

Engaging Elementary Students in Conversations About Science Using Media

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CASUM is a classroom intervention in which teachers receive professional development and resources for initiating and facilitating classroom conversations in which students learned to work together to explain science presented in illustrations, animations and interactive simulations. The CASUM project provided professional development to teachers during which they learned a) how to control and navigate within a Flash program that presented students with science problems, solutions to the science problems, and multiple choice questions to assess their understanding of the science, b) when to stop the presentation and ask students questions that stimulated them to reason about the science, make connections between ideas proposed by other students, and work together to co-construct knowledge and accurate explanations. CASUM was tested in 18 classrooms with English learners with low English language proficiency, and special needs students. Teachers' reports provided strong evidence for the feasibility of implementing CASUM dialogs in classrooms.

Why CASUM?

CASUM is a classroom intervention in which teachers initiate and sustain conversations in which students build on each other's ideas to explain science presented in Flash animations. CASUM is designed to provide teachers with effective tools and strategies for helping young learners engage in scientific discourse and argumentation.

We developed CASUM after a review of the scientific literature on classroom discourse revealed that classroom conversations about authentic questions, in which students work together with the teacher to arrive at an answer to a question, or at least consider alternative answers, are extremely rare in US classrooms. Two large scale studies of classroom discourse, conducted by Nystrand and Gamoran (1991) and Nystrand, Gamoran, Kachur, and Prendergast (1997), revealed that teachers rarely ask students authentic (deep reasoning) questions that lead to classroom discussions, and that conversations lasting more than about 30 seconds are practically nonexistent in elementary and middle school classrooms in the US. As Osborne (2010, page 463) noted, "Argument and debate are common in science, yet they are virtually absent from science education."

These findings are especially puzzling, given that meta-analyses of programs in which teachers learn how to facilitate classroom discourse, provide strong evidence that well-managed classroom conversations improve learning and comprehension of texts (Murphy, Wilkinson, Soter, Hennessey, & Alexander, 2009; Soter et al., 2008). Moreover, the critical role of scientific discourse in K-12 science education is emphasized in the influential National Research Council Report "Taking Science to School: Learning and Teaching Science in Grades K-8" (NRC-2007), which identifies four crucial principles of scientific proficiency:

"Students who are proficient in science:

1. know, use, and interpret scientific explanations of the natural world;
2. generate and evaluate scientific evidence and explanations;

3. understand the nature and development of scientific knowledge; and
4. participate productively in scientific practices and discourse” (pg. 2).

We note that understanding and constructing “scientific explanations” and engaging in “scientific discourse” are foundational skills in three of the four components of scientific proficiency. The report also notes that a) *scientific inquiry and discourse is a learned skill*, so students need to be actively involved in activities in which they learn appropriate norms and language for productive participation in scientific discourse and argumentation, and b) evidence from developmental psychology and cognitive science (synthesized in the report) indicates that children enter school with the cognitive and linguistic abilities to form hypotheses, evaluate evidence, and share, reflect on and modify their ideas during scientific discourse.

In sum, a) our nation’s top scientists and educational researchers emphasize the critical importance of incorporating scientific discourse and argumentation into classroom science curricula, b) there is strong evidence that classrooms conversations in which students share and build on each other’s ideas improves student engagement and learning, and c) authentic conversations in any subject area are extremely rare in US classrooms. There is thus a clear and urgent need to develop programs that make it easy and for teachers to engage students in conversations in which they learn to engage in scientific discourse and argumentation. CASUM was designed to address this need.

During our interviews with teachers who used CASUM, several independently shared that they did not feel comfortable initiating classroom conversations in which students do most of the talking. This was especially true for the Magnetism and Electricity module, where conversations may lead to questions that teachers do not have the depth of knowledge to answer. This is not surprising, given that most teachers receive much less professional development related to science teaching, relative to reading and math. Teachers are comfortable teaching, they are less comfortable, and often do not have experience, managing conversations in which they help students share and build on each other’s ideas to co-construct knowledge. We therefore decided, to investigate the feasibility of having teachers control Flash applications that first present a science problems, and then work through a solution to the problem, with the goal of engaging children in scientific discourse during which they explain the science in their own words.

CASUM: What’s That All About?

CASUM dialogs are centered on the science presented in teacher-controlled Flash animations. These animations are designed to direct and focus students’ attention on specific science problems and phenomena, and discuss both the problems and their solutions. The Flash animations consisted of: 1) static illustrations (a single frame of a Flash animation, used to present the title page, or any other frame of the animation the teacher decided to present), 2) animated sequences that presented science problems, and animated sequences that showed solutions to the problems, 3) multiple choice questions with challenging answer choices. The teachers learned to navigate the Flash application to present visual information and ask questions, based on the context of the ongoing classroom conversation.

During a CASUM dialog, the teacher initiates a discussion by displaying an illustration or animation. After a short interval during which students study the visual, she asks an open-ended

question such as “What’s going on here?” As students present their ideas, the teacher facilitates the conversation using a small number of effective “dialog moves” that help students clarify or expand their own or others’ explanations, make connections between ideas presented by different students, and challenge them to apply their explanations to new situations. At appropriate points in the discussion, the teacher refers to the illustration or animation while posing an authentic question that challenges students to apply their knowledge to a new situation. This experience with scientific conversation blends several dynamics widely recognized as cultivating scientific sophistication: it elicits the student’s thinking and draws the student into externalizing that thinking; it nurtures appreciation for alternative explanations and testable hypotheses; it emphasizes the role of observation and connecting observation to hypothesis; and it emphasizes the role of reflection and analysis after observation. The CASUM project relies on and researches this blend of dynamics as they are implemented through media.

How do teachers initiate and manage CASUM dialogs?

CASUM dialogs use a proven approach to classroom discussions called Questioning the Author, or QtA, developed by Isabel Beck and Margaret McKeown (McKeown & Beck, 1999; McKeown, Beck, Hamilton & Kucan, 1999; Beck & McKeown, 2006). QtA is a mature, scientifically-based and effective program used by hundreds of teachers across the U.S. It was designed to improve comprehension of narrative or expository texts that are discussed as they are read aloud in the classroom. The program has well established procedures for training teachers to interact with students, for observing teachers in classrooms and for providing feedback to them. Recent studies (Murphy & Edwards, 2005; Murphy, Wilkinson, Soter, Hennessey, & Alexander, 2009) identified QtA as one of two approaches out of the nine examined that is likely to promote high-level thinking and comprehension of text. Relative to control conditions, QtA showed effect sizes of .63 on text comprehension measures, and of 2.5 on researcher-developed measures of critical thinking/reasoning (Murphy & Edwards, 2005). Moreover, analysis of QtA discourse showed a relatively high incidence of authentic questions, uptake, and teacher questions that promote high-level thinking—all indicators of productive discussions likely to promote learning and comprehension of text (Nystrand & Gamoran, 1991; Soter *et al.*, 2008)

Questioning the Author is a deceptively simple approach. Its focus is to have students grapple with, and reflect on, what an author is trying to say in order to build a representation from it. In the context of an inquiry-based science program, the perspective of the “author” in “Questioning the Author” moves from questions about what a specific author is trying to communicate, to questions about science phenomena and outcomes. In a sense, the “author” is Mother Nature, and the “texts” are the observations and data sets that accrue from science books, presentations, or investigations.

