

# ANALYSIS OF DIFFERENT CATEGORIES OF EPISTEMIC AND METACOGNITIVE DISCOURSE IN ARGUMENTATION

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## Abstract

*Argumentative practices have been shown to deepen understanding and improve academic performance. After 10 years of work with science curricula designed to develop reasoning, we present a framework grounded in data from our projects for identifying different forms of metacognitive engagement in science inquiry classes. We focus on four categories of discourse from our data: object of thought or discourse; expressions of what someone is thinking; degree of specificity; and discourse applying and tailoring understanding of epistemic cognition to particular topics. We present multiple examples in each of these categories. Our goal is to provide analytic tools along with examples to better identify and code argumentative discourse that advances students' apt epistemic performance.*

## Keywords

*Metacognition, epistemic cognition, argumentation*

Argumentation can be used instructionally to promote learning of content (arguing to learn) as well as to advance students' competence in argumentation and reasoning (learning to argue; Andriessen, 2006). In this paper, we focus on the latter goal: learning to reason through argumentation. When students engage in argumentation, as they give reasons and evidence in support of ideas, they may learn about how to engage appropriately in such reasoning. This is effectively an epistemic goal: educators aim for students to improve their epistemic competence through engaging in argumentation. Some scholars (e.g., Barzilai & Chinn, 2018; Kuhn & Dean, 2010) have argued that metacognitive understanding and regulation play an important role in promoting epistemic competence. Accordingly, in this paper, we explore different ways that metacognitive understanding and regulation can appear in argumentative discussions.

Building on the virtue epistemology of Sosa (2015), Barzilai and Chinn (2018) developed a systematic framework for analyzing what is needed to promote epistemic growth. The authors posited that the goal of epistemic education is *apt epistemic performance*. *Epistemic performance* refers to people's responses with respect to knowledge-related matters. Some examples of epistemic performances are forming or reevaluating beliefs, or developing models or explanations. *Apt* epistemic performances are epistemic performances that are successful (e.g., one develops a well-supported explanation) due to one's competence (e.g., one uses appropriate processes of selecting and evaluating evidence for developing this explanation, and these processes are the cause of the well-justified explanation that one develops).

Barzilai and Chinn (2018) argued that epistemic competence involves use of the three main components of epistemic cognition from the AIR model of epistemic cognition (Chinn, Rinehart, & Buckland, 2014). Epistemic Aims and value refer to the goals that people have, such as finding things out or developing explanations, and the value that one places on these aims. Epistemic Ideals are the criteria that are used to evaluate whether the epistemic aims have been met (e.g., fit with evidence). Reliable epistemic processes are procedures, strategies, and methods that have a good probability of achieving epistemic aims (e.g., careful procedures of selecting representative samples in a study).

The Apt-AIR framework developed by Barzilai and Chinn (2018) extends the AIR model by showing that apt epistemic performance involves competent engagement with the three components of the AIR model across five aspects of performance: (a) cognitively engaging in epistemic performance (engaging in cognitive processes that reliably achieve epistemic aims in accordance with epistemic ideals); (b) metacognitively understanding and regulating epistemic performance; (c) participating in epistemic performance with others in varied social configurations and settings; (d) caring about and enjoying epistemic performance; and (e) adapting epistemic performance across diverse situations.

In this paper, we focus particularly on argumentative practices that enact the cognitive and metacognitive aspects of epistemic performance, both individually and socially, in inquiry-based science classes. There are many reasons to think that metacognitive understanding and regulation are important in supporting effective performance at the cognitive level (Barzilai & Chinn, 2018). Many studies support the general value of metacognitive understanding in improving academic performance (e.g. Barzilai & Ka'adan, 2017; Barzilai & Zohar, 2012; Blank, 2000; Schwarz & White, 2005). However, recent work (Barzilai & Chinn, 2018; Barzilai & Zohar, 2014) has developed more nuanced views of the different forms that metacognitive understanding and regulation can take, and therefore there is a need to identify what these forms are. Scholars have argued that some forms of metacognitive knowledge may be more valuable than others; for example, in the domain of science learning, several scholars (Allchin, 2011; Hogan, 2000; Sandoval, 2005) argued that distal, formal knowledge of what scientists do may be less valuable in supporting students' reasoning than more proximal, practical knowledge of how to engage in sensemaking in their own classroom.

