, 2002; Takao & Kelly, 2003);
- Sandoval's framework for examining the conceptual and epistemic quality of arguments (Sandoval, 2003; Sandoval & Millwood, 2005); and
- Lawson's framework for examining the hypothetic-deductive validity of arguments (Lawson, 2003).

The focus of the review was "(a) illustrating the logic and assumptions that have pervaded research in the field, (b) summarizing the constraints and affordances of these different approaches, and (c) making recommendations for new directions" (p.655). The analyses were conducted with lenses examining the epistemological criteria used by each of the 5 frameworks. What Sampson and Clark report is that the extant frameworks do not get down to a precise level of epistemic criteria:

> Unfortunately, .. the majority of the analytical methods that have been developed to assess and characterize the nature of the rhetorical arguments ... have provided very little information about how the rhetorical arguments generated by students reflect these criteria" (p 659).

There remain concerns about the quality of argumentation and reasoning that can emerge if more refined epistemic criteria are not introduced to students. Sampson and Clark proposed 5 criteria for examining the quality of scientific arguments (pp. 658–660):

1. *Examine the nature and quality of the knowledge claim*—analytical methods should focus on the types of claims made by students and the ability to coordinate claims with available evidence.
2. *Examine how (or if) the claim is justified*—students need to learn to provide empirical evidence but also need to learn what kinds of evidence are needed to warrant an argument.
3. *Examine if a claim accounts for all available evidence*—students tend to not focus on the patterns in data but rather give priority to single pieces of evidence that support personal beliefs.
4. *Examine how (or if) the argument attempts to discount alternatives*—more than one claim may be an acceptable explanation for a phenomenon, students need to learn how to challenge weaknesses in alternative explanations.
5. *Examine how epistemological references are used to coordinate claims and evidence*—students need to learn how to justify/evaluate the ways evidence is gathered and interpreted, students do not examine the design of investigations or the methods used to obtain evidence.

A promising framework not reviewed by Sampson and Clark is Walton's (1996) argumentation schemes for presumptive reasoning. My claim is that the Walton framework can help address most of the 5 criteria put forth by Sampson and Clark. The theoretical framework for the adoption of argumentation discourse that is presented in the next section is developed from three studies employing 9 of Walton's categories to examine student discourse. The initial study to use Walton categories (Duschl et al., 1999) was grounded in an evaluation of Project SEPIA. Sibel Erduran and I worked on the design, piloting and implementation of the group interview protocols. Sibel Erduran conducted the group interviews. Kirsten Ellenbogen and I coordinated and implemented the analysis of the group interviews. The Walton analytical scheme was also used to analyze discourse first in a study of computer-supported classroom science learning (Goldman et al., 2002); and second in a study of argumentation discourse used in extended writing responses on A-level course examinations (Osborne et al., 2002) In the rest of this chapter, I will describe the use of Walton's framework for the assessment of middle school students' argumentation. First I will provide a rationale for the theoretical background to the research programme, Project SEPIA, that has led to the design of learning environments to support argumentation in middle school science classrooms.

Theoretical Framework on Argument

A trend in science education is the move away from the implementation of discrete single lessons that seek outcomes related exclusively or predominately to students' concept learning regarding facts and principles. There is new focus on knowledge use with an emphasis on the coordination of evidence and explanation or of observation and theory (NAEP, 2006) Traditionally, science education learning goals have oscillated between content and process emphases New understanding of learning derived from the learning sciences (Bransford et al , 1999; Duschl et al., 2006; Pellegrino et al., 2002; Sawyer, 2006) are emphasizing the importance of supporting the development of complex reasoning among learners. According to Bransford et al (1999) research over the past 30 years has contributed five themes that have changed our conceptions of learning:

1. Memory and Structure of Learning—how learners develop coherent structures of information;
2. Analysis of Problem Solving and Reasoning—how learners acquire skills to search a problem space and then use these strategies;
3. Early Foundations—assessing infants' early learning is causing us to rethink the skills and abilities children bring with them to school;
4. Metacognitive Processes and Self-regulatory Capabilities—how learners engage in self-monitoring and executive control of one's performance;
5. Cultural Experience and Community Participation—how learners become attuned to the constraints and resources, the limits and possibilities, that are involved in the practices of communities.