Because the dialog modeling used in QtA is well understood, can be taught to others (Beck & McKeown, 2006), and has been demonstrated to be effective in improving comprehension of informational texts, it is well suited for implementation in classroom discussions about science. Classroom discussions using the QtA approach use “dialog moves” such as *marking*, *re-voicing* and *turning back* to encourage the student to make sense out of their experiences.

A teacher who is trained in the QtA approach uses open-ended queries and dialog moves to fully engage students in conversations where individual students formulate and express their ideas about science, and is able to sustain and subtly direct the conversation so that the exchange of

ideas leads to accurate scientific explanations. Examples of QtA dialog moves during a classroom conversation with Ms. Galusha are described in Appendix A.

The mechanisms that QtA uses to get students to respond to each other's ideas begin with the teacher modeling the process of listening carefully, extracting meaning, and making connections using established dialog moves such as *revoicing* and *turning back* which paraphrase or elaborate student's ideas and asks them to continue the conversation. The teacher invites other students to follow up using questions such as: "So Ron notices that Jack was slouching when Jill measured him the second time. What do you think this means?" Questions designed to help students construct explanations by building on each other's ideas are done in a substantive way. That is, the teacher does not ask questions like "How many centimeters are in a meter?" Instead, the teacher's dialog moves are used for modeling the connections between ideas and the direction to pursue for productive discussion that builds understanding. This is done by asking explicitly for connections among student contributions: "How does that fit in with what Wayne said?" Or, "So are you disagreeing with what Jennifer said?"

A key point in QtA is that student to student interactions are valuable only if they involve students truly listening to each other and building on each other's ideas. QtA dialog moves, used by the teacher, are designed to do exactly this. The role of the teacher is to model this process through the questions she asks, so students listen to each other, reflect on what other students have said, and self-assess and revise their ideas. The role of the media in this process is to enable students to visualize the problem or phenomenon they are discussing and trying to understand and explain, and integrate the visual information with the verbal expression of ideas to create rich multimodal mental representations and models. Both the media and QtA questions are used simultaneously to scaffold learning and facilitate the co-construction of knowledge.

What are the benefits of using Flash animations during CASUM dialogs?

CASUM dialogs are centered on science presented in teacher-controlled Flash animations. These animations are designed to direct and focus students' attention on specific science problems and phenomena, and to help students visualize and try to make sense of the science presented in narrated multimedia animations. The Flash animations consisted of: 1) static illustrations (a single frame of a Flash animation, used to present the title page, or any other frame of the animation the teacher decides to present during the classroom discussion, 2) a narrated animation that presented a science problem, and 3) multiple choice questions with challenging answer choices that teachers could use to assess individual student's knowledge of the science, and initiate discussions about the different answer choices. Examples of each of these components of CASUM dialogs are presented below.

The design of Flash animations for CASUM dialogs was informed by a substantial body of research on multimedia learning (see Mayer, 2001; 2005 for reviews). Mayer (2005) investigated students' ability to learn how things work (motors, brakes, pumps, lightning) when information was presented in different modalities; e.g., text only, narration of the text only, text with illustrations, narrations with sequences of illustrations and narrated animations. A key finding of Mayer's work is that simultaneously presenting speech (narration) with visual information (e.g., a sequence of illustrations or an animation) results in the highest retention of information and application of knowledge to new tasks. Mayer argues that when a person is presented with a narrated animation, the auditory and visual modalities are processed independently and in parallel to produce an enriched mental representation.

In a series of studies conducted and reviewed in Mayer and his colleagues (2005, p. 169 - 182), researchers investigated students' ability to learn how things work (motors, brakes, pumps, how lightning forms) when information was presented in different modalities; e.g., text only, narration of the text only, text with illustrations, narrations with sequences of illustrations and narrated animations. A key finding of Mayer's work is that simultaneously presenting speech (narration) with visual information (e.g., a sequence of illustrations or an animation) results in the highest retention of information and transfer of knowledge to new tasks. This finding, known as the multimedia principle, motivates the use of narrated animations in CASUM. A few sentences here on Mayer's theory of enriched mental representations.

Mayer's cognitive theory of multimedia learning holds that well-designed narrated animations provide an optimal way to present concepts because it enables learners to construct enriched multimodal representations of knowledge. Based on three assumptions- separate processing of verbal and pictorial material, limited capacity in each channel, and active construction of knowledge- Mayer proposes five steps in his cognitive theory of multimedia learning. The learner must (1) select relevant words from the verbal input (presented as speech or text), (2) organize the words into a verbal model that makes sense of the verbal input (e.g., as a causal sequence), (3) select relevant images or from pictures or animations, (4) organize the images into a pictorial model that provides a structured representation of knowledge in terms of these images, and (5) integrate word-based and image-based representations with each other and with prior knowledge to create a new mental model in long term memory.

Articles in the *Cambridge Handbook of Multimedia Learning* (Mayer, 2005) summarize hundreds of studies that have been synthesized into a set design principles for developing multimedia presentations that are likely to optimize learning. Our design of multimedia presentations in CASUM tutorials is informed by this research.

One important principle involves designing multimedia presentations that reduce cognitive load, which can be substantial when new content is continuously presented to students in a narrated animation. If speech and visual information are presented too rapidly to assimilate, or too much visual information is presented at the same time—e.g., showing two important but different things happening at the same time—it can overwhelm and confuse the student. CASUM media are designed to reduce cognitive load in several ways; by narrating the animation clearly and slowly, by pausing the presentation at logical stopping points so students can reflect on the information presented, by directing the students' attention to an object or an area of the screen being talked about (using arrows, outlining, highlighting, etc.), by highlighting objects when they are first named using scientific terms, and then immediately using the vocabulary in subsequent sentences.

Research in multimedia learning has also demonstrated that engaging students in activities that facilitate acquisition of prerequisite knowledge, such as vocabulary terms, improves learning, with effect sizes due to pre-training, measured by performance on far transfer tasks, ranging from .57 to 1.22, with a media effect size of 0.92. (R Mayer, 2003; 2005). This research helped inform the design of the initial problem scenario in each CASUM dialogs, which introduced the science in the context of a real world problem identified and discussed by two characters, Jack and Jill; their discussion of a problem introduced and used vocabulary to help students make connections with real word events and prior knowledge.

