Assessing Students' Ability to Argue across Multiple Modalities

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During the last two decades, science educators have increasingly recognized the importance of argumentation in the development of scientific knowledge and have advocated for its central role in the science classroom. This role has been reflected in the new Framework for K-12 Science Education (National Research Council, 2011) and Next Generation Science Standards (Archieve, 2012), as well as common core standards for literacy (Common Core State Standards Initiative, 2010). A wide range of research has been conducted from a variety of perspectives to examine how students argue, and more recently, these efforts have also been linked to the development of new assessment and instructional approaches for fostering argumentation (S. Erduran & Jimenez-Aleixandre, 2007; Khine, 2012).

Among these, Learning Progressions (LPs) have gained growing attention because LPs are proposed as a means to align standards, curriculum, and assessment (NRC, 2007). LPs embody a developmental approach to learning by describing theoretical paths that students might take as they develop progressively more sophisticated ways of reasoning about concepts and practices. Yet, there are concerns around LPs regarding theoretical foundation and driven methodologies to refine constructs and ways to gather evidence (Duschl, Maeng, & Sezen, 2011). That is, although theoretical foundations of LPs vary, a prevalent way to define students' progress is based on the theory of conceptual change and novice-expert paths where students improve from less expert ideas to more expert ideas (Duschl, Maeng, & Sezen, 2011). While these types of LPs based on a strict sense of cognitive development might suggest where students' progression comes from, or how it might proceed, there is less consideration given to "what conditions" can support productive learning progressions (Schauble, 2008).

A learning progression for scientific argumentation (Berland & McNeill, 2010) notes this limitation and suggests that LPs for scientific argumentation must take the complex relationship between instructional environment and students' work in practice into consideration. They underscore the importance of supporting the learning environment including curriculum, tools, classroom culture, and discursive norms to describe learning progressions in terms of argument process and product. From this notion of LPs for scientific argumentation, it seems essential to understand "under what conditions" students are capable of or have difficulty as they engage in argumentation practices.

In this paper, we take different modalities of argumentation—in particular, reading and talking—as important and different conditions to understand students' argumentation practice better as scientists engage in these modes for different opportunities. Scientists read others' publications to extend their understanding of the field, argue verbally with others in meetings and conferences to communicate, and write and publish their own arguments (Latour, 1987; Pearson, Moje, & Greenleaf, 2010). Although literature reviews on scientific argumentation have examined how argument interventions promote scientific argumentation (Cavagnetto, 2010; Clark & Sampson, 2008), little is known about how students argue across multiple modalities, particularly in association with different kinds of supporting interventions. Therefore there is a growing need to better understand students' ability to engage in argumentation across modalities with supporting interventions. In particular, whereas a number of studies on students' written argument have been conducted, little is known about spoken argumentation and reading argumentation.

This study reviews and analyzes the characteristics of argument-based interventions in the area of literacy and science education to understand students' abilities to argue in reading and spoken argumentation. We then show how we reflect these findings from our review into the assessment design process. Two questions are answered: (1) In reading and oral argumentation, what capabilities and difficulties do students show? Are there commonalities and differences in different modalities? (2) What epistemic and rhetorical aspects of scientific argumentation should be assessed in different modalities?

We searched argumentation studies that were conducted in upper-elementary and secondary schools (mostly middle schools) in science-related contexts. We categorized these studies into larger trends and approaches in each modality (e.g. Disciplinary Oriented Reading, Toulmin's Argument Pattern in oral argumentation, Computer-Scaffold Tools use). We investigated four characteristics of argumentation for each paper, including the modes and types of argumentation (e.g., reading to understand arguments, speaking to construct and critique arguments), the capabilities and difficulties encountered (e.g., constructing causal claims but experiencing difficulty in developing justifications), and an explicit comparison among multiple modes, if applicable (e.g., providing rebuttals in oral argumentation but not in written argumentation).