Thus, some forms of metacognitive engagement may be more productive for epistemic growth than others. But to investigate which forms are most productive, we need to continue to develop our understanding of the different forms that metacognitive engagement can take. Thus, our research question was: What are different forms that metacognitive engagement can take during argumentation in inquiry-based science? Because our research focused on inquiry-based science classes, we will focus on categories of metacognitive engagement that emerge in our data from elementary- and middle-school science classrooms.

Why would an analysis of different forms of metacognitive engagement in argumentation be valuable? One reason is to provide conceptual clarity about different forms that metacognitive discourse can take in argumentation. There is still no unified theory of metacognition or its subcategories (Barzilai & Zohar, 2014), and we hope to contribute to analyses of what metacognitive discourse looks like during argumentation. To facilitate metacognitive discourse in argumentation, teachers and researchers must first understand and be able to identify the variations such discourse can take.

A second reason is to provide guidance for coding written and discourse data. We have had many discussions during the past years among ourselves and with other coding teams about how to characterize different kinds of cognitive and metacognitive discourse. Our analysis can provide guidance for such coding.

The third and most important reason is that analyzing the types of metacognitive discourse in argumentation can allow for identification of the types most conducive to learning. To begin investigating which forms of

metacognitive discourse are most productive in advancing apt epistemic performance, we need first to identify more of the different forms that metacognitive discourse can take during argumentation.

Our analytic approach in this paper follows rhetorical work on argumentation, in which examples of discourse are offered as evidence for relevant distinctions and claims about argumentation (e.g., Johnson, 2000; Perelman & Olbrechts-Tyteca, 2000). Like many working in this tradition (e.g. Walton, 2016), we present examples that mostly come from actual arguments and argumentative discourse. We describe the data sources from which our examples are taken below.

### Data Sources

Our examples of argumentation representing different types of metacognitive discourse come from elementary- and middle-school students participating in the PRACCIS: Promoting Reasoning and Conceptual Change in Science project (Chinn, Duncan, & Rinehart, 2018). PRACCIS design takes the broad view that the process of learning to reason is sociocultural and dialogic (Reznitskaya & Gregory, 2013). The goal of the PRACCIS learning environment is to advance simultaneously students' understanding of science content and their proficiency in the epistemic practices of science. As part of PRACCIS, students participated in a model-based, life-sciences inquiry curriculum over an extended period of time. Throughout this curriculum, students used evidence to develop, evaluate, and revise scientific models, and they developed public, shared lists of epistemic criteria that they could use for model and evidence evaluation. As part of the intentional PRACCIS lesson design, students evaluated evidence of varying quality; for example, evidence was anecdotal or involved studies with flaws such as poor measures or confounded experiments. Students were provided scaffolds to evaluate evidence and models and how they relate to one another.

Our data are drawn from three instances in which this work was implemented, twice in middle school (seventh grade) and once in elementary school (fourth and fifth grades). At the middle-school level, 12 teachers in five schools and their students participated in this project; nearly half of the classes were regularly video recorded during a 5 to 6-month intervention in which students engaged in model-based inquiry activities encouraging argumentation. At the elementary-school level, 20 students from one school participated in the project in an after-school science club setting and were recorded during weekly meetings for six weeks.

Throughout the PRACCIS curricula, students engaged in inquiry in which they used evidence to develop and evaluate scientific models on life-science topics such as genetics, the function of mitochondria, and how natural

selection occurs in particular contexts. The intended discourse was usually argumentation; the curricula were designed to encourage students to engage in argumentation as they developed their own models, evaluated their own and others' models, scrutinized the quality of evidence available, and evaluated the strength of justifications given to support various claims.