Perhaps most important, learning in multimedia presentations is optimized by sequencing presentations in terms of component concepts that are fully explained. Segmenting presentations into short, manageable intervals that can be presented and then discussed, helps assure mastery of concepts that provide the foundation for subsequent learning. As noted, Flash animations are designed with pauses between segments, which provide logical stopping points for students to attempt to make sense of the presentation, they also provide an ideal time for the teacher to initiate discussion. Designing CASUM media with pauses at logical stopping points is consistent with research demonstrating that students who are given control of the pace of a multimedia presentation, i.e., being able to pause and resume the presentation, retain more information and are able to transfer knowledge to new problems better than students who are presented the entire presentation at a normal pace (Mayer 2005). While teachers, rather than students, control the pace of presentation during CASUM dialogs, during professional development the teachers learned the importance of pacing the presentations, and we observed that they became proficient at pausing and resuming the media presentation as they continuously assessed students' understanding of the science. Teachers learned to navigate within the Flash presentation, and to replay and discuss parts of animations to help assure mastery of key concepts as the discussion evolved.

We note that constructivist approaches to science education rarely advocate presenting students with explicit explanations. We believe, however, that the proven benefits of well-designed multimedia presentations, which can help students construct enriched multi-sensory mental models, provide an excellent starting point for constructivist activities that can lead to deeper learning. The fact that students have received classroom science instruction, and have subsequently been presented with a well-designed multimedia presentation, does not assure that each student has achieved a deep understanding of the science. While students may believe they understand the science after conducting a classroom investigation and watching a narrated animation, they may be unable to explain the science accurately in their own words. We hypothesize that achieving deep understanding will be facilitated by engaging students in conversations about science in which they construct self-explanations and then reflect and refine their explanations as they co-construct knowledge.

How did teachers learn to conduct CASUM dialogs?

One week before the beginning of classes in a summer science camp (SLC, described below) our project team held a 2 hour PD workshop with 11 third grade science teachers. We discussed the goals of the pilot study, the scientific basis for CASUM dialogs, and conducted a CASUM dialog with teachers for "What is a Meter?" (The focus of the SLC was measurement; the students planned and planted a garden and conducted science investigations in the FOSS Measurement science module.) The June 2011 study involved 11 third grade classrooms in four schools, with approximately 15 students in each classroom. The June 2012 study involved 7 third grade classrooms in three schools.

The day before the SLC began we visited each of the 18 participating classrooms to show teachers how to navigate within the Flash applications to present the media and pace discussions. Each teacher was given a teacher guide that summarized the Flash application, suggested logical stopping points, and provided examples of questions that could be asked to initiate discussions. During the second day of classes in the SLC, a BLT project tutor skilled in QtA dialogs (through experience in the My Science Tutor project) conducted the first CASUM dialog in each of the 18

classrooms. A project tutor observed each teacher's first CASUM dialog session, and provided feedback to the teacher after the class. In addition to these activities, each teacher was provided with a laptop they could use to review the Flash animations, and a teacher guide which described, for each CASUM dialog, the desired learning goals, logical stopping points for stopping the Flash animation, and questions the teacher could ask at these points. We were concerned that the level of professional development we provided teachers was quite limited, and that they might be concerned or intimidated by the prospect of "going solo." We would have liked to have given teachers the opportunity to practice the QtA dialogs with other teachers and provide them with feedback before classes started, but the logistics of the summer science camp prevented us from doing this. We were most gratified to learn, as discussed below, that teachers reported that the level of professional development they received was adequate, and that they felt confident they could conduct CASUM dialogs during their first session.

How Were CASUM Dialogs Aligned to Classroom Instruction?

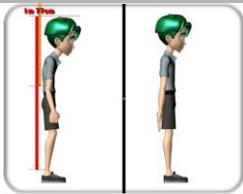
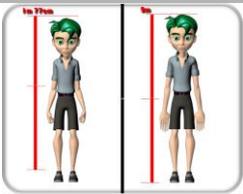
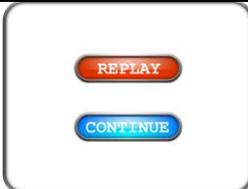
CASUM dialogs were aligned to classroom instruction using Full Option Science System (FOSS; 2014)). FOSS is an inquiry-based science program used in every state by over 100,000 teachers and 2 million students; it is used in 50 of the 100 largest U.S. school districts. FOSS is a kit-based program, with each kit containing the materials required for students to conduct approximately 16 classroom science investigations during an 8 to 10 week period. We developed CASUM dialogs aligned to FOSS learning goals (which are aligned well with state and national science standards) associated with the individual classroom science investigations, which students conduct in small groups, for the FOSS Energy and Electromagnetism module, typically taught in fourth or fifth grades, and for the FOSS Measurement module, typically taught in third grade. The structure of FOSS, with its focus on science investigations aligned to specific vocabulary, concepts and learning goals, its alignment to Colorado state standards, and its standardized pretest and posttest assessments, make it an ideal program for investigating hypothesized benefits of tutorial dialogs. We note that while CASUM dialogs were integrated into classroom activities using the FOSS program, they are designed for integration into any elementary science curriculum, and do not incorporate scenarios or digital content that is specific to FOSS.

What is the sequence of activities in a CASUM dialog?

Title Screen: Each CASUM dialog begins with an important title screen. The CASUM dialog is introduced with an authentic question because research has shown that presenting a student with an authentic or deep reasoning question before engaging in instruction or solving a problem improves learning (Driscoll et al., 2003; Gholson et al., 2009; Sullins et al., 2010).

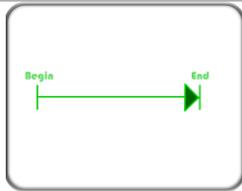
TITLE	
	<p><i>Teacher initiates CASUM by loading up title screen. Then they have kids read / write and think about the question.</i></p> <p><i>When ready they begin the CASUM tutorial by clicking on start.</i></p>

Engaging Real-life Scenario: The first component of a CASUM dialog is a narrated animation that presents a real life scenario. For example, The Scenario introduces the science. It associates the science with materials and situations likely to be familiar to most or all of the students, and provides the basis for a discussion in which students can make connections between their own experiences and background knowledge about the science being learned. The Scenario provides the teacher with an opportunity to help students make meaningful connections between the science and their own experiences and knowledge, to introduce and discuss scientific vocabulary and concepts, and to reflect on the Scenario’s problem and its relationship to the deep reasoning question that introduced the CASUM session.