Reading Arguments in the Classroom

Students' ability to read a scientific argument has been hardly addressed. The reason for this is in part because most work of students' scientific argument has been focused on students' construction of arguments, and there has been little work on the evaluation or critique of arguments that assess students' ability to comprehend, interpret, and evaluate arguments (Osborne, MacPherson, Patterson, & Szu, 2012). It is important to note what we mean by *reading* before we discuss reading arguments. By reading, we do not mean simple decoding of words on paper or acquisition of new vocabularies; we hold a much more comprehensive view of reading that involves an understanding and the ability to take different perspectives, especially through understanding disciplinary-oriented perspectives and complex reasoning.

One goal of learning to scientifically argue is to promote scientific literacy that prepares students to be informed and responsible citizens in a democratic society. While lay people might hardly engage in writing or even talking about a scientific issue, they commonly engage in reading science-related texts in this digital media era. Based on their reading, people develop understanding, raise questions or issues, and determine where they stand on the issues in everyday lives.

For reading argumentation, the assessment of reading scientific arguments often focuses on measuring students' ability to comprehend texts and develop summaries (E.B. Moje, 2010; Sutherland, 2008). However, reading scientific arguments could help students develop an understanding of the importance of coordination of claims and evidence, identify the adequacy and relevance of evidence, and understand the genre-specific nature of text structure. These potentials are found in a range of research that integrates literacy and science (Pearson et al., 2010). Although these works hardly use the exact terms "epistemic or rhetorical quality" of scientific argumentation, their findings suggest that engaging students in reading argumentation can significantly support their improvement of the epistemic and rhetorical aspects of scientific argumentation. For example, when students compare scientific and lay-audience texts, they develop an understanding of different kinds of claims, whether based on the prediction of observational phenomena or based on simple inference (E.B. Moje et al., 2004; Textual Tools Study Group, 2006). They also evaluate how evident the presented data are in relation to the claims, and thus whether the argument is rhetorically appropriate (Textual Tools Study Group, 2006). Consequently, we not only visit articles published in the area of science education, but also extend our review to literacy literature—in particular, disciplinary-oriented literature.

Adapted Primary Literature (APL): Understanding Coordination between Theory and Evidence

Adapted Primary Literature (APL) suggests how reading scientific arguments—especially through the format of professional science articles—could help students improve their epistemic and rhetorical understanding of scientific arguments. The scholars using this approach in the classroom particularly highlight the advantage of presenting a current *theory* (a scientific argument) to students, as opposed to presenting an argument as static facts in the science textbooks.

The APL approach uses science research articles for science class. Considering students' content knowledge levels and reading comprehension levels, the professional journal articles are modified and adapted to enable students to adequately read and comprehend the articles in relation to the content area taught. Compared to science textbooks, the adapted professional articles maintain the canonical structure of the research article (research question, background, method, results, discussion, and future direction). These articles also provide more basic background knowledge in the front of the paper and describe the methods in much more specific detail. Results and discussion are presented in a manner in which scientists precede their results in an authentic way with promises and limitations, rather than presenting them as mere facts.

Baram-Tsabari and Yarden (2005) found that students were more likely to raise scientific criticism regarding the coordination between theory and evidence compared to when students were asked to read a popular science magazine. They argue that this seems to occur because students understand through reading these APL resources that scientists include argumentation as a means of presenting and weighing evidence and assessing alternatives, and thus they come to better understand the attitudes of uncertainty for both the techniques and results of scientific inquiry, which are subject to continual changes and reexamination. Falk and Yarden (2009) provided similar results, showing that students better understand the nature of coordination in science when using APL as opposed to science textbooks. Students showed enhanced understanding of new knowledge building; that conclusions should cohere with reading of evidence, even when data show some conflicts; and that scientific modeling and theory should satisfy high scientific standards. For the rhetorical perspective, students not only better understood that interpretation of texts and evaluation of concepts' potential are dependent upon the ways in which scientists present their argumentation, they also understood that a central communicative feature of primary literacy in science is the use of multiple representations including graphical representations to display the results from experiments more effectively (Hapgood, Magnusson, & Sullivan Palincsar, 2004).