PRACCIS incorporates a variety of scaffolds to support students' reasoning. A scaffold that is particularly salient for our discussions in this paper is the development, refinement, and use of public criteria for model quality, argument quality, and the quality of scientific evidence. For example, after some initial experiences with models, students develop lists of criteria (ideals) that characterize good scientific models—criteria such as “models should fit the evidence,” “they should show all the steps,” and “they should answer the question.” Some students also developed lists of reliable processes that should be followed (by themselves and by scientists) when developing high-quality scientific evidence. Thus, the curricula focused on having students develop explicit knowledge ideals and reliable processes that are relevant to scientific inquiry.

### **Categories of Epistemic Cognitive and Epistemic Metacognitive Discourse in Argumentation**

Our analysis aims to identify forms of epistemic cognitive and metacognitive discourse in argumentation that have emerged in our analyses of middle-school science argumentation. Most analyses of metacognitive discourse distinguish between two kinds of metacognition: metacognitive knowledge or understanding, and metacognitive skills (see Barzilai & Zohar, 2014). *Metacognitive knowledge or understanding* refers to the knowledge or beliefs that one has about epistemic matters, such as what knowledge is, how knowledge is produced, and how one comes to know (Barzilai & Zohar, 2014; Flavell, 1979). *Metacognitive skills* are the processes and strategies that people use to regulate epistemic activities such as developing beliefs and engaging in inquiry (Barzilai & Zohar, 2014; Veenman, Van Hout-Wolters, & Afflerbach, 2006).

We used a bottom-up analysis of the discourse that we have seen in the project over the last 10 years. This analysis revealed four categories (Table 1) that are relevant to whether statements in argumentative discourse are metacognitive and, if so, the respects in which they are metacognitive; we will discuss each category below. Collectively, the four categories specify different forms that metacognitive statements can take. The first two categories, *object of thought or discourse* and *expressions of what someone is thinking*, have traditionally been used to define metacognitive levels of thought and discourse. The other two categories, *degree of specificity* and *applying and tailoring*

*epistemic components (aims, ideals, and processes) to particular topics*, introduce other forms of metacognitive discourse that may advance apt epistemic performance. Our discussions of these categories highlight distinctions that define different forms of epistemic cognitive and epistemic metacognitive discourse.

Table 1

*Categories of Metacognitive and Epistemic Discourse in Argumentation*

Category	Definition
Object of thought or discourse	Whether the topic of discussion is cognitive (e.g., topic-based content) or metacognitive (e.g., epistemic products and processes).
Expressions of what someone is thinking	Statements that show metacognitive monitoring of one's own or another's thinking.
Degree of specificity	The topic of discussion as it falls on a continuum from highly general to highly particular. See Figure 1.
Applying and tailoring epistemic components (aims, ideals, and processes) to particular topics	Metacognitively adapting components of epistemic thinking for use in new situations.

Throughout our analysis of the four categories, because we are focusing on argumentative discourse (written or oral), we will treat terms such as *thought*, *idea*, and *statement* as interchangeable because in the context of language, thoughts and ideas are expressed through statements in language. Also, because our own research is in the domain of science education, we will refer especially to scientific discourse, knowledge, and ways of knowing; we believe, however, that these issues are equally applicable to other domains (history, social sciences, mathematics, etc.). Note that all example transcripts and work samples are verbatim, and thus may include spelling and grammatical errors.

#### *Category 1. Object of Thought or Discourse*

This category lays part of the basic groundwork for defining cognitive versus metacognitive statements. Metacognitive knowledge is typically defined as including knowledge about cognition and regulation of cognition (Brown, 1978; Flavell, 1979; Veenman et al., 2006). Thoughts or discourse at the level of cognitive engagement have topic-based content (science concepts and principles, etc.) as their objects. In contrast, thoughts and discourse at the metacognitive level are thoughts with epistemic products and processes (e.g., claims, models, arguments, procedures for knowing) as their objects (Barzilai & Zohar, 2014). Examples include people thinking or talking about the nature of scientific models, about good inquiry practices that are reliable at finding things out, and about the qualities of good evidence.

