Group Sense Making of Multiple Sources in a Hypertext Environment

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Abstract: Collaboration is important for learning science through inquiry. Hypertext and hypermedia environments are increasingly being used to help support inquiry and enable students to build background conceptual knowledge. Previous research has found that students have difficulty reading multiple texts in groups, so this study explored collaborative discussion of multiple sources in a hypertext system after students read individually. Results indicated that the group that engaged most frequently in monitoring the understanding of group members, evaluating ideas and generating questions to share with the class developed the most sophisticated scientific conceptions. Simply navigating the hypertext system effectively and engaging in elaborated science reasoning was not sufficient for students to develop sophisticated conceptual understandings, reiterating the importance of helping young learners to actively reflect on their understanding and question development during collaboration.

Introduction

Inquiry-based learning is an increasingly important part of many science classrooms. Learning science through inquiry requires collaboration to make sense of the multiple forms of information that students are asked to reason about and integrate in order to learn about scientific concepts (NRC, 1996; Olson & Loucks-Horsley, 2000; Varelas & Pappas, 2006). One resource that students are often asked to make sense of is scientific texts, especially digital text in the form of hypertext and hypermedia systems. Hypertext and hypermedia environments can be an effective way to present multiple sources of information as well as support learning by making relationships among information sources visible through the structure of the system (e.g., Rouet, Potelle, & Goumi, 2005; Gerjets, Scheiter, Opfermann, Hesse, & Eysink, 2009). Including digital texts as part of the inquiry process can help students build the background conceptual knowledge that they need to supplement their in-the-moment experience with an understanding of the concepts underlying their activities. Students in inquiry classrooms are frequently required to reason about multiple texts. But even though reading is largely an individual activity, students are often asked to read and make sense of these multiple texts in collaborative groups. Previous studies that have investigated groups collaboratively reading multiple texts have identified problems with this arrangement, such as a lack of active engagement by the entire group with the texts (Schwarz, 2003) and a lack of engagement in evaluation of the text resources and text content while reading collaboratively (Wiley & Bailey, 2006). However, since collaboration is an essential part of learning science through inquiry, more research is needed on how students can productively work together to actively make sense of multiple textual sources to support their inquiry activities.

Facilitating active engagement when thinking about scientific concepts is important because relationships are very often complex, and learners may have difficulty understanding conceptual relationships. For example, common to the findings of researchers investigating momentum and impulse is that students lack a coherent understanding of momentum, confuse the scientific terms of momentum and impulse with their meanings in everyday language, and are very poor at making causal connections between momentum and impulse (e.g., Bryce & MacMillan, 2009; Lawson & McDermott, 1987). A recent review by Nussbaum (2008) concluded that collaborative group discourse can enhance conceptual understanding of content when diverse student views of conceptual principles are considered and evaluated and group members model elaborative and metacognitive strategies. Additionally, research has found that groups in which students facilitated members' comprehension of content by asking for explanations and challenging each other's conceptual understanding showed greater learning gains than groups that only engaged in explanation construction (e.g., Asterhan, & Schwarz, 2009).

One potential solution to help facilitate engagement with texts and still allow time for the collaborative discussion important to inquiry is to have students read the texts individually and then come together as a group to make sense of what each student has learned. In a previous study (Smith, Sullivan, & Puntambekar, 2009), we found that students who navigated in a hypertext environment individually and then came together to discuss were less off-topic and shared more information about science concepts than students who discussed content while they were navigating as a group. Therefore, we conducted this study to examine how students collaboratively made sense of information presented in multiple documents in the hypertext system that they had read individually to prepare for their hands-on inquiry exploration. Our goal was to examine the kinds of discourse that seemed to help students to successfully develop a more sophisticated understanding of physics concepts and what kinds of support could be provided either by the system or the teacher to improve their discourse and learning.

Methods

The data were collected in an 8th grade science classroom in which students used the hypertext system CoMPASS (Puntambekar, 2006) as part of a science unit on Forces and Motion (see Figure 1). Students used CoMPASS to learn about concepts related to forces and motion in order to prepare for five design explorations throughout the unit. The goal of the unit is to design roller coasters and other rides for an amusement park. Prior to the Forces and Motion unit, students completed a unit on Work and Energy, in which they also used the hypertext system CoMPASS. Thus this was at least students' eighth experience using the CoMPASS system, and they were therefore familiar with its navigation and layout. For this study, students navigated CoMPASS individually for approximately 30 minutes to research concepts for the Stop the Car exploration, which required them to figure out how to stop their roller coaster car safely by applying concepts such as *momentum* and *impulse* to their design. For this exploration, students should have focused on concepts within the topic of linear motion. After navigating individually, students were given approximately 10 minutes to meet in their groups and discuss what they had learned about the physics concepts for their exploration. The class in which data were collected consisted of five groups with three students in each group. The teacher determined group composition based on students she felt could collaborate productively. Groups were named after elements: Helium, Oxygen, Argon, Sodium, and Zinc, and consisted of both boys and girls. In addition to discussing how concepts would inform the design for their hands-on exploration, another group goal was to develop questions about concepts they didn't understand in order to prepare for a whole class discussion.