Despite these promising advantages, however, the scholars also found challenges and limitations of this approach. Students' general reading comprehension level influenced students' understanding of APL texts. Whereas the canonical structure boosts comprehension, some students develop an idea that all science in the real world is an ordered process similar to the way science articles are organized (Falk & Yarden, 2009). Falk and Yarden (2009) also note students' difficulty with reading discussion. Even though some studies also recognized the advantage of reading discussion that help students understand the uncertainty of scientific knowledge as well as the importance of arguments, some students, on the contrary, experienced difficulty with reading discussion. The students identified that this kind of discussion is foreign to them, and thus it was hard to understand the possibility of new research, the relation to other research, and the limitations of their own research.

Disciplinary Literacy Pedagogy

The disciplinary literacy pedagogy approach explicitly focuses on the importance of understanding disciplinary nature when one engages in literacy activities, especially around student reading. Moje (2007) suggests that learning a subject matter is not merely about learning the product of disciplines; it is more about understanding the processes and practices by which the product is produced. Therefore, she argues that understanding and production of disciplinary texts requires knowing how members of the disciplines think and write. Producing such texts must involve an understanding of the goals of the writing task as well as the perspectives and interests of the target audience. This notion that learning discipline requires an epistemological understanding of the process of knowledge production reflected in texts is strongly consonant with the highlighted importance of argumentation practice in science education. Scientific argumentation, by definition, is knowledge building and the process of validating such knowledge, which makes science knowledge different from other disciplinary knowledge (Driver et al., 2000; Duschl & Osborne, 2002). Students, thus, were expected to develop such an understanding through argumentation practice.

Scholars in this approach are interested in characterizing and developing texts that reflect the ways in which scientists think and how scientists use these texts to enhance students' understanding of disciplinary nature. Some early researchers in disciplinary pedagogy specify the cognition of members of the disciplines as they either comprehend or produce oral and written texts (Moje, 2007). They compare these identified cognitive processes of disciplinary members with learning in the subject matter area (Collins, Palincsar, & Magnusson, 2005; Hand, Hohenshell, & Prain, 2004; Hand, Pain, Lawrence, & Yore, 1999; Hand, Wallace & Yang, 2004) and apply this cognitive process to educational practice (Hynd, Holschuh, & Hubbard, 2004; C.D. Lee, 2005; Moje, 2006).

Palinscar and Brown (1984) suggest that reciprocal teaching, which models the reading and writing strategies of disciplinary professionals, scaffolds students' ability to read science texts. As students read texts, they are expected to learn not only reading comprehension skills but also critical reasoning skills that professional scientists use. Engaging in small group or entire classroom activities, students develop inferences and test them by using clarifying and summarizing ideas, developing predictions, and building explanations. Researching and reading disciplinary texts are taken as important cognitive tools that facilitate the understanding of sophisticated cognitive strategies. While these earlier works are focused on a more generic sense of critical reasoning, Palinscar's recent work (Collins et al., 2005; Palinscar & Magnusson, 2001) highlights how reading science texts becomes a way to help students improve their scientific thinking, which is more disciplinary-oriented and epistemological. A fictional scientist's notebook models how scientists use and interpret others' data and results with a critical stance, and how scientists draw a conclusion from multiple sources of evidence. Students discuss and consult this notebook and learn the disciplinary-specific manner in which professional scientists interpret and evaluate evidence. Whereas APL measures students' enhanced epistemological understanding using a developed instrument, this approach suggests enhanced understanding by assessing students' produced science texts after they substantially engage in reading the fictional notes.

Brian Hand and his colleagues focus on Science Writing Heurstic (SWH)(Brian Hand, Hohenshell, & Prain, 2004; B. Hand, Lawrence, & Yore, 1999; B. Hand, Prain, & Yore, 2001; B.

M. Hand, Bisanz, & Yore, 2003; B. M. Hand, Florence, & Yore, 2004; B. M. Hand, Prain, & Yore, 2002). They suggest that better writing could be achieved using the SWH strategy for every step of the science investigation, especially through reading and comparing one's own and others' arguments. By reading others' arguments, students have opportunities to reflect and evaluate the quality of the claim, the evidence, and its coordination to support the argument.