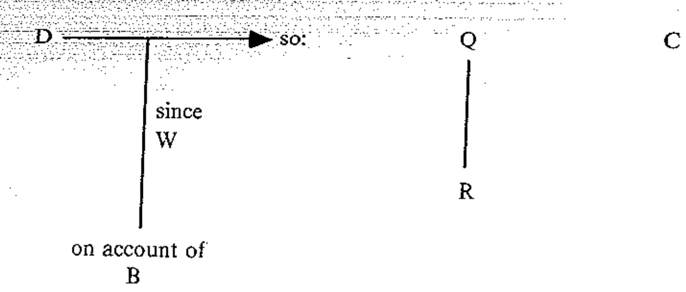
In science education, the development of reasoning often has an evaluative component with respect to the examination of evidence and explanation. New policies speak to the importance of instructional contexts that seek outcomes related to students' reasoning and communication in science contexts. In the United Kingdom, the policy recommendations in the document *Beyond 2000* (Millar & Osborne, 1998) suggest formatting science instruction such that goals relating to a public understanding of science and ideas-about-science are addressed and not squelched by concept learning. In the USA, the National Science Education Standards (NRC, 1996, 2001) make Inquiry, Unifying Themes and Principles, Science in Social and Personal Perspectives and Nature of Science four of the eight content goals. In short, the message internationally evidenced by other worldwide policies in science education (Jiménez-Aleixandre & Erduran, this book) is that there is more to science learning than knowing facts and principles. The message is that in addition to a focus on students' learning about what we know, science education needs to also focus students' attention on how we know what we know and why we choose to believe it over alternatives. The how and the why focus requires adoption of dialogic discourse processes, of which argumentation is a part, in order to engage learners in the epistemic practices involving the selection of evidence for the development of scientific explanations.

Argumentation has three generally recognized forms: analytical, dialectical, and rhetorical (van Eemeren et al, 1996). Analytical arguments are grounded in the theory of logic and include, as examples, material implications, syllogisms, and fallacies. Essentially in the analytical approach an argument proceeds inductively or deductively from a set of premises to a conclusion For analytical arguments of categorization, the form is the syllogism: All men are mortals; Socrates is a man; Therefore, Socrates is mortal. For analytical arguments of causation, the form is material implication: If p then q; p; Therefore q.

Dialectical arguments are those that occur during discussion or debate and involve reasoning with premises that are not evidently true. Dialectical arguments are a part of the informal logic domain. Rhetorical arguments, on the other hand, are oratorical in nature and are represented by the discursive techniques employed to persuade an audience. In contrast to the other two forms of argument where the consideration of evidence is paramount, rhetorical arguments stress knowledge of audience. In science, there is general agreement that all three forms of argument are used as theories are refined and justified but dialectical and analytical owing to the focus on evidence are more exacting and representative of high quality scientific argumentation.

Designing learning environments to facilitate and promote argumentation is a complex problem given that the discourse of science involves the three different forms of argumentation. The central role of argumentation in doing science is supported by both psychologists (Kuhn, 1993) and philosophers of science (Siegel, 1995) Argumentation is seen as a reasoning strategy and thus also comes under the general reasoning domains of informal logic and critical thinking as well.