An example of discourse primarily at the cognitive level comes from a discussion in which a pair of students tried to figure out why fish in a fish tank simulation were dying. One student made a claim, and the other student refuted it; the talk was clearly focused on content (why the fish were dying):

Example 1

S1: So, I see fish dying because we have very bad poor water quality.

S2: That's not true! They said they died because of other causes!

S1: Okay, so we have a lot of other causes that made our fish die.

An example of discourse at the metacognitive level comes from a discussion in which students were revising a class list of criteria for good models:

Example 2

S1: We also thought that every model should have a justification. Even if it has a picture, it should have an explanation.

T: All have a justification or explanation?

S1: Oh, explanation.

S2: Just because the picture or visual might not explain fully what you want to say.

Again, one student made a claim, and the second student supported the claim with a reason. But here the topic of the discussion was the nature of good models, an inherently metacognitive topic about the epistemic product “models.” This was a discussion in which students developed a metacognitive understanding of ideals for good models.

In PRACCIS, students’ metacognitive discussions of epistemic ideals and reliable processes (as in Example 2) provide a metacognitive understanding that can be leveraged in later class discussions as students build and evaluate explanatory models in science inquiry. We return to this issue and provide examples of this in our discussion of Category 4.

*Category 2. Expressions of What Someone is Thinking*

The state of being metacognitive is relative (S. Barzilai, personal communication, October 1, 2019; Nelson & Narens, 1994). When a student says, “*I think* that mitochondria produce energy,” the use of “I think” indicates that the student is metacognitively monitoring the believability of the cognitive-level science statement about mitochondria. When a student says, as in Example 2, “We also thought that every model should have a justification,” the student is metacognitively monitoring her classmates’ collective evaluation of a statement that is already at the metacognitive level. Thus, there can be multiple levels of being “meta.”

Statements can be shifted to a higher metacognitive level simply by saying that someone “thinks,” “believes,” “knows,” or “concludes” something; by saying that something is true; and so on. Student 2’s exclamation “That’s not true!” in Example 1 is an example of Student 2 monitoring her epistemic evaluation of Student 1’s statement. Example 3 shows two students monitoring their knowledge and certainty about cognitive-level statements. The students were discussing patterns seen in a simulation about fish in an aquarium. Two students were looking at a graph generated by a run of a simulation and trying to understand why the line indicating water quality was fluctuating:

### Example 3

S1: Alright, so I think that... well, actually, really, I don’t know why it happened.

S2: I think that the line is going up because it’s showing how much the food is rotting at different periods of time, and so...

S1: Why is it going up and down? I don’t know. Actually wait, I think I do! I think it’s because the less fish that there are when they keep on dying, the less... wait! No, it should be going more down because the less fish there are, the more food is left, and then the more food that’s left for a long time, it’s going to rot a lot.

After several attempts at explanations, the two students had not yet resolved the issue, both declaring that they were “not sure.” When students use phrases such as “we know...” or “I believe...,” it indicates that they have evaluatively monitored the positions taken by the class and the degree of certainty they have in order to deem something to be “known,” “believed,” and so forth. Although students may spontaneously monitor their understanding and positions, in PRACCIS we engineered opportunities for monitoring building in areas of disagreement, such as including incomplete or conflicting evidence. We further facilitated students’ monitoring of their knowledge by enabling them to develop class lists of shared epistemic ideals for good models and good evidence that they could use to evaluate models and evidence.

One complication in coding concerns markers such as *maybe* or *probably*. These are often treated as “qualifiers” in analyses of argumentation (following Toulmin, Rieke, & Janik, 1984). However, they can also be regarded as explicit indicators of epistemic stances toward the qualified statement. Students who say that “Mitochondria probably produce energy” are indicating their epistemic stance that they have some degree of confidence but do not regard the statement as certain. This is again treating the statement as the object of epistemic evaluation to determine the degree of certainty. Analysts must decide how to address these issues and must be consistent in their treatment of such cases.