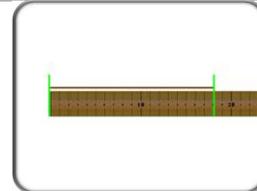
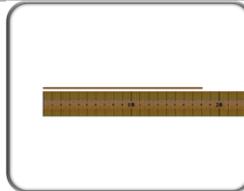
SCENARIO				
				
“Today I measured how tall Jack was.”	“The first time I measured him he was 1 meter 77 cm tall”	“The second time I measured him he was 2 meters tall”	“What’s going on here?”	
“How do you measure accurately?”				
<p><i>PAUSE: Engage in conversation. Reiterate deep question and then collect students ideas and have them build off each other.</i></p>				
		<p><i>Suggested actions: Replay again, discuss what they notice going on about the quality of measurements that Jill is taking and why they are different. Then click on Continue. OR, just Continue to EXPLANATION.</i></p>		

Explaining the Science: After students discuss the science problem, the teacher presents the students with a narrated multimedia explanation of the science. The design of these narrated animations is based on theory and research in multimedia learning, reviewed above. Each narrated animation is segmented into intervals, separated by pauses. Each interval presents a specific concept. The teacher is encouraged to stop the animation at these points and ask questions that lead to discussion of the concept. The sequence of concepts across these intervals are designed to build on each other, so the teacher can facilitate discussions that lead to complete and accurate explanations. When students have demonstrated their understanding of these concepts, the Flash animation enables the teacher to test the students’ ability to transfer their knowledge to a new problem. For example, the teacher can present a simulation of electricity flowing through a circuit, and ask: *What will happen if we flip the battery?*

EXPLANATION



“When measuring length, it is important to begin and end your measurement at the right places.”



“It is also very important to make sure things are flat and lined up with your meter stick.”

PAUSE: *Teacher could pause and connect this visual to the first one so kids see that the thing you measure has a distinct beginning and end* -What are the green lines all about? -How do they connect to what is important about measuring length?



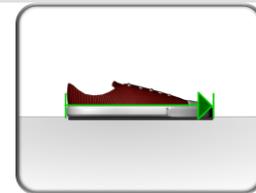
“Take this shoe for example.”



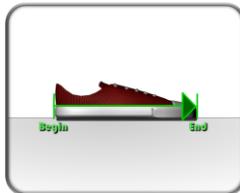
“Do you see how the tip of the shoe is lifted up a bit?”



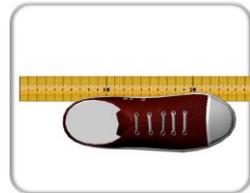
“In order to get a good measurement, we first have to make sure that the object we are measuring is as flat as possible.”



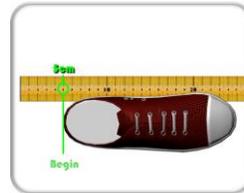
“Then we start our measurements at the back of the shoe
And measure all the way to the tip of the shoe.”



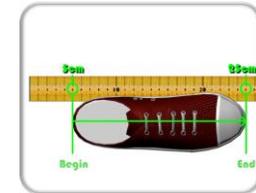
“These two spots are the beginning and end of our shoe”



“But we need our meter stick to make an actual measurement.”

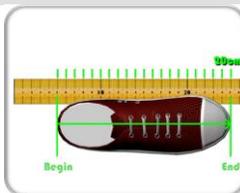


“When we look at the meter stick, we see that the back of our shoe is at the 5 cm mark...”



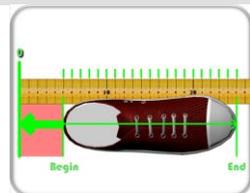
“...and the tip of our shoe is at the 25 centimeter mark. Does that mean our shoe is 25 cm long?”

PAUSE: This is a good time to pause to review what they have seen happening and how that connects to what they think are ways to measure accurately.

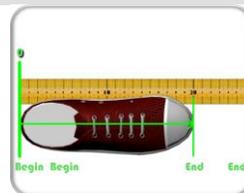


“ Well, when we actually count the centimeters starting at the back of the shoe and ending at the tip of our shoe....we count twenty centimeters, not twenty-five.”

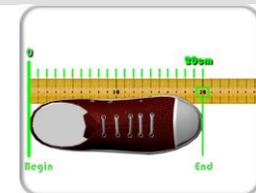
“Oh, instead of counting the units in-between, is there an easier way?”



“Sure, the easiest and best thing to do is to just move the shoe to the zero mark and start your measurements from the end of the meter stick.”



“And see what happens? Our shoe starts at the zero mark and ends at the twenty mark.”

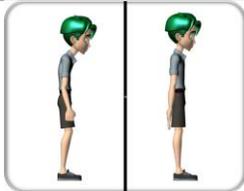


“We measured the shoe as being twenty centimeters long. That’s the same measurement that we got before. Perfect!”

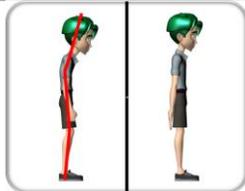


“Well, now that we figured it out...that was pretty easy.”

SOLUTION



“Well Jill when you measured me you go two different measurements. Maybe how I was standing was part of the difference in those measurements.”



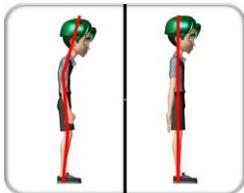
“The first time I wasn’t standing straight, I was hunched over.”



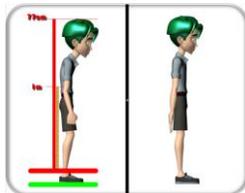
“And my first were not close to the wall, so I was not flat against the wall.”



“But the second time I did put my feet close to the wall And I pressed my back up...”



“...so I was nice and straight all along the wall.”



“And remember the first time the meter stick was not down on floor by your feet. It was up by your calf above your ankle. See, I started at the wrong place.”



“So this time I’ll measure the first meter...”



“...and mark it right here.”



“Then I’ll move the meter stick up and line it up with the mark.”



And finally I can measure the last length, which is a nother full meter.”



“Then I add the two measurements together: one meter plus one meter is two meters! That’s the same measurement we got before when I also used goo measuring techniques”



“So you are two meters tall; that’s pretty tall Jack.”



“Well, now that we figured it out...that was pretty easy.”

Formative Assessment (MC Question): The CASUM dialog concludes with presentation of an authentic question that can be answered if students have achieved a deep understanding of the science. The question may be the same as the deep reasoning question that introduced the CASUM session or the question may be presented with a picture and require an answer that demonstrates application of the science knowledge to the situation shown in the picture. Following presentation of the question each student is asked to write an answer in their science notebook. When they have completed this task, students are presented with the question a second time, along with four response alternatives. The teacher then leads a discussion in which students discuss and defend the different response choices. After students have discussed their answers, each incorrect answer choice that students defended is reviewed and the correct choice is revealed and discussed. At the conclusion of the discussion, students may revise the answer they wrote in their science notebook.

MULTIPLE CHOICE QUESTION	
	<p>How do you measure accurately?</p> <ul style="list-style-type: none"> A) Begin and end at the correct place and carefully add up all of the units. B) Begin and end at the correct places, but don't add up any more than a meter. C) Begin and end wherever you want and get a close measurement. D) Begin and end at the same place on the meter stick.