Given the wide use of Toulmin's Argument Pattern (TAP) (Toulmin, 1958) as a model of evidence-to-explanation transformation process, some further exploration is warranted. A generic representation of the TAP discourse model from data to conclusions is depicted in Fig 8.1. Toulmin posits that the quality of an argument can not be judged by form alone (e.g., modus ponens, modus tollens, material implication). Rather, the content and context of an argument (i.e., the evaluation of arguments as they occur in practice) are critically important for determining what counts as data, warrants, and backings. For this reason, Toulmin introduced the idea of argumentation field. The field frames the content for the argument. Thus, the content of an argument will be composed of both field-dependent and field-independent elements



D=data, W=warrants, B=backings, Q=qualifiers, R=rebuttal, C=conclusions

Fig. 8.1 Toulmin's argument pattern (Toulmin, 1958)

The difficulty of using TAP, discussed above by Sampson and Clark, as a template though is the interpretations one allows or accepts for the inclusion or exclusion of claims about the data, the warrants, the backings, the qualifiers, the rebuttals and the conclusions. One problem with TAP according to van Eemeren (1996) "is the vagueness, ambiguity, and sometimes even inconsistency in his use of key terms (...) Toulmin gives the impression that the terms *field of argument*, *topic*, and *discipline* are synonymous"(p 155, italics in original). In other words, what one chooses to monitor and against what criteria shapes the evaluation of the discourse The issue is related to learners' knowledge of the field within which the argumentation task is occurring. The task is further complicated since the knowledge of the field is often that which is held by a community of inquiries. But it is here at the level of making decisions about "what counts" where science is properly done and, subsequently, where classroom discourse and assessments should focus. That is, the focus should be on epistemic contexts Thus, the question to raise with respect to TAP is how effective is it at helping students and teachers ascertain "what counts".

The issue that arises with TAP is what is the appropriate level of detail that should be expected for the reasons given to make an argument. The TAP uses very general and broad categories (e g., data, warrants, backings, rebuttals, qualifiers, conclusions) to characterize arguments. A closer examination of argumentation discourse reveals that statements frequently make "appeals" to specific positions like appeal to authority or appeal to analogy. The examination of the content or focus of the "appeals" enables an analysis that gets closer to the epistemic criteria being used to establish and justify the quality and strength of the argument. Walton's audience for his 1996 book was the legal community and in particular law students preparing for the presentation of cases. Over 20 categories

of "appeals to"-type argumentation moves are put forth. Of these, 9 were judged to be relevant to features of middle school science classroom discourse (see Table 8.2). The rationale for using Walton's scheme is that if the goal is to improve students' scientific reasoning, then a more nuanced and detailed framework is needed to monitor and guide how students are employing evidence in the construction of explanations. The Walton schemes for presumptive reasoning, I believe, provide such details.

The adoption of the Walton presumptive reasoning schemes facilitates employment of frameworks for the analysis of argumentation discourse in science classrooms. Dialogue logic occurs during dialectical argumentative exchanges, like that which occurs during collaborative small group science investigations and assessment conversations (Duschl & Gitomer, 1997) as well as asynchronous computer-supported communication environments. During a dialogue a proponent may carry any number of changing commitments as the burden of proof shifts during an exchange. In a dialogue context, the sources of evidence employed to shift burden of proof are much more extensive than those employed in analytical contexts. Rescher (1976, 1977), and more recently Walton (1996), maintain that dialectical argumentation is grounded in burden of proof, presumption, and plausibility. Walton (1996) defines presumptive reasoning as that reasoning which occurs during a dialogue when a course of action must be taken and all the needed evidence is not available. Such reasoning is not based solely on knowledge and probability but instead focuses on shifting presumption (e.g., burden of proof) onto the other dialogue participants. Such a scenario of reasoning from a partial set of experiences and evidence reflects quite well what typically occurs in middle school science classrooms.

A Study of Argumentation Discourse in Middle School Science Classrooms

The next sections of the chapter report the initial research study (Duschl et al., 1999) that assessed the quality of argument ation by students participating in SEPIA classrooms using Walton's framework for presumptive reasoning. First, a brief overview of the SEPIA instruction and assessment models is provided Next, is a section on methods and data sources used in the study. Here the discussion reports on efforts to initially try and use TAP with "Appeals to" categories as the analytical framework Owing to difficulties presented above, TAP was abandoned and Walton adopted as the analytical framework for discourse coding. Results are then presented followed by a last section that discusses conclusions of the study and implications for the use of frameworks that seek to quality argumentation by promoting consideration of epistemic criteria.