### *Category 3. Degree of Specificity*

Discussions can vary along a continuum from focusing on particular topics to focusing on highly general topics. Figure 1 suggests such a range of categorization. We will begin our exploration of this category by examining the two endpoints on this continuum, as well as the intermediate levels between them:

- *The particular.* The discussion is at the level of cognitive engagement with particular claims, explanations, models, and arguments about particular science-content topics, such as the function of mitochondria or why fish are dying in a pond. These include most of the examples we have discussed so far (Examples 1, 3, and 4).
- *The highly general.* At the other extreme are general discussions about very general epistemic aims, ideals, and processes. Our PRACCIS curricula do not focus on this level of generality, but an example would be a class discussion of the nature of knowledge, generalizing across all domains. Such discussions are at the level of metacognitive understanding, at a very general level. Some research focused on promoting development in general epistemic beliefs has focused on this level of generality (e.g. Hefter et al., 2015).
- *Intermediate levels of generality.* In between these two extremes are other forms of discourse at intermediate levels of generality. All are metacognitive because the conversations focus explicitly on ways of knowing to various degrees of generality rather than on particular science content.

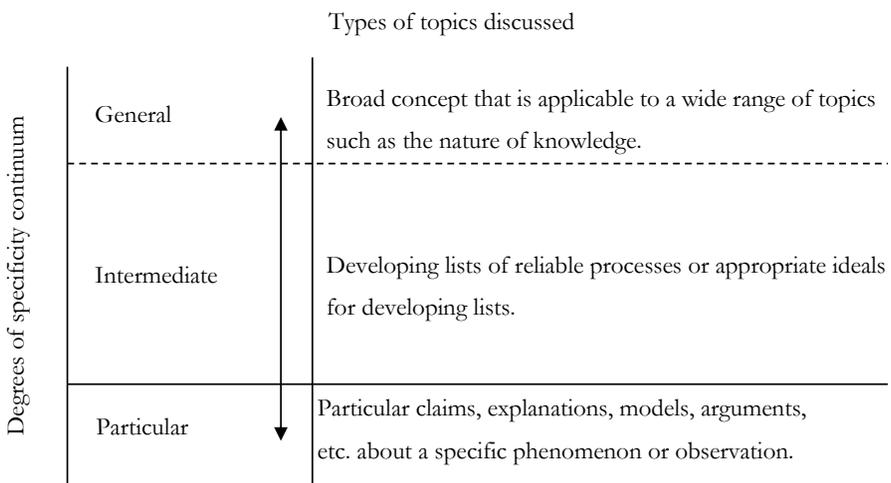


Figure 1  
*Continuum of degrees of specificity*

Some of this discourse is still at quite a general level. For example, some programs that promote understanding of the nature of science include a focus on understanding that scientific knowledge is social and that it is culturally embedded (Lederman, Abd-el-Khalick, Bell, & Schwartz, 2002). The idea that science is a social and culturally embedded process is itself highly abstract and general (Hogan, 2000). Discourse that addresses such abstract concepts will necessarily be quite abstract and general.

In contrast, one could discuss social processes of science at a much more practical level, by which we mean that the discussion addresses aims, ideals, and processes that are immediately applicable to evaluating particular knowledge claims (such as the use of the ideal of “fit with the best evidence” to explain the function of mitochondria). For example, students could consider specific social processes such as how scientists submit their work to peer review, how peer review works, and how reliable these social processes are for rooting out methodological errors and other problems. Such discussions would be highly applicable to evaluating reports that students read online; they can use the practical knowledge gained from discussions to evaluate whether the empirical research discussed in these reports have been properly peer reviewed.

PRACCIS incorporates regular argumentative discussions at this practical, intermediate level of generality. Students develop, use, and periodically revise lists of ideals (or criteria), such as ideals for good models or good arguments. We have also had students develop lists of features of good methodologies (i.e., reliable processes) for producing evidence. The products of these discussions are practical lists of ideals and processes that students can apply when they engage in evaluation of particular models, arguments, and evidence.