First pilot study: Mandy's fourth grade classes

CASUM was first piloted in the spring of 2011 at a rural elementary school in Colorado. The teacher, Mandy, had three years' experience teaching science using FOSS. She taught two science classes with an average of fifteen children in a rural Colorado school. Her professional development consisted of an initial one hour meeting with Cindy Martin and Jeannine Moineau (also a dialog developer and project tutor). The group reviewed a set of Flash applications for Magnetism and Electricity (M&E), which Mandy would soon teach, and discussed how QtA could be used with the animations to engage students in discussions. Mandy was provided with Beck and McKeown's (2006) book *Improving Comprehension with Questioning the Author: A Fresh and Expanded View of a Powerful Approach* (Beck & McKeown, 2006). Prior to conducting her first CASUM dialog, Mandy watched Cindy and Jeannine conduct 3 CASUM conversations with her students. Mandy then took over, and was provided feedback on her first CASUM dialog. Mandy then carried out 11 CASUM dialogs with each of her 2 classes over 5 weeks.

Mandy reported that students were fully engaged in the conversations and in listening to and selecting response alternatives to the MC question. She greatly appreciated the ability to pace the conversations, and to play, pause and repeat the videos. She reported that the CASUM experience was a positive one; her students related well to the multimedia explanations, which strongly reinforced the scientific concepts they encountered in the classroom investigations. She noted that several students in her class, including a special education student with limited vocabulary, had great success acquiring and using authentic scientific vocabulary from the media and support from their classmates. Also, Mandy used CASUM in innovative ways: After watching and listening to the Explanations a few times, her students were asked to watch the animation without sound and explain what they were seeing. She asked students to go to the

smart board to trace and explain the path of electricity in circuits. On two occasions Mandy had students use clickers to select response choices to the MC question; she reported that students really enjoyed using the clickers and seeing the responses made by all of the students. Mandy offered clear suggestions for improving CASUM which included a) improving the user interface to the Flash applications to navigate within each animation rather than only be able to repeat each segment, and b) shorten the animations; some animations were too long and presented too many concepts, which made the conversation more difficult.

CASUM pilot studies with English learners and students with special needs

We conducted two pilot studies of CASUM, in June 2011 and June 2012 with third graders in 18 classrooms who attended a Science Literacy Camp (SLC) organized by the Boulder Valley School District for ESL and Special Needs students. *All English learners who attended the SLC had low English language proficiency, based on test of English language proficiency administered by the Boulder Valley School District.* The 18 classrooms in the two studies taught the same science content, based on a) classroom science investigations and science notebook activities using the FOSS Measurement module, and b) students' planning and planting a garden and observing and measuring outcomes of these activities. Teachers conducted an average of 8 CASUM dialogs with their students. The discussions occurred soon after students conducted FOSS classroom science investigations; the content of the Flash animations used in the CASUM dialogs were aligned to the science content in the FOSS science investigations. Additional information about the SLC can be found in Messier (2001).

Results of the 2011 and 2012 CASUM SLC pilot studies. All 18 teachers responded to a 20 item survey and provided optional written comments following each question. A 4-point Likert scale was used to assess teachers' impressions of CASUM. The questionnaire included a set of positive statements, such as "CASUM conversations helped students speak more confidently" and teachers responded to the statement by selecting one of the 4 response categories: Strongly Agree, Agree, Disagree, and Strongly Disagree.

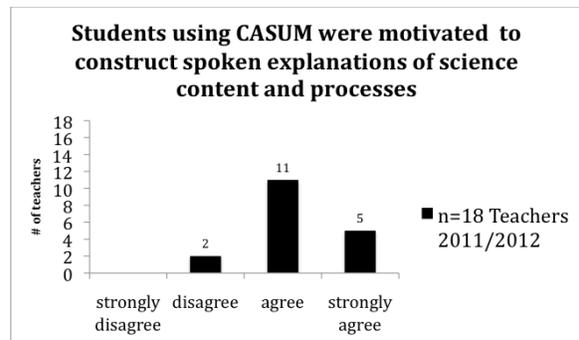
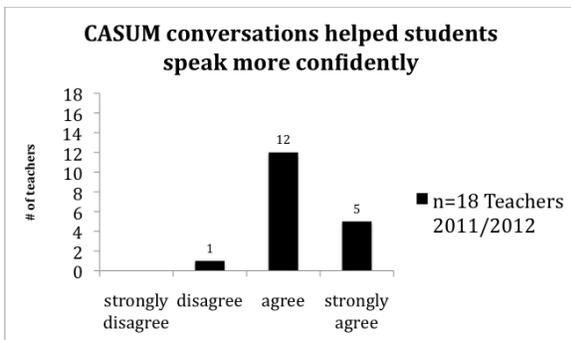
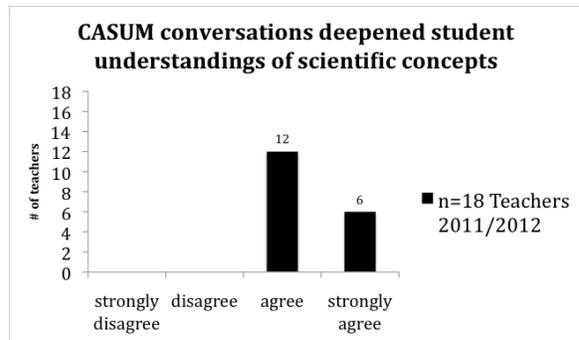
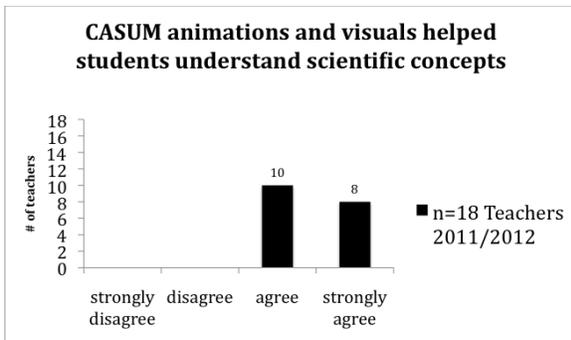
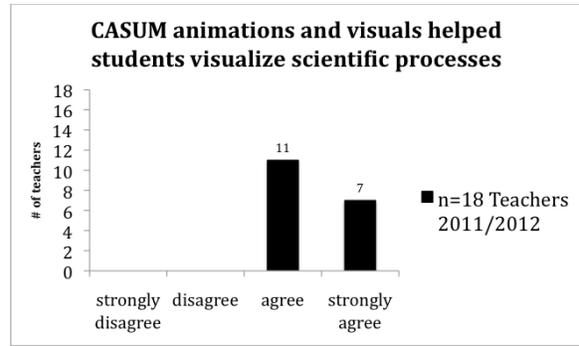
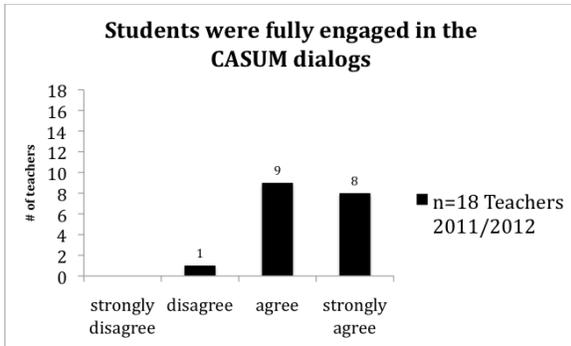
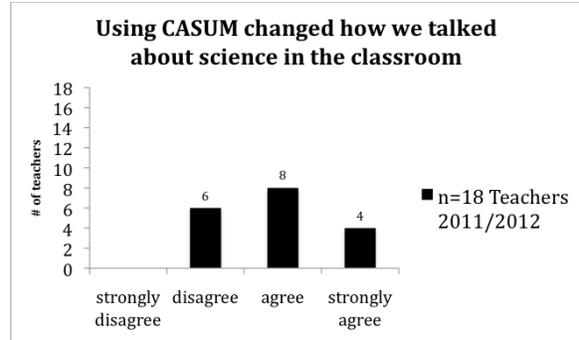
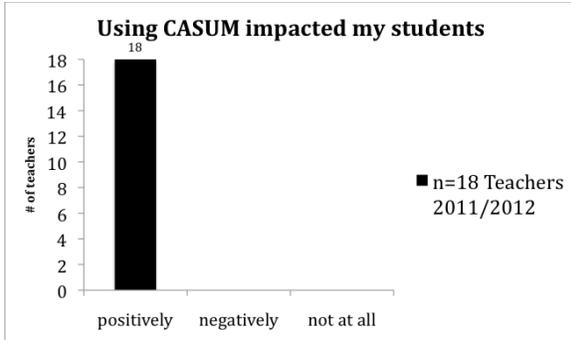
Teachers' responses to the survey questions are presented below as histograms that show the distribution of responses of the 18 teachers to each statement. It can be seen that over 90% of all responses to questions about the perceived value and benefits of the program fell into the Strongly Agree and Agree categories. Teachers' written comments indicated that most were extremely enthusiastic about the potential of using CASUM dialogs, and would like to implement the treatment in their classrooms during the regular school year.