SEPIA—Science Education through Portfolio Instruction and Assessment

The design of SEPIA curricula is a blending of guidelines from cognitive psychology and philosophy of science (Duschl & Gitomer, 1991; Gitomer & Duschl, 1995; Goldman, et al., 2002). A general goal is to develop scientific reasoning. The specific goals are to develop students' ability to reason about explanations, experiments, and models. Three units were developed, *Vessels* with the epistemic goal of evaluating causal explanations; *Acids & Bases* with the epistemic goals of evaluating chemical models; *Earthquakes & Volcanoes* with the epistemic goals of evaluating scientific arguments. Many years into the effort, the teachers, researchers and advisors working on Project SEPIA feel the approach proceeds from five key features:

1. The topic of investigation is an authentic question or problem that has some consequence to the lives of the children.
2. Conceptual goals are kept to a limited number so as to facilitate an understanding and adoption of epistemic criteria that assess the accuracy and objectivity of knowledge claims.
3. Assessment of students' understandings and ideas proceeds from assignments that are designed to produce a diversity of outcomes.
4. Both the criteria for the assessment of students' products and performances and the products and performances themselves are publicly shared employing a direct teaching discourse strategy labeled an 'assessment conversation'.
5. The depth of student understanding is assessed and communicated employing a portfolio process.

The principal focus for SEPIA units is on epistemic goals as learning outcomes. Such goals seek to develop students' understanding of the structure of knowledge for the purposes of proposing and evaluating knowledge claims grounded to the evidence from the inquiry. Hence, epistemic goals seek to establish the criteria or rules upon which decisions and choices are made, for example, "what counts". Epistemic goals establish the ground rules to construct and evaluate scientific arguments, scientific explanations, models or theories, scientific experiments and scientific hypotheses.

Methods and Data Sources

Seventeen triads of middle school students participated in a structured 45–60 minute long interview. The task for the group was to review and then provide constructive feedback for the improvement of a science fair project. Students were seated in front of the science fair poster—a three panel cardboard presentation on buoyancy and flotation including pictorial representations of the investigations done by a 7th-grade student. Interview protocols were designed, reviewed, piloted

and revised. There were three components of the interview. First, a warm-up activity that involved students cooperatively constructing tangram figures was used. This was done to encourage group work and group decision-making in particular. Second, a set of open-ended questions focusing on the format and content of the science fair project were presented. This was done to focus attention on the parts of the project showing the data table, the hypothesis being tested, the methods used and the conclusion statement. Finally, a set of questions focusing on the evidence and the claims made in the science fair project were presented to students. All sessions were video-taped, audio-taped and then transcribed. Transcripts of the sessions were reviewed for accuracy. The analysis below only examines the last (or third) section of the structured group interview for it is here that the use of epistemic criteria was most likely.

Analysis of the group was the method of inquiry for the present study. Two argumentation schemes were trialed for the analysis of student discourse—Toulmin's argument scheme and Walton's argumentation schemes for presumptive reasoning. But in the end, for reasons described below, only the Walton schemes were used. The application of Toulmin's model followed closely the procedures adopted by Pontecorvo and Girardet (1993) in a study of children's group reasoning in the context of examining history book passages. These authors first analyzed the frame of discourse which identifies the general orientation of the discussion. The second level of analysis examines "reasoning sequences" in which particular epistemic actions are pursued. The final unit of analysis was the "idea unit". Each idea unit was submitted to a double categorization (see Table 8.1). At the first stage, the unit was assigned to an argumentative operation and then it was assigned to an epistemic operation.