The goal has been to engage students in argumentation to develop their explicit metacognitive understanding of aims, ideals, and processes used in science. Students articulate what they think are valuable ideals and reliable processes and give reasons (justifications) for their ideas. Example 2 provided one excerpt of such a discussion. Here is another (Chinn et al., 2018, p. 249):

#### Example 4

- S1: Because, um, things are more important than visual aids like you need everything to stick on topic, that’s more important than visual aids, so stick on topic should be number one.
- T: ... S2, what do you think of that?
- S2: I agree, but it shouldn’t be number one because I think that, um, diagrams and pictures and explanations are more important than just sticking on topic. Well it’s very important...
- S3: Well, if you have, if you have good, um, like text and evidence and good pictures, that won’t even matter if the model that they’re involved in

doesn't relate to the topic because if the topic is like how like the water cycle and like you have a picture of like a volcano erupting but it's a really detailed picture and it's got evidence supporting how it erupts, that's not gonna matter because it doesn't relate to the topic...

In this example, students were developing ideals that they could use to evaluate the models that they themselves create in their future inquiries. Students 1 and 2 disagreed about whether sticking on topic or other ideals are the most important criteria for good model quality. Student 3 provided a reason for thinking that sticking to the topic is a more important criterion for good models than visual aids. As such, these conversations are meta at two or more levels. For example, the statement "Models need to stick to the topic" is an example of a metalevel statement because the objects of thought are cognitive/epistemic entities (models). The reasons given to support it are reasons for evaluating this claim positively and thus are meta with respect to a claim that is itself already meta. By having students engage in reflective argumentation about valuable ideals and about the reliability of different processes, argumentation of this sort can advance students' metacognitive understanding of ways of knowing.

Whether discourse is at a particular or more general level, analysts can distinguish between whether students are referring to (a) their own ways of knowing within the classroom or (b) the ways of knowing of others (such as scientists whose research they may read about; see also Hogan, 2000; Sandoval, 2005). Students may focus on their own ways of knowing (such as reliable processes for how they themselves conduct measurements in their classroom or their own reliable processes for deliberating about ideas in class discussions) or on ways of knowing that others such as scientists use (such as use of microscopes of a power that students do not have access to or peer review publication processes that scientists use). For example, the students in Example 5 below applied their metacognitive knowledge of microscopes used by scientists to discredit a report by someone who claimed to observe mitochondria through a magnifying glass:

#### Example 5

S1: I dispute him because he used only a magnifying glass and lights and reading glasses.

T: And what does that mean?

S1: Nothing. You can't see mitochondria without a powerful microscope.

T: Ok.

S2: And if you can't see mitochondria, you can't know if it's producing energy or not.

S3: Yeah the mitochondria it you can't see it without the proper tools.

It is frequently helpful to distinguish between whether students' epistemic reflections are addressing their own ways of knowing or others' (such as scientists) ways of knowing (Barzilai & Zohar, 2014). Both forms of metacognitive understanding can be relevant to particular inquiry problems.

In our discussion of Category 3, we have unpacked an important dimension along which metacognitively focused discourse can vary: its generality. Metacognitive discourse can be highly general or can occur at intermediate levels of generality. The discourse that may be most applicable to inquiry that students will engage in is at an intermediate, practical level of generality. We have also noted that the aims, ideals, and processes that students articulate may be their own or those used by others such as scientists.

*Category 4. Applying and Tailoring Understanding of Aims, Ideals, and Reliable Processes to Particular Topics*

When students are engaged in argumentation about particular science topics (e.g., why fish are dying), they can bring to bear their more metacognitive understandings about epistemic aims, ideals, and processes that they have developed previously to help them evaluate claims as they engage in inquiry on science topics. In Example 5, students applied their understanding of appropriate observational tools to a particular instance in which an observer used a magnifying glass inappropriately. Accordingly, we argue for the value of discourse that applies more general ideals and ideas about reliable processes to reasoning about particular science inquiry topics. Such language also tailors the use of those ideals and processes to the particular situation, thus enriching students' understanding of those ideals and processes. For instance, when students argued that a classmate's model of photosynthesis does not "show all the steps" (which was one of the class ideals for good models) by saying that the steps do not include what they learned from the evidence on chloroplasts, the students were both applying the general ideal to this situation and elaborating on the conditions of application by articulating a particular step that is important in this case (Chinn et al., 2018). We refer to such elaborative discourse as tailoring ideals and processes to the particular situation.