Moje and her colleagues (E.B. Moje et al., 2004; Textual Tools Study Group, 2006) engage students in reading both scientific and lay-audience texts. Students are asked to interpret multiple data representations, which require developing explanations to make sense and communicate. Students then participate in peer review activities in which they evaluate and compare what they originally hypothesize with the results they have and what those results mean related to their original claims. Through these activities, students develop an understanding of different kinds of claims, whether based on the prediction of observational phenomena or based on simple inference (E.B. Moje et al., 2004; Textual Tools Study Group, 2006). They also evaluate how evident the presented data are in relation to the claims, and thus whether the argument is rhetorically appropriate (Textual Tools Study Group, 2006). Students demonstrate enhanced understanding regarding rhetorically appropriate characteristics of scientific arguments and explanations.

In summary, students' practice in reading arguments is supported in two ways: students are asked to read the adapted version of scientists' arguments or they are asked to compare two arguments of different epistemic and rhetorical quality. Through reading scientists' texts, students could develop a sense that scientific argument is not a declaration of absolute facts, but rather a continually examined theory. The genre-specific nature of text structure helps students understand such nature. When comparing two arguments, students could learn and examine what counts as a scientific argument, in particular by comparing the link and coordination between claim and evidence.

Spoken, Dialogical Argumentation in the Science Classroom

The importance of promoting collaborative verbal argumentation has been highlighted in science education (Chin & Osborne, 2010; Hogan, Nastasi, & Pressley, 2000; Martin & Hand, 2009; McNeill & Pimentel, 2010; Ryu & Sandoval, 2012). Martin and Hand (2009) highlight that students' ownership of learning increases as they have more opportunities to engage in spoken argumentation. Chinn and Osborne (2010) found that students could manage small group discussion productively, as they have more opportunities to talk. Providing opportunities for verbal argumentation leads to enhanced attitude and engagement (Ogborn, Kress, Martins, & McGillicuddy, 1996), and its potential for improving conceptual understanding and reasoning skills is also getting more attention (von Aufschnaiter, Erduran, Osborne, & Simon, 2008).

Despite this recognized importance, common classroom discursive practice does not seem to promote oral argumentation and thus it rarely occurs. While students generally distinguish claims from evidence and develop a causal claim, they have difficulty collecting and presenting several pieces of evidence (Bell, 2004). In particular, when they engage in spoken argumentation with others, students often insist on their original claims even though their data do not support the claim and show contradiction (Evagorou, Jimenez-Aleixandre, & Osborne, 2012; Jimenez-Aleixandre, 2002). Similar to these studies, Berland and Reiser (2011) found that students have difficulty revising their claims in light of others' ideas and critiques. Students also find it difficult to rebut a claim of others (Cavagneetto, Hand, & Norton-Meier, 2010) and hardly provide explicit and relevant justification for evidence unless explicit scaffolding is given (Sandoval & Millwoold, 2005). Argumentation around evidence often occurs when others challenge a link to a claim. But, such challenges are not often raised even when a claim is wrong (Coleman, 998; Jimenez-Aleixandre et al., 2000; Kelly, Druker & Chen., 1998; Resnick, Salmon, Zeitz, Wathen, & Holowchak, 1993).

Findings around student oral argumentation show that students' ability to argue in oral argumentation depends heavily on classroom discursive culture, in particular, ways of social interaction. This might not be surprising because argumentation discourse in the classroom is clearly not the norm of classroom interaction in many science classrooms.

Toulmin's Argument Pattern in Oral Argumentation

Toulmin's Argument Pattern (TAP) has been commonly used not only for analyzing structural quality but also for developing instructional approach in spoken argumentation. Duschl et al.(2000) analyzed high school students' oral argumentation by employing TAP. The study assesses how students use data, warrants, backings, and qualifiers as they discuss a genetic issue. They also investigated students' epistemic operations as well as their use of analogies. According to their findings, students are often satisfied with presenting claims to perform their tasks (doing the lesson) without justifications.

Kelly and his colleagues (Kelly et al. 1998) examined students' oral argumentation and employed TAP in the study of students' reasoning about electricity. They note that students' warrants often do not engage their scientific knowledge, or that warrants are often missed in students' conversation partly because the warrants they need to address are implicitly shared by students.