For the "Appeal to" category the following list of options was provided by Pontecorvo and Girardet: analogy, exemplar cases or instances, conditions, rules or general principles, motives/intentions/goals, consequence/implications, authority

Table 8.1 Operations used by Pontecorvo and Girardet (1993)

Argumentative operations	Epistemic operations
Claim – Any clause that states a position.	**Definition** – A statement about the essential nature of an event or about the meaning of a word, including a shift of meaning.
Justification: Any clause that furnishes adequate grounds or warrants for a claim.	**Categorization:** When something is considered as being a member of a class, including a shift of categorization
Concession: Any claim that concedes something to an addressee, admitting a point claimed in the dispute	**Predication:** The action of asserting something about a topic *without* any evaluative dimension.
Opposition: Any claim that denies what has been claimed by another, with or without giving reasons.	**Evaluation:** The action of asserting something about a topic *with* an evaluative dimension.
Counter-opposition: Any claim that opposes another's opposition, which can be more or less justified.	**Appeal to:** The action of supporting a claim by appealing to something that the speaker content considers relevant to the topic.

Table 8.2 Argumentation Schemes for Presumptive Reasoning (Walton, 1996)

Argument from:	Definition
Sign	References to spoken or written claims are used to infer the existence of a property or occurrence of an event
Commitment	A claims that B is, or should be, committed to some particular position on an issue, and then claims that B should also be committed to an action.
Position to Know	A has reason to presume that B has knowledge of, or access to, information that A does not have, thus when B gives an opinion, A treats it as true or false.
Expert Opinion	Reference to an expert source external to the given information.
Evidence to Hypothesis	Reference to premises followed by a conclusion.
Correlation to Cause	Infers a causal connection between two events from a premise describing a positive correlation between them
Cause to Effect	Reference to premises that are causally linked to a noncontroversial effect.
Consequences	Practical reasoning in which a policy or course of action is supported or rejected because the consequences will be good or bad
Analogy	Used to argue from one case that is said to be similar to another.

(expert, author, source), time, sociocultural context, spatial temporal context. Here we can see an extension of claims, warrants and backings by, in particular, the use of the "Appeals to" category

Nine of the 25 argumentation schemes proposed by Walton were selected for the second analysis. The selected schemes are presented in Table 8.2. As you will note there is some overlap between Walton's categories and Pontecorvo and Girardet's "Appeal to" categories. The difference is that we applied the 9 categories to the reasoning sequence or larger chunks of conversation, a level above the idea unit used by Pontecorvo and Girardet.

Results

In contrast to the success Pontecorvo and Girardet (1993) had with applying Toulmin's argument pattern to analyze group reasoning in a history context, we found that the analysis of discourse employing argumentative and epistemic operations to the idea unit in our data on science students did not adequately distinguish signal from noise. First, the idea units did not work well with the argumentative operations. The argumentative operations were too broadly defined which led to a large assignment of sentences and statements to generic categories without adequately accounting for the diversity that existed within the category. Consequently, distinguishing the structure and patterns of argument was difficult. Difficulties were also encountered with the assignment and analysis of epistemic operations. The dialectical nature of the group interview made the assignment of analytic epistemic operations like definition, categorization, predication, evaluation, warrants, and backings rather awkward. At times it felt as if square pegs were being forced into round holes. There was more success at assigning the epistemic operations to the reasoning sequences than to the idea units.

The use of Walton's presumptive reasoning schemes more adequately fit the discourse structures (e.g., dialectical and rhetorical) and reasoning sequences of the group interview (see Table 8.3). Given the emphasis on dialogue, the appropriate unit of analysis was the reasoning sequence. The reasoning sequences is the conversation that takes place between group members when debating or argu-