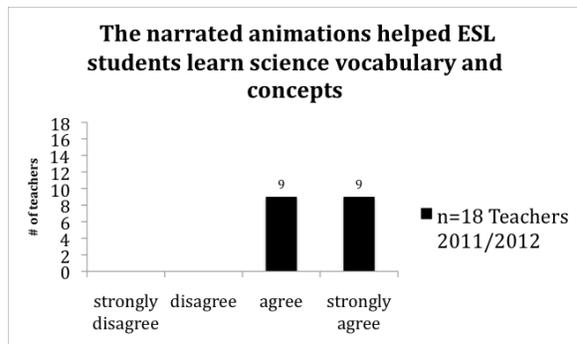
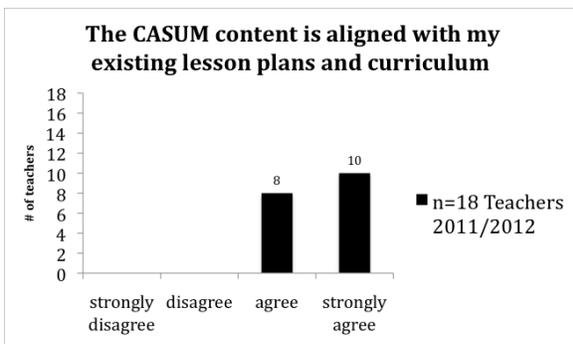
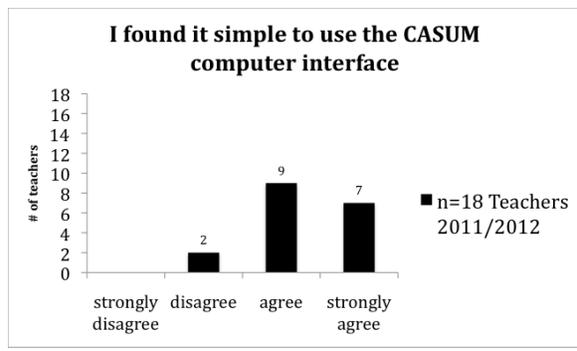
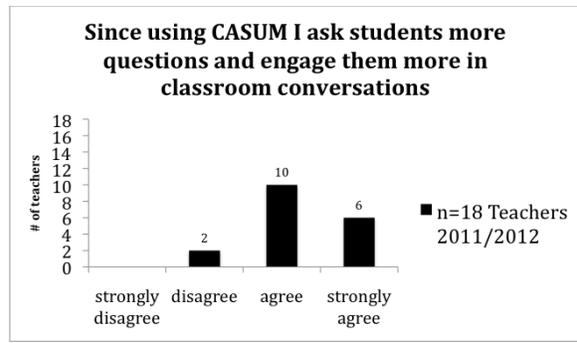
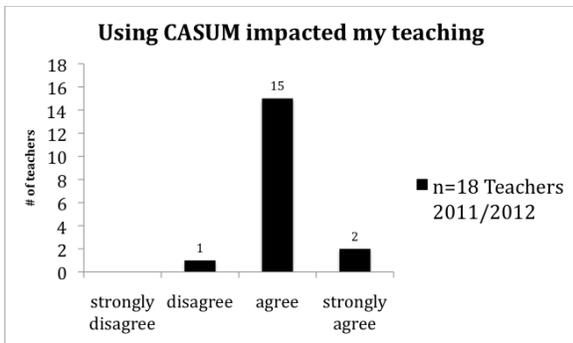
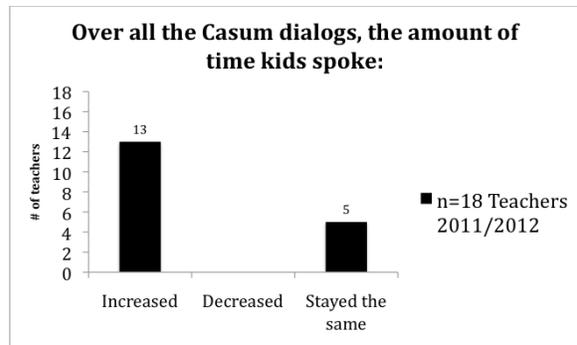
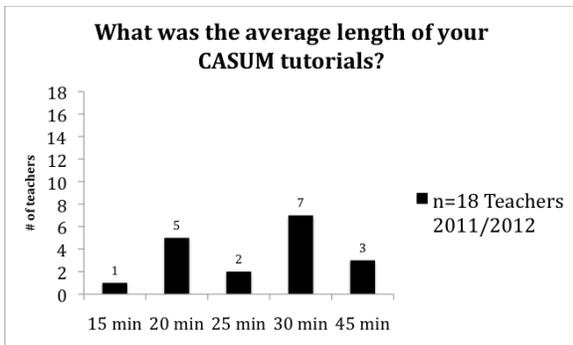
Formative Assessment (MC Question): After the multimedia presentation is completed, students were presented with an authentic question that could be answered correctly if students had achieved a deep understanding of the science. The question was sometimes the same as the deep reasoning question that introduced the CASUM dialog. Questions were often accompanied by illustrations, and required answers that demonstrated application of the science knowledge to the situation shown in the picture.