The discourse from our project has many instances, in both written and oral argumentation, of such applications of ideals and processes that have been discussed more generally in previous epistemic discussions at a general level (e.g., application of ideals on a list of class ideals). Here is an example in which a student applied several more general ideals about good models to a written argument evaluating two models that explain why leaves fall from trees in autumn:

## Example 6

S1: I believe that the Poisonous Chemicals model is a better model of why leaves fall from trees to the ground during the autumn season. Firstly, there's more evidence to back up Model A. For example, evidence 3 states "...but there were more dead cells in leaves that just fallen." This is similar to Model A because the leaves fall because of a poisonous chemical or dead cells. Also, it feels that's more real or true: I mean it sounds more real than Model B meaning it actually happens. Finally, it has diagrams, facts, or short paragraph to back up the picture.

This essay includes general epistemic ideals for good models that were developed as a class during previous metacognitive discussions (e.g., fit with evidence, using diagrams, and including facts or information) to reason about this particular problem.

Another example comes from class discussions in which students were evaluating several alternative models of how lead (which is poisonous to cells) is able to get into cells; then they reported their conclusions to the class. Each of the teacher's classes provided many instances of students applying their class lists of ideals of good models to this particular inquiry topic. Here are the responses of two groups, making claims about model quality and then supporting their claims with reasons derived from their previous metacognitive discussions of the ideals for good models:

## Example 7

G1: We thought that the first one was the worst because it didn't have any good information... It just said that it was bad... It doesn't say why except that he saw something on the Internet, but you don't know that what he saw on the Internet was right, and so like it just seems like he going on his gut feelings... Yeah, he doesn't have any evidence to like show anything.

G2: She doesn't really answer the question... Like the question is how lead gets into the cell; she just wrote like exposure and drew a line and the cell... and actually it tells you... I don't know... It doesn't answer the question.

These students had previously developed practical ideals at an intermediate level of generality (in this instance, the ideals referred to are "has good information" and "answers the question"). These ideals are practical because they are at a grain size that can be used to help students evaluate particular scientific models in future inquiries. This is an example of tailoring the use of these ideals ("has good information" and "answers the question") to the

particular situation. For example, this discourse helps students clarify what it means to “answer the question” as G2 argues that the model just shows *that* lead gets into the cell, and it does not tell *how* it gets into the cell. This argument clarifies that the particular question word used (*how* in this case) is vital for appraising whether the question has been answered. We posit that such discourse tailoring that shows how ideals and processes apply to particular situations can deepen students’ understanding of what ideals mean and how they can be applied.

We regard such argumentation discourse as focused on particular science topics while applying a prior, more general, understanding of aims, ideals, and processes to these topics. Students can also elaborate on how the aim, ideal, or process applies to the particular situation through “tailoring” language in the argumentation. Notice that such discourse depends on students having access to more general understandings that are sufficiently practical to be usable. Highly general notions such as “science is social” may be too distal from practical problem-solving to be useful.

Here is a final example that shows students applying to a particular topic their more general understandings of reliable processes for carrying out investigations. Students were reading and evaluating (on a scale of 0 to 3) the quality of a piece of evidence bearing on whether mitochondria produce energy or instead produce movement. During the discussion, the students noted several problems with the method used to produce the evidence, as exemplified in this excerpt:

#### Example 8

T: What do you think, S1?

S1: Uh, I think it’s a 2 because he explains himself and (inaudible).

T: S2?

S2: I agree with S1, but I disagree with her because he [the experimenter in the report they read] checked all his work, like he checked his work with his lab partner and like they couldn’t have all gotten like everybody gotten it wrong and like they say two heads are better than one so like if the work of the lab partner they could have corrected (inaudible).

Student 1 tailored a general understanding of good work methods to this situation by elaborating on what it is about the procedures that amounts to “good work methods”: checking work and collaborating with others. These kinds of elaborations might lead to revisions of the class’s list of reliable methodological processes, such as adding “confirming results with others” to the list of reliable processes.