The CoMPASS hypertext system was developed as part of a design-based physics curriculum in which students engage in design exploration challenges and investigations. CoMPASS provides navigable concept maps that were designed by physics experts to mirror the conceptual structure in physics, affording students a visual representation to help them gain a rich understanding of concepts and their numerous relationships. The CoMPASS system provides two representations: a navigable concept map and text that describes the concepts. The concept that the student selects to read about becomes the center (focal) point of the map and the other concepts move accordingly based on the strength of their relationship to the center concept.

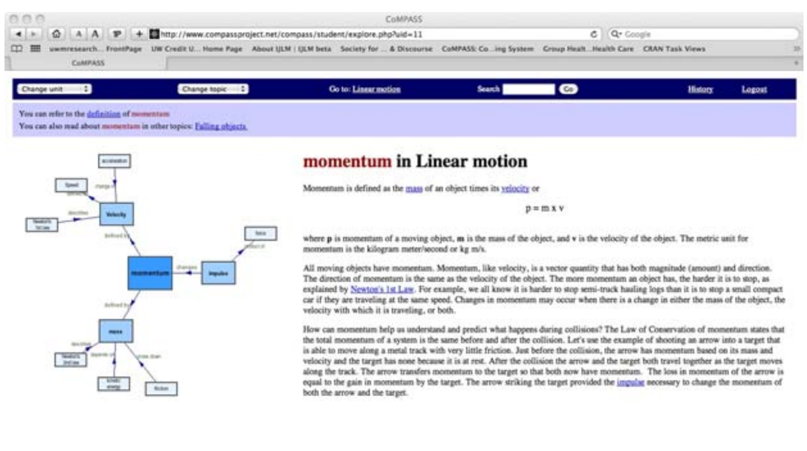

Figure 1. Screenshot of the CoMPASS Page for the Concept of Momentum in the Topic of Linear Motion

Data Sources and Analysis

For this study, we used multiple sources of data from five groups of 8th grade students. We looked at (i) students' individual initial conceptions of the concept of impulse using a pretest (described below) that was given before they began the unit, (ii) patterns of navigation exhibited by each of the group members while using CoMPASS, (iii) group audio of students' dialogue as they attempted to make sense of the information from the multiple texts in CoMPASS, and (iv) students' conceptions of impulse at the end of the unit after the Stop the Car exploration using the same question as the pretest.

Pre and Posttest Conceptions of Impulse

As part of the pre/posttest, students were given an open-ended essay question about impulse. The purpose of the question was to elicit students' initial conceptions about impulse and to see whether they developed a more sophisticated understanding of impulse throughout the unit. Students were required to write a short paragraph addressing the following scenario:

> Imagine throwing two identical eggs with the same amount of force. The first egg is thrown against a cement wall. The second egg is thrown into a deep pile of hay. The egg thrown into the wall breaks, but the egg thrown into the pile of hay does not. Please use science concepts *impulse* and *momentum* to explain the different results.

Pre and post-test responses were scored using a 0 to 5 point scale. Categories were drawn from research on students' understanding of momentum and impulse (e.g., Bryce & MacMillan, 2009; Lawson & McDermott, 1987) that examined common initial conceptions, especially the difficulty with which students make causal connections between momentum and impulse. The increasing scale represents student responses that suggest differential understanding beginning with everyday language, inclusion of appropriate science concepts, recognition of a causal relationship, and finally the identification of a mechanism within the relationship. For example, a level-1 response would be, "The egg landing in the hay has soft impact compared to the one thrown into the cement wall." Whereas a level-5 response would be exemplified by:

> Both eggs have the same mass and velocity, so they have the same momentum. But, since the cement wall has very little give, the egg hits it with a greater force because the time isn't spread out. But the egg which hits the hay doesn't break because although both eggs hit with the same impulse, the hay extends the time it takes for the egg to stop which decreases the force that it hits with.

We combined the scores for all three of the group members in order to obtain a score that represented the level of understanding of impulse for the group. We did this because we wanted to focus on development of understanding by the group as a whole. A group's score on the question could range from 0 to 15. Using these scores we broke the groups down by their level of understanding of impulse: Low 0 to 5, Medium 6 to 10, and High 11 to 15 points.

CoMPASS Navigation

Computer log files were used to look at students' navigation behavior, while they used CoMPASS to conduct research for their hands-on exploration, in order to examine whether navigation patterns were related to group dialogue and understanding of impulse. The log files recorded in chronological order the topics and concepts that students visited and the time spent on each. In order to understand student navigation in relation to the goal of the hands-on exploration, log files for the Stop the Car exploration were analyzed using Pathfinder (Schvaneveldt, 1990). Pathfinder is a graph theoretic technique used to create network representations consisting of nodes and links that characterize a group's navigation patterns in CoMPASS, allowing us to look at similarities and differences in navigation paths and whether students missed key information. The graphics of the navigation patterns (see Figure 2) show the number of times students "navigated to" a concept and the number of times students "navigated from" a concept and from which concepts students navigated to others. For example [3:2] means that a student "went to" a concept three times and "went from" that concept to another concept two times. Navigation patterns make visible the choices that a reader makes in following links, and help us to understand the process with which a reader constructs the meaning of the text (Bolter, 1998). We combined the navigation patterns of all three of the members in each group in order to obtain a complete representation of all concepts visited by students in the groups.