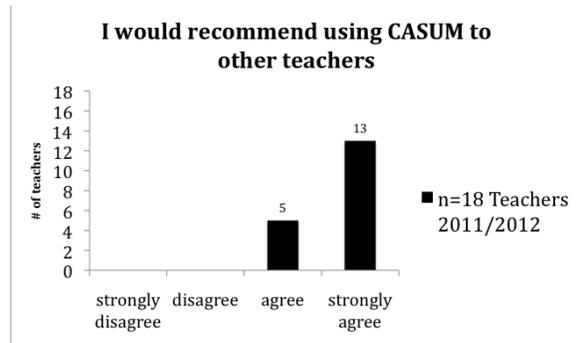
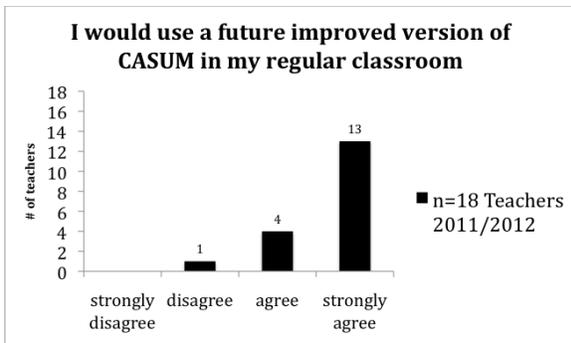
Students were required to listen to the virtual tutor read each of four answer choices aloud and were then asked to select the best answer. All choices were presented for two reasons: a) some answer choices were correct, but were not the best (e.g., most complete) answer to the question, and b) we wanted to be sure that students in small groups listened to each question so students could discuss the answer choices.

APPENDIX

Figure X – Teachers Impressions of CASUM

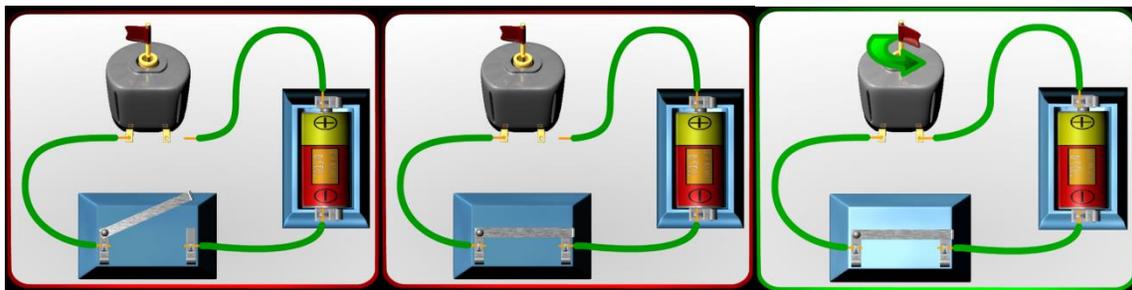






Appendix A

Example of a CASUM Conversation



1a

1b

1c

(Note: Question the Author (QtA) discussion moves are given in **BOLD CAPS**. A description and examples of QtA moves are given below.)

[Ms. Galusha begins the discussion by introducing the deep question. She invokes the Flash application, which presents the question: What is an electric circuit all about?]

Ms. G: Let's talk about this. What is an electric circuit all about?

[After giving the class a moment to think about the question, she clicks on the screen, showing the illustration of a circuit shown in **Figure 1a**. After giving her students a moment to review the illustration, she asks...]

Ms. G: So what's going on here? (**GENERAL QUERY**)

Vignesh: Those are the parts of a circuit, but it's not complete.

Ms. G: You mentioned something about an incomplete circuit. Tell me more about that. (**REVOICING**)

Shumet: One of the wires isn't connected to the motor.

Ms. G: What is important about the wires being connected or not? (**MARKING**)

Rachel: The wire needs to be connected so the electricity can flow. If the wires aren't connected the electricity can't flow.

Amir: Yeah, all the wires must be connected from the D-cell to the motor so the electricity can get to the motor.

Ms. G: Ok, so I think I heard you say that if we connect the wire to the motor, the electricity will get from the D-cell to the motor. Does anyone have anything to add? **(RECAPPING)**

Semira: The switch is open.

Mark: Yeah, the switch has to be closed too so there is a complete pathway back to the D cell.

Ms. G: So you're saying the switch has to be closed and the wire connected to complete the circuit? **(REVOICING, RECAPPING)**

[Several students nod their heads.]

Ms. G: Let's see if you're right. First I'll close the switch. **(TURNING BACK)**

*[Ms. Galusha clicks on the switch, **Figure 1b**. The motor still does not run.]*

Ms. G: What's going on? **(GENERAL QUERY)**

Amir: Why can't the electricity jump from the wire to the motor? That's what lightning does.

Ms. G: That's a really great question Amir. I think lightning has special properties. I'll look that up and get back to you. But we can see that it didn't happen here. The electricity did not pass through the air, because air does not conduct electricity and the motor is not running. Let's see what happens now when we connect the wire. Will the motor start?

*[**Figure 1c**; Ms. Galusha connects the wire by clicking on it. The circuit is complete; the motor runs and the flag spins counterclockwise. Ms. Galusha then asks the class...]*

Ms. G: So, what is an electric circuit all about? **(GENERAL QUERY, RECAPPING)**

Semira: It's a complete path that lets the electricity flow from the D-cell through the insulated wire to a motor.

Ms. G: Sandy, what do you have to say about what Semira said? **(TURNING BACK)**

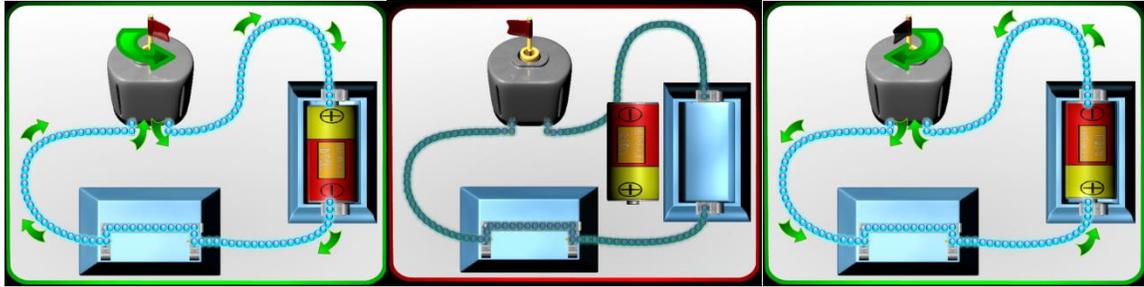
Sandy: Yes, I think she's right about a circuit being a complete path.