Table 8.3 Adaptation of Walton's Schemes for Presumptive Reasoning

Argument from	Definition	Look for...
Sign	References to spoken or written claims are used to infer the existence of a property or event.	References to the project "look at this" "it shows"
Commitment	Suggests action should be taken. A claims that B is, or should be, committed to some particular position on an issue, and then claims that B should also be committed to an action.	Look for a request for action "should" "could"
Position to Know	There is insufficient information to make a judgment. Involves request for more information. A has reason to presume that B has knowledge of, or access to, information that A does not have	Look for opposition statement
Expert Opinion	Reference to an expert source (person, text, group consensus, etc.) external to the given information. Supports a personal inference or point of view	"we did this before.." "the book says"
Evidence to Hypothesis	Reference to premises followed by conclusion Includes a hypothesis—a conjecture or generalizable prediction capable of being tested. (The hypothesis can come as part of the "if" or the "then" part of the argument.)	"I think ..." "it looks like ..." "it probably would..." "if it had..." "then it would"
Correlation to Cause	Infer a causal connection between two events. Characterized by an inferential leap, based on a natural law, but devoid of any reference to observational evidence	Often based on plausibility rather than probability
Cause to Effect	Reference to premises that are causally linked to a noncontroversial effect. Effect is an observable outcome, with no need for testing	"it will..."
Consequences	Practical reasoning in which a policy or action is supported/rejected on the grounds that the consequences will be good/bad. A statement about the value of the conclusion without any expressed concerns for the properties nor the events that comprise the full argument.	"then it would be better" "it's basically good"
Analogy	Used to argue from one case that is said to be similar to another.	"like" or use of a metaphor

ing for, or against, a specific course of action or when evaluating a particular claim. There are multiple reasoning sequences in any given group discourse.

The scoring of the transcripts was carried out by six individuals trained to use the presumptive reasoning categories. Confusions among scorers between either one or the other related categories (e.g., Sign, Commitment, Position to Know) prompted us to collapsed categories (e.g., Request for Information and Inference) for purposes of the analysis. For example, when looking at students discourse it was difficult to distinguish Cause to Effect from Consequence when the Effect (boat sinks) is a negative outcome. As a summary, the collapsed categories were as follows:

- Request for Information = Sign, Commitment, Position to Know
- Expert Opinion = Expert Opinion
- Inference = Evidence to Hypothesis, Correlation to Cause, Cause to Effect, Consequence
- Analogy = Analogy

Inter-rater reliability for the collapsed categories on two different transcripts was 90% and 84% respectively.

The broad array of presumptive reasoning schemes employed by students, such as Argument from Sign and Argument from Consequences, suggests that the authentic argumentative practices of students reflect a blending of analytical, dialectical, and rhetorical devices. There are two prominent patterns that emerge from the analysis of the data. The first pattern is that the SEPIA groups in comparison to the non-SEPIA groups engage in a higher frequency of dialogic argumentation schemes in all categories of presumptive reasoning. The second pattern is that the rank order of argumentation schemes displayed by SEPIA and non-SEPIA (i.e., the average number of arguments per student group per scheme) are the same. The data suggest that a developmental corridor for argumentation would begin with the dialectical structures or patterns and build toward the analytical structures or patterns.

Overall, the comparison between the average number of arguments per student group is 35 for SEPIA and 22 for non-SEPIA (Fig. 8.2). The data suggest that there is a treatment effect for SEPIA vs. non-SEPIA.

Although our small sample does not support statistical significance, several patterns in the data are noteworthy (Fig. 8.3). One pattern is the higher frequency of inference schemes (14 versus 9) being employed by SEPIA groups as compared to non-SEPIA groups. Another pattern is the slightly higher frequency of requests for information schemes (18 versus 13) for SEPIA groups.