## Summary and Conclusions

In this paper, we have analyzed four categories of metacognitive discourse that can emerge in oral and written argumentation. The first two categories draw on previous ways of defining metacognition. Category 3 identifies ways in which metacognitive discourse can vary in specificity. We distinguished between highly general and intermediate levels of generality in metacognitive discourse. We also suggested that the most useful forms of discourse may be at the intermediate levels, with a focus on epistemic aims, ideals, and processes that can be used in practical ways on particular inquiry problems. We also noted that such argumentative discourse can address one's own epistemic aims, ideals, and processes or, instead, those used by others such as scientists. Finally, in our discussion of Category 4, we emphasized that students can apply more general understandings of aims, ideals, and processes to particular cognitive inquiries. This discourse can also include tailoring elaborations that specify how more general ideals and reliable processes can be contextualized to fit particular situations. It is important to note that these four categories are not meant to be exhaustive; rather, they represent categories that have emerged from the data from our project. We anticipate that data from tasks that may have other affordances and constraints may yield some differences, which will contribute to the field's developing understanding of metacognitive discourse.

One purpose of identifying categories of metacognitive discourse in argumentation is to provide clarity about different types of metacognitive discourse, as well as guidance for research teams seeking to code argumentative discourse. But our ultimate purpose is that these four categories collectively identify different forms of cognitive and metacognitive discourse that may be differentially effective at promoting epistemic growth in students' reasoning and argumentation. Below we briefly summarize some of the forms of discourse our analysis highlights.

First, we highlight simply that argumentative discourse can be at a metacognitive level. Much of the research on science inquiry has focused on engaging students mainly in inquiry on particular science topics, with limited discourse directed specifically at building students' explicit metacognitive understanding (Chinn, Barzilai, & Duncan, 2020). Our analysis points to the potential importance of engaging students in metacognitive levels of discourse that engages students in argumentation about epistemic aims, ideals, and processes (cf. Barzilai & Zohar, 2014; Chinn et al., 2020; Chinn et al., 2018).

Second, our analysis highlights that argumentative discourse can be at very different levels of generality. Much of the research on promoting understanding of the nature of science has focused on promoting explicit metacognitive knowledge of a quite general level (e.g., the idea that science is social; Lederman et al., 2002). In contrast, our approach emphasizes

developing a metacognitive understanding of aims, ideals, and processes that are highly practical—that is, they are directly applicable to reasoning and argumentation about particular science topics. These understandings focus on a practical and intermediate level of metacognitive generality.

Third, like others (e.g. Barzilai & Zohar, 2014; Hogan, 2000; Sandoval, 2005), we note that explicit metacognitive reflection can be directed at one's own ways of knowing, versus the ways of knowing that others use. Some have suggested that scientists' ways of knowing are not very applicable to students' own inquiry in science classes (e.g. Hogan, 2000). However, our analysis points out that understanding scientists' ways of knowing at a more practical level of generality (e.g., understanding the specific reliable processes used in science) can enable students to engage in their own inquiry, when that inquiry involves reading online documents that report on evidence that scientists produce.

Fourth, our analysis points to a form of discourse that has not been emphasized in previous research—the form of discourse that involves using previously learned general aims, ideals, and processes in argumentation about particular inquiry problems. When students gain a metacognitive understanding of practically useful aims, ideals, and processes, they can apply these (through their discourse) to their own future inquiry activities.

Our own expectations are that explicit metacognitive discourse directed at developing explicit metacognitive understanding is valuable, especially when the aims, ideals, and processes that emerge are practical and are at an intermediate level of generality. We also expect that applying and tailoring these aims, ideals, and processes to particular inquiry topics will prove productive to students' growth in reasoning and argumentation.

In short, our framework provides analytic tools to code argumentative discourse in ways that can enable researchers to investigate the benefits and drawbacks of different forms of metacognitive discourse. And we believe that our analysis has pointed to some forms of discourse that have been insufficiently investigated by current researchers.

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