While TAP is flexibly applicable across contexts, its ambiguity in identifying argument components—in particular, resolving data from warrants—has been frequently raised as an issue (R. Duschl & J. Osborne, 2002; Sibel Erduran, Simon, & Osborne, 2004; G.J. Kelly, S. Druker,

& C. Chen, 1998). In order to overcome TAP's limitations, Osborne et al. (2004) suggest that the use of rebuttals indicates the high quality of oral arguments because it forces students to integrate an original and an alternative theory and to find how to challenge a claim from its linked evidence. They also note that rebuttal would more likely occur in oral argumentation than other modes because there are naturally more opportunities of opposition. Using this adapted TAP model for teaching argumentation, Osborne and his colleagues (2004) note that the quality of justified claims as well as medium-high-level (3 and 4 among 5 levels total) rebuttals increase over time.

Tool Mediation for Promoting Discursive Interaction

Students seem more likely to challenge others when they engage in verbal argumentation than other types of argumentation. For example, although students generally did not provide sound evidence for claims when they produced oral arguments about the function of electricity, students were more likely to challenge each other during discussions (Kelly et al., 1998). Berland and McNeill (2010) also suggest that dialogical interaction provides students with tangible motivation and reasons to develop rich and convincing arguments because they could see their teacher and students as a meaningful audience. For this reason, they argue that students' ability to communicate orally is more advanced than their ability to produce written work. Yet, a recent study (Knight & McNeill, 2012) suggests that the quality of written arguments could be stronger than their oral arguments in terms of final-product quality of providing relevant justification. This finding shows a demonstration regarding not only what and how to measure the quality of arguments but also under what conditions, such as participant structure, associated social interaction could affect it.

Students show better engagement in spoken argumentation when mediation tools are available. Some of them are computer-based scaffolding tools in which students develop argumentation as they collaboratively interpret and represent data; synchronous and asynchronous communication tools are used to facilitate argumentative and knowledge discourse, including proposing, constructing, and evaluating discourses (see Clark & Sampson, 2008, for review). Conceptual cartoons and puppets are also used to promote oral argumentation (Brenda Keogh, 1999; B. Keogh, Naylor, & Downing, 2001; Shirley Simon, Naylor, Keogh, Maloney, & Downing, 2008). Looking closely at the use of tools for promoting argumentation, one key advantage of using these tools is to mediate and shift students' social interactions, and in particular, to help students find their peers a meaningful audience to persuade. The dialogue—in which several ideas and perspectives are exchanged, refined, and evolved—seems activated when these tools mediate student social interactions. For example, when students are asked to take a cartoon character's role and to speak, they had to declare which opinion was correct and had to defend their viewpoints. By taking a puppet or cartoon character's role, they also felt comfortable challenging opposing ideas provided by their peers and asking questions of them.

The promotion of social norms through language practices also shifts discourse use in science classrooms and helps students to better engage in spoken argumentation. Certain types of questions or discourse patterns are used as a mediation tool. Brown and her colleagues (Brown & Campione, 1990; Brown, 1992; Brown et al., 1993) facilitate students' engagement by encouraging them to generate, manipulate, and discuss their ideas in a public forum. Hatano and Inagaki (1991) suggest that students' use of the three metacognitive practices of clarifying, disputing, and coordinating knowledge is central for the students' successful engagement in the science classroom. Referring to Hatano and Inagaki's work, Herrenkohl and Guerra (1998) also suggest three practices: monitoring one's own comprehension of another's ideas, coordinating theories with existing evidence, and challenging the claims put forth by others. Herrenkohl and Guerra found that students are more likely to coordinate claims and evidence by taking an audience role that encourages students to provide clarifying and monitoring comments.

This line of research suggests that students could participate in a social and discursive practice of scientists by engaging them in meaningful situations that request coordination between theories and evidence and critically evaluate the quality of the claim and evidence. Across these studies, an important aspect of dialogical argumentation—that ideas and perspectives are exchanged, refined, and evolved—is highlighted by asking students to take the role of an audience actively involved in initiating engagement rather than simply taking the role of passive intellectuals. Similarly, Conant Rosebery and Warren (1992) found that students not only use acquired knowledge to generate hypotheses but also provide better scientific explanations after participating in curriculum highlighting scientific discourse use for an academic year. Minstrell and Van Zee (1997) found that students become more active in classroom discourse through efforts to shift the authority of classroom discussion from teachers to students. By using the "reflective toss" method, which provides extensive opportunity to elaborate on student statements, the students became more active in classroom discourse. Engle and Conant (2002) found that specific types of disciplinary talk—especially talk around evidence—is advanced when students actively take suggested roles and norms through the notion of disciplinary productive engagement. Ryu and Sandoval (2012) found that students are more likely to ask for claims, evidence, and justification and to appropriate persuasion as a meaningful goal when a classroom community negotiated and appropriated discursive norms throughout the year.