The interpretation of the frequency data is seen as a positive indication that the curriculum, instruction, and assessment models that guide the design of SEPIA units are effective toward promoting presumptive reasoning discourse and do so in two important areas, for example, Requests for Information and Inferences. This in and of itself is not a surprising result given Duschl and Gitomer (1997) also report the success of SEPIA design features in getting students to communicate a diversity of ideas. What the results of the present suggest though is that there is a pattern of

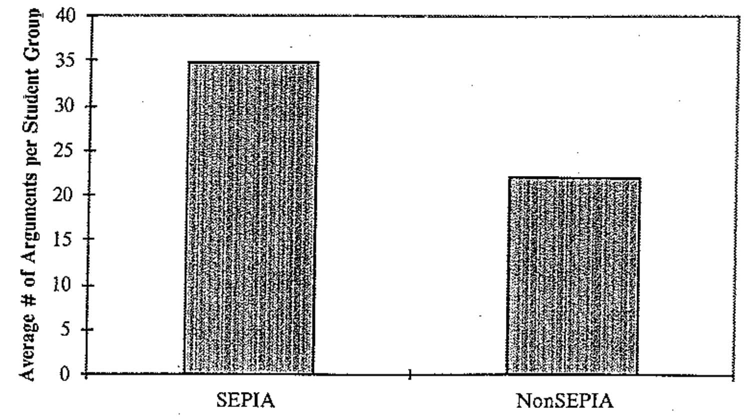


Fig. 8.2 Average number of arguments SEPIA vs non-SEPIA students

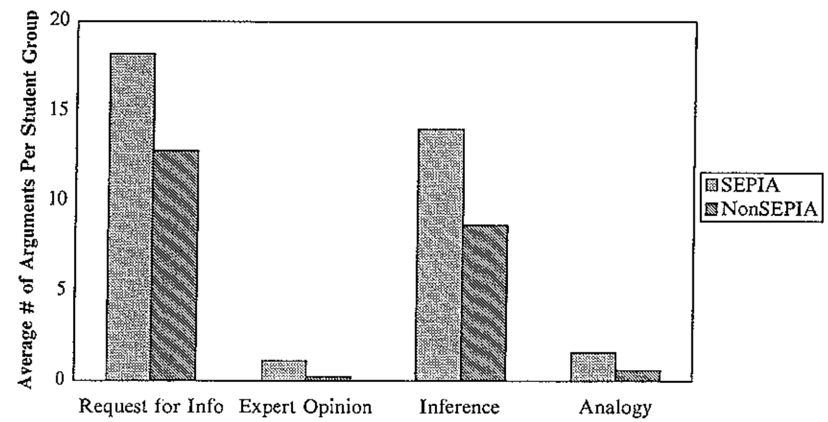


Fig. 8.3 Categories of reasoning schemes, SEPIA vs Non-SEPIA

argumentation that the students employ. More importantly, the pattern is one that teachers and students could monitor and use to develop criteria for the evaluation of knowledge claims. For example, students can examine the arguments made and ascertain the kinds of evidence and premises being used or not used. An understanding of how students engage in argumentation can promote reasoning about reasoning (i.e., metacognition).

A second prominent pattern to emerge from the data is the similar ranking of argumentation schemes between SEPIA and Non-SEPIA students (Fig. 8.4). The rank correlation of argument schemes using the Spearman Rank Correlation Coefficient

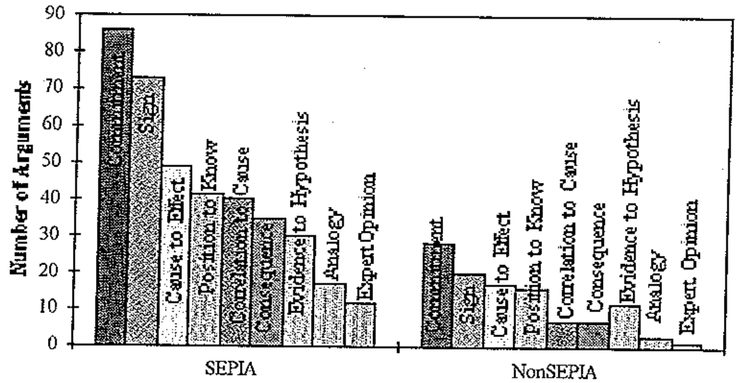


Fig. 8.4 Walton's categories for SEPIA vs. non-SEPIA groups' arguments

is 0.95. Regardless of the students' prior experiences with learning environments, the structured interviews around the science fair project stimulated presumptive reasoning discourse. Asking students to evaluate and then give advice on how to improve a product exposes the evidence and premises as well as the beliefs and assumptions that the students employ