Mark: It doesn't have to have a motor. It could have a light bulb. And the electricity can come from plugging a plug into the wall.

Ms. G: What do you think about that? **(GENERAL QUERY)**

Minh: Yeah, electric circuits make lots of things happen. There just needs to be a complete pathway from the electricity source.

Ms. G: OK, I think we have done a great job describing some important things about an electric circuit.



1d

1e

1f

Ms. G: Let's explore another important concept about electricity.

[clicks on the arrow in the illustration, which presents the question: What's going on with the flow of electricity in a circuit? She points to the circuit with the motor running and says...]

Ms. G: What's going on here? (GENERAL QUERY)

Maria: The electricity comes out of the D-cell and goes through the wires.

Ms. G: Great observation! Tell me more about that. (GENERAL QUERY)

Jose: It comes out of both sides of the battery and goes to the motor.

Ms. G: Hmm, is that what is going on here? Let's take another look. What's going on?

Kashina: I think electricity flows from the negative end of the D cell through the circuit and back to the positive end of the D cell.

Ms. G: Good thinking. What makes you say that?

Vignesh: Well, the minus sign on the battery is the negative. The plus sign is the positive. The electricity must flow that way because the motor is spinning that way.

[Ms. G points to the circuit and moves her arm in a circle from negative to positive.]

Ms. G: So you think it flows this way?

Vignesh: Yes.

Ms. G: I think you are on to something. What does everyone else think? (TURNING BACK)

Tina: Yes, I think that's right because we know the electricity has to flow in one direction only.

Ms. G: So I hear you saying that electricity flows from negative to positive through the pathway? (REVOICING)

[When no one disagrees, Ms. Galusha clicks on a wire, which shows an animation of the electricity as a series of little blue colored balls flowing through the circuit from the negative pole of the battery to the positive, Figure 1d.]

Ms. G: OK, I can see that you are all thinking like scientists; the current is flowing in one direction from positive to negative. (RECAPING) So here's a question for you. What happens if I flip the D-cell over so it faces the other way? (GENERAL QUERY)

[Ms. Galusha clicks on the animation, and the D-cell flips over, but hovers over its cradle, Figure 1e. After a moment, Jose says...]

Jose: Then the negative will be on the other side. The current goes from negative to positive so it will go the other way.

Ms. G: George, what do you have to say about that? (TURNING BACK)

George: Yeah.

Ms. G: Tell me more about why you agree. (**TURNING BACK**)

George: Jose got it right. It will flow the opposite way since it goes from negative to positive.

[After a pause Ms. G clicks on the animation, which shows the current flowing from negative to

Ms. G: Anyone have anything else to add? (**TURNING BACK**)
*positive, **Figure 1f**, with the flag turning in the opposite direction.]*

Ms. G: Any questions?

[Ms Galusha then moves to sum up what has been learned so far...]

QtA Discussion Moves

In QtA, good querying practices are based in several “Discussion Moves”. The following are the main Discussion Moves that we will employ in the CASUM program:

- **Marking**
- **Turning Back**
- **Re-voicing**
- **Recapping**
- **Modeling**
- **Annotating**

Marking is “responding to student comments in a way that draws attention to certain ideas” (Beck, McKeown; 2006). In doing this the teacher lets the student know that something s/he said is of particular importance. Take the following example:

S: Well, we took the wire things and we sort of hooked them up to the D-cell and then we still didn’t get the bulb to light, but I’m not sure why.

T: Okay, you said you hooked the wire to the D-cell. What was that all about?

By pulling out something important the student said, the teacher lets the student, and the class, know that was/is a significant thing and also underscores the fact that the student still hadn’t gotten the bulb to light at this point in her/his experiment. Marking is something that comes in very handy when talking about science with elementary school students as, in our experience, conversations can often go astray.

Turning Back can focus a student’s attention back to what s/he did in class and hopefully clarify her/his thinking (Beck, McKeown; 2006). For example:

T: Let's review what we have been doing in science lately.

S: I don't remember. Did we do science this week?

T: How about some tests with water? Maybe with water and some lids?

S: Oh yeah! We put water in different types of lids and then we...

Turning back can also be useful to ask things such as:

- How does this connect to...
- What does this have to do with...
- What did other students/groups discover?

Re-voicing is a way to put students words into a more concise and precise statement and/or to encourage student thought and discussion. The former helps students who are struggling to express what they want to say and to make a more articulate contribution to the discussion. For example:

S: We took the plane and we changed one thing on it and then we like, flew it again and watched it to see what changed and if that thing had an effect.

T: So you had your FOSS plane and changed one variable and tested to see if that variable had an effect on the flight of the plane? Someone tell me more about that.

Re-voicing is a lot like marking, but instead of picking out just a few correct words and saying them back exactly, the student's, or students', comments are re-worded to "emphasize and/or set up ideas so they can become part of a productive discussion" (Beck, McKeown; 2006)

Re-voicing in the student's own voice is also a good way to give an unsure student a boost of confidence. Take this example:

S: Ummm, I don't really know what we did with magnets. I think we did something with them being able to stick to certain things, but I'm not really sure. I guess I don't know.

T: I think you're on the right track. You said you did something with magnets being able to stick to certain things. What was going on with that? What can anyone add to that?

Recapping is asking the student to summarize what s/he has said so far, or asking a student to summarize the class's ideas. Recapping can be done in stages at different points in your conversation and at the end of your conversation. Recapping at the end of a lesson can be very helpful to students as it assists them in consolidating concepts they have just learned and acquired.

Modeling is a way to show students the process of thinking about science. For example:

S: We did something with variables. And there was something about one being dependent or not dependent or something, but I can never figure that out.

T: Figuring out dependent and independent variables can be pretty tough. One thing I do is to think about is which variable am I *depending* on to give me my results. So if it is how many winds of the propeller does it take to fly the plane, I am depending on the winds of the propeller to give me my answer and so this is the dependent variable. Tell me what you can do to figure out which is the dependent and independent variable in your experiment.

Annotating is a way to fill in the vocabulary and/or knowledge gaps students might have:

S: We made a mix of water and baking soda. The mix was a special mix because both the water and the baking soda were evenly distributed throughout it and the mixture was clear.

T: Right! So you made a solution. Someone tell me more about solutions/the solution you made.

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APPENDIX A