Teachers' Roles in Supporting Spoken Argumentation

Teachers' roles are essential to shift students' social interactions and thus change ways that they talk in the classroom. The typical Initiation-Response-Evaluation (IRE) discourse requires a "correct" answer to be evaluated by the teacher. Therefore, the goal of engaging in argumentation or discussion tends to be seeking an answer, and this type of IRE is also reproduced in student-student discussion in small groups. Because the authority and epistemic agency for knowledge production belong solely to the teacher, students rarely take other peers as a meaningful audience, which boosts argumentative and critique discourse. Students hardly attempted to directly respond to others' opinions and tended to wait for the teacher's evaluating comment.

Although there are shared understandings and widespread recommendations about how teachers should promote argumentation (Simon, Erduran, & Osborne, 2006), there is little empirical study that shows how teachers promote classroom oral argumentation. The study of Martin and Hand (2009) provides useful information because they observed the same classroom for over two years. One of major findings is the reciprocal influence of teachers and students on each other. While the teacher tended to use simple answer-seeking questions in the beginning of the year, her shift toward using open-ended questions gradually occurred as student participation and voice increased. Using open-ended questions seems a key to promote oral argumentation in another study (McNeill & Pimentel, 2010). In the study of McNeill and Pimentel (2010), although persuasive interactions hardly occurred across classrooms, one classroom in which the teacher preferred to use open-ended questions showed such persuasive interactions (McNeill & Pimentel, 2010). Chin and Osborne (2010) also noted that the use of open-ended and critical questions could significantly improve students' oral argumentation. In the study, teachers first introduced and used a set of critical questions, and students were also asked to generate these questions corresponding to their new topic. Students challenged others' ideas and developed explanations in response to these challenges. They were also more likely to use logical connectives such as *because*, *so*, *thus*, and *since*. They also presented the hypothetical nature of scientific claim by the use of *if*, *would*, or *think*. A related work could be Anderson and his colleagues' collaborative reasoning work. They showed that once a student starts using argumentative questions and discourse successfully, this approach spreads to other children in the group both in in-classroom and digital collaborative work (Kim, Anderson, Nguyen-Jahiel, & Archodidou, 2007) and this pattern can be established as a new classroom norm (Ryu, under review).

Epistemic and Rhetorical Aspects to be Assessed for Reading and Spoken Arguments

The purpose of a literature review is to enrich the process of assessment design. We pay attention to modalities' common and specific developmental progress, associated with supporting interventions. We are particularly interested in critical aspects for such development in different modalities, which may provide different kinds of opportunities for students to engage in argumentation. For example, while students are more likely to challenge and critique others in verbal argumentation than in written or reading argumentation, they could be better at comparing two arguments (by locating argument components or by identifying different forms of justification) in reading arguments.

Through our review, we determined important epistemic and rhetorical aspects of reading and oral argumentation that we want to include in construct maps. Construct maps are theoretical representations of what students are capable of at different levels. The epistemic aspects of scientific argumentation are concerned with the process of generating and validating scientific knowledge, regarding what counts as claims, evidence, and justification, and so forth (R. Duschl, 2007, 2008). By contrast, the rhetorical aspects of scientific argumentation are concerned with how claims and evidence are organized into persuasive accounts (Sandoval & Millwood, 2005). We are particularly interested in addressing whether and how students understand and appropriate the persuasive nature of scientific argumentation.

By reviewing literature on argument interventions regarding reading and verbal argumentation, we decided on some common epistemic and rhetorical features that could be addressed and compared across reading and oral arguments. For the epistemic aspects, we focus on the coordination practice—adequacy and relevance of evidence and forms of justification. For the rhetorical aspect, we focus on the genre-specific nature of the text structure of scientific arguments.