The high rank correlation reported in Fig 8.3 is also seen as evidence that middle school age children have the cognitive and social tools to engage in presumptive reasoning on science topics. More specifically, the children are capable of employing a diversity of schemes with reference to an array of relevant evidence and premises. The data support Lemke's (1991) claims about how discourse in science classroom can shift from conceptual to structural dynamics of language if the right context is provided.

Conclusions and Educational Implications

The analysis employing the Walton scheme demonstrates that individuals bring a great deal more to argumentation than are identified by strict analytical logical schemes or rhetorical schemes like Toulmin's Argument Pattern. Such refinements help provide frameworks for getting at the five criteria set down by Sampson and Clark (2006). Argumentation frameworks that employ more refined categories or "Appeals to" structures offer productive pathways for researchers to examine the quality of argumentation in terms of epistemic criteria. Augmentation of students' discourse to promote critical thinking and reasoning would benefit by a shift from an emphasis on deductive and inductive argumentation schemes to an initial emphasis on the more natural dialogue logic found in dialectical contexts. Interventions in the form of formative feedback from teachers as well as engage-

ment in authentic tasks and activities that promote various genres of discourse that employ argumentation would seem to be important for moving students along the "talking science" continuum (Lemke, 1990). Presumptive reasoning analyses seem to be a natural entry point for the assessment and development of student's argumentation strategies. Moreover, it is appropriate to begin thinking about how the argumentation schemes for presumptive reasoning can be used as normative, "appeals to" categories within the TAP framework of warrants, backings, and rebuttals. It isn't enough to only assert the frequency of warrants, backing, and rebuttals as a measure of student argumentation because the quality of argumentation will depend on various "Appeals to" types of evidence used by students and recognized by teachers.

The decisions associated with making commitments and resolutions are guided by "the goodness, normative status or epistemic forcefulness, of candidate reasons for belief, judgment and action" (Siegel, 1995; p 162). In addition to learning about what we know in science, science education programs need to also develop learners' capacities to understand how we have come to know and why we believe what we know Having this broader science education goal depends on students' opportunities to engage in rendering decisions about the beliefs, judgments, and actions of inquiries conducted by fellow students Driver, et al. (1996) emphasized the same idea when they wrote: "if it [school science] is to contribute effectively to improved public understanding of science, [it] must develop students' understanding of the scientific enterprise itself (...) [s]uch an understanding, it is argued, is necessary for students to develop an appreciation of both the power and the limitation of scientific knowledge claims." (p 1.)

Argumentation provides a fruitful way to approach the analysis and interpretation of science classroom discussions and debates, especially for purposes of understanding how teachers and students engage in the construction and evaluation of scientific knowledge claims. Argumentation is a genre of discourse and an epistemological framework central to doing science (Driver et al., 2000; Kuhn, 1993; Lemke, 1990; Siegel, 1995). Whereas the final reports of science that appear in journals and textbooks typically portray science as purely analytical and logical, studies of science in the making (e.g., ethnographies of research groups) reveal that much of science involves dialectical and rhetorical argumentation schemes. Furthermore, as Toulmin (1958) has shown, the critical dynamics of the arguments (i.e., locating warrants, evidence, and reasons) seem to be field or domain dependent. Situating argumentation as a critical element in the design of inquiry learning environments both engages learners in the co-ordination of conceptual and epistemic goals and, for purposes of assessment, can help make thinking and reasoning visible In this way, epistemic goals are not seen as additional extraneous aspects of science that are marginalized to single lessons or the periphery of the curriculum. Rather, the pursuit of epistemic goals and the establishment of epistemic criteria for the evaluation of science claims (e.g., Sandoval and Millwood, this book) can become a core component of argumentation practices used in science education

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