Developing Construct Maps for Reading Arguments

Understanding the coordination practice: Epistemic status of data

As shown, our review suggests that coordination between claim and evidence is a representative epistemic practice for both reading and verbal argumentation. Coordination practice is defined as "the process of allowing new knowledge claims into the scientific cannon" (Falk & Yardern, 2009), and Deanna Kuhn (1993) declares it as the core practice of scientific arguments. Scientific claims should cohere with evidence, and claims are warranted by providing justifications.

In order to interpret and evaluate arguments properly from a written text, students first interpret and infer the relationship between claim and data, and must determine the epistemic status of data. Students have to determine what data can be counted as evidence. Data that only support the claim are counted as evidence. In our construct map for determining quality of evidence, students are first asked to locate the evidence (easiest level), and then they distinguish evidence that is relevant and supportive of a claim (Table 1).

Table 1.

Relevant-Supporting evidence construct maps for the reading assessments

Attribute level	Description
4	Student critiques the evidence in two related arguments based on both relevance and support.
3	Student critiques evidence in one argument based on both relevance and support.
2	Student identifies new relevant-supporting evidence
1	Student locates the evidence of an argument.
0	Student does not locate the evidence of an argument.

Understanding the coordination practice: Epistemic status of justification

When reading scientific texts, one first attempts to know what is being argued (claim) and then tries to infer how this claim is being argued. Namely, one understands the fit between claim and justification. While the degree of persuasion depends on many other factors, for example, the credibility of methods used or its consistency with the existing theoretical or conceptual understanding, understanding a making-sense fit between a claim and used justification is a prominent epistemic decision to evaluate arguments. In fact, a number of researches engaging students in reading, evaluating, and critiquing science texts have asked students to identify and explain this fit. As a main task, students are asked to learn one clear epistemic preference: scientific arguments designate a higher epistemic status to empirical evidence over other forms of justifications. In the design of our construct maps, additional sources of justifications are included. "What an expert said or wrote" is one source of justification added because preadolescent students are known to rely on expert opinion and recognize it as an important justification.

As summarized above, we also note that students' practices in reading arguments are typically organized in two ways: Students are asked to read a single argument and identify the structure of arguments and evaluate epistemic quality of evidence, and also to determine the coordination between claim and evidence. In advanced tasks, they compare two arguments of different epistemic and rhetorical quality. Appreciating these patterns of practices, students' evaluation of a single argument is identified as an easy attribute in our construct map, whereas comparing two arguments is located at the upper level (Table 2).

Table 2.

Forms of justification construct maps for the reading assessments

Attribute level	Description
4	Student critiques the type of justification used when comparing 2 arguments
3	Student critiques the type of justification used in an argument
2	Student identifies the form of justification used in an argument.
1	Student locates the justification of an argument
0	Student does not locate the claim or justification of an argument.

Understanding the genre-specific, rhetorical nature of scientific arguments: Text structure and logical connectives

A rhetorical argument is used to persuade an audience. The success of a rhetorical argument depends on its persuasive nature, mostly by considering the audience's interest, knowledge, and characteristics. The rhetorical nature of scientific argument is recognized as important, as Kitcher (1993) sees scientific argument as a rhetorical tool. For example, the articles in many scientific journals start by stating a prevalent theme or world concern/view and highlight how their theory can be preferred in light of these.

One of the prevalent rhetorical strategies used in science texts is to demonstrate its mostly causal and often sequential structure that facilitates logical inference. Discourse cues, or logical connectives that signal a cause-effect relationship, could help readers to better understand logical inference applied in a scientific argument. By becoming familiar with this structure, students identify claim, evidence, and reasoning even when they are less familiar with content knowledge (Table 3).

Table 3.

Text structure construct maps for the reading assessments

Attribute level	Description (simple argument)	Description (complex argument)
3	a. Student infer/predicts text structure in a simple argument.	b. Student infer/predicts text structure in a complex argument.
2	a. Student identifies text structure in a simple argument.	b. Student identifies text structure in a complex argument.
1	a. Student identifies the argument components (CER) in a simple argument.	b. Student identifies the argument components (CER) in a complex argument.
0	Student does not identify the argument components (CER)	

Developing Construct Maps for Spoken Argumentation

Understanding persuasion through evidence-based critique

As shown in the review, persuasion is a core aim of scientific argumentation and students are expected to better appropriate this goal as they engage in spoken argumentation. Ford (2008) suggests that scientific argumentation is dialectic between construction and critique, and scientists naturally shift their roles of constructor and critic as they work to construct and persuade. However, this “natural shift” for scientists rarely occurs in students’ classroom discourse practice. Instead, students tend to focus more on securing right answers to make sense to others, rather than engaging in persuasion. In order to appropriately shift of roles, Sampson, Grooms, and Walker (2011) suggest that engaging in critical moves of argumentation—disagreeing, challenging, rebutting—is necessary. Students are more engaged in such critical moves when they agree that these critical moves are evidence-driven, which helps students worry less about hurting one another’s feelings (Ryu, under review).

In designing construct maps for spoken argumentation, therefore, it is important to highlight that critical moves should be based on evidence-based oppositions. Students’ argumentation without evidence-based criteria tends to be limited, and thus they are not willing to accept or revise their argument in light of others’ challenges (Berland & Reiser, 2011). When evidence-based critique becomes the norm for the classroom discourse, students are more willing to revise and change their argument and further move to build a consensus resolving different arguments (Ryu, under review).

At the lower level, students disagree with others and provide challenges without providing evidence. At higher levels, students disagree and challenge others based on evidence.

Scaffolding rebuttal and counterargument by argumentation modeling digital tool

The unit of analysis and measurement for spoken argumentation is the individual discourse move when one participates in a dialogic argumentation where two or more claims are provided and defended.

As described above, the ability to provide a rebuttal—a justification for how or why an alternative explanation could be disarmed—has been taken as evidence of producing a high-quality argument (Erduran et al., 2004; McNeill & Pimentel, 2010). In our definition, the ability to provide rebuttal is not just the ability to oppose an argument or provide unsatisfied conditions as examples, but highlights the ability to oppose the argument with justification.

Osborne et al. (2004) characterized weak and strong rebuttals and developed a rubric to measure group-based dialogic argumentation. From this framework, the episodes with rebuttals are assigned to the higher level, but individual discourse moves are not coded separately. In fact, rebuttals hardly occur in the classroom discourse, especially when students control their spoken argumentation by themselves. In addition, students who provide rebuttals could be a small number of students who are academically advanced and personally outgoing.

Paying attention to the advantages of using cartoon characters or puppets, we are exploring the possibility of utilizing a digital avatar as an agent that provides scaffolding rebuttals and counterarguments. Although it is in the design stage, we see a couple of strong benefits for students in learning and assessing their ability to engage in spoken argumentation. First, as pointed out, while only a small number of students engage in providing rebuttals and counterarguments, individual students can practice these argumentative techniques when they engage with a digital avatar associated with the argumentation modeling tool. Second, in this way, the modeling tool as an assessment not only diagnoses an individual student's ability to provide a rebuttal and counter argument, but also provides prompted-feedback.

Concluding Remarks

A learning progression for scientific argumentation, and its associated scientific argumentation assessment, must take the complex relationship between instructional environment and students' work in practice into consideration. In this paper, we pay attention to the different opportunities and possibilities that reading and oral modalities may provide as students engage in related interventions by conducting a literature review. Across reading and oral argumentation, the ability to coordinate claims and adequate evidence has been highlighted. In reading arguments, students' abilities to understand the genre-specific, canonical structure of scientific arguments helps them to comprehend scientific arguments better and to understand the nature of scientific argument as a theory in examination. In spoken argumentation, we highlight the unique possibility that students may understand the goal of persuasion better when engaging in oral argumentation and the importance of providing evidence-based critique. We also explore the use of a digital-based tool as an assessment and mediation tool. While students' abilities to argue is often taken as a context-independent skill, understanding the capabilities and difficulties of students when they engage in different modalities with interventions may provide an extended understanding of students' scientific argumentation and the development of effective assessment tools.

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