Analysis of Student Discourse

We transcribed the audio of the student discourse during the time that students came together in their small groups to discuss what they had learned on CoMPASS to help them with their Stop the Car exploration. We were interested in understanding the types of student discourse that helped students to actively think about their understandings of the science concepts in order to prepare them for their whole class discussion and hands-on exploration. Total audio data consisted of approximately one hour of audio and 33 pages of transcripts. A coding rubric was developed based on prior work examining students' collaborative talk when using CoMPASS in the classroom (e.g., Bopardikar, Sullivan, & Puntambekar, 2009). A process of axial coding (Strauss & Corbin, 1998) was then employed whereby the existing coding rubric was applied to the transcripts and modified based on the types of discourse that emerged from the initial analysis of the transcripts, resulting in eight codes (see Table 1).

We coded the transcripts at the utterance level, which we defined as an individual turn at talk by a student. All groups had the same amount of time to discuss the content (10 minutes), but varied in the degree to which they were on task and focused on physics ideas. As a result, transcripts were reviewed to identify the areas in which students were discussing physics concepts, and only these sections of the transcripts were coded. Utterances could be multiply coded, and utterances that could not be assigned a code were eliminated. The first two authors applied the coding rubric to 20% of the transcripts and established an interrater reliability of 90%. Disagreements were resolved through discussion. The first author coded the remaining transcripts. We then counted the number of times that the various types of talk were coded for each group.

Table 1. Codes used for student discourse

Code:	Definition:	Examples:
SE: Surface Science Explanations	Stating a definition, formula, or science idea without elaborated explanation. This includes just reading from notes.	"It says...well it said something...about ((reading)) law of conservation states that total momentum is the same before and after a collision."
ER: Elaborated Science Reasoning	Going beyond stating a definition or formula to elaborately explain ideas or concepts with discourse related to interpretation, analysis, evaluation, reasoning, and problem-solving skills employed to think through science ideas and concepts. For example, using concrete explanations or examples to better understand the abstract concepts in CoMPASS.	"That there's a...there's a -- there isn't velocity, so there shouldn't be any momentum." "Yeah 'cause the oil...like, [you] grease it up before and... it reduces the friction."
SM: Science Misconceptions	Making an incorrect statement about science concepts.	"If you have impulse, you have momentum. If you don't have impulse, you don't have momentum."
QR: Question Raising	Questions raised by group members about science concepts for group discussion.	"Would friction cause brownies to get stuck to a pan?"
RC: Reference to Information from CoMPASS	Reference to specific content about concepts coming from CoMPASS and discussion of what information was read or found by group members.	"It says online -- er, on the thing that it was a force." "Or wha -- like...yeah, did anybody look up anything on Newton's laws? I didn't."
RE: Reference to Current Exploration	Reference to the exploration for which they are using CoMPASS to investigate concepts.	"That would help us with the stop the car exploration because it's like..."
CD: Ideas for Class Discussion	Reference to ideas or questions for class discussion.	"Um, maybe we can do that in the class discussion when …"
GM: Group meaning making processes	Recognizing a personal lack of understanding about an idea or concept and sharing this with the group. Checking the understanding of other group members. Challenging a science idea articulated by another student.	"I don't understand how friction can be a force." "Okay. Do you understand it now [S3]?" "But it couldn't push it by itself."

Results

We will first address the changes in students' conceptions of impulse from the pre to the posttest by looking at the group score on the impulse question. We will then attempt to relate the change, or lack of, in students' understanding of impulse to their discourse when discussing in their small groups what they had learned from the multiple texts in CoMPASS while navigating individually.

Prior Knowledge and Final Conceptions of Impulse

Groups' scores on the impulse question could range from 0 to 15. We will discuss groups by their level of understanding of impulse: Low 0 to 5, Medium 6 to 10, and High 11 to 15. In terms of students' prior conceptions of impulse, the Helium and Oxygen groups both started out at a low level conceptual understanding. The Sodium, Zinc, and Argon groups all started out with a middle level conception of impulse (see Table 2).

The only group in which all students achieved a high level of understanding of impulse on the posttest was the Helium group. In fact, all students in this group achieved a level 5 score on their responses to the impulse question, which was the highest score possible. The Oxygen group remained at a low level of understanding, and Sodium, Zinc, and Argon all remained at a middle level conception of impulse, with only a slight increase or decrease in score for these four groups (see Table 2). Only one student in each of these four groups made learning gains from pre to posttest, and the other two group members either made no gain or decreased in score.

Table 2. Group totals for students' pre and posttest conceptions of impulse

Group	Pre Total	Post Total
Helium	4	15
Oxygen	2	5
Argon	10	8
Sodium	8	9
Zinc	8	9

Group Navigation Patterns

The differences in navigation patterns among the groups can be illustrated by looking at the graphics representing navigation patterns of students in the groups (see Figure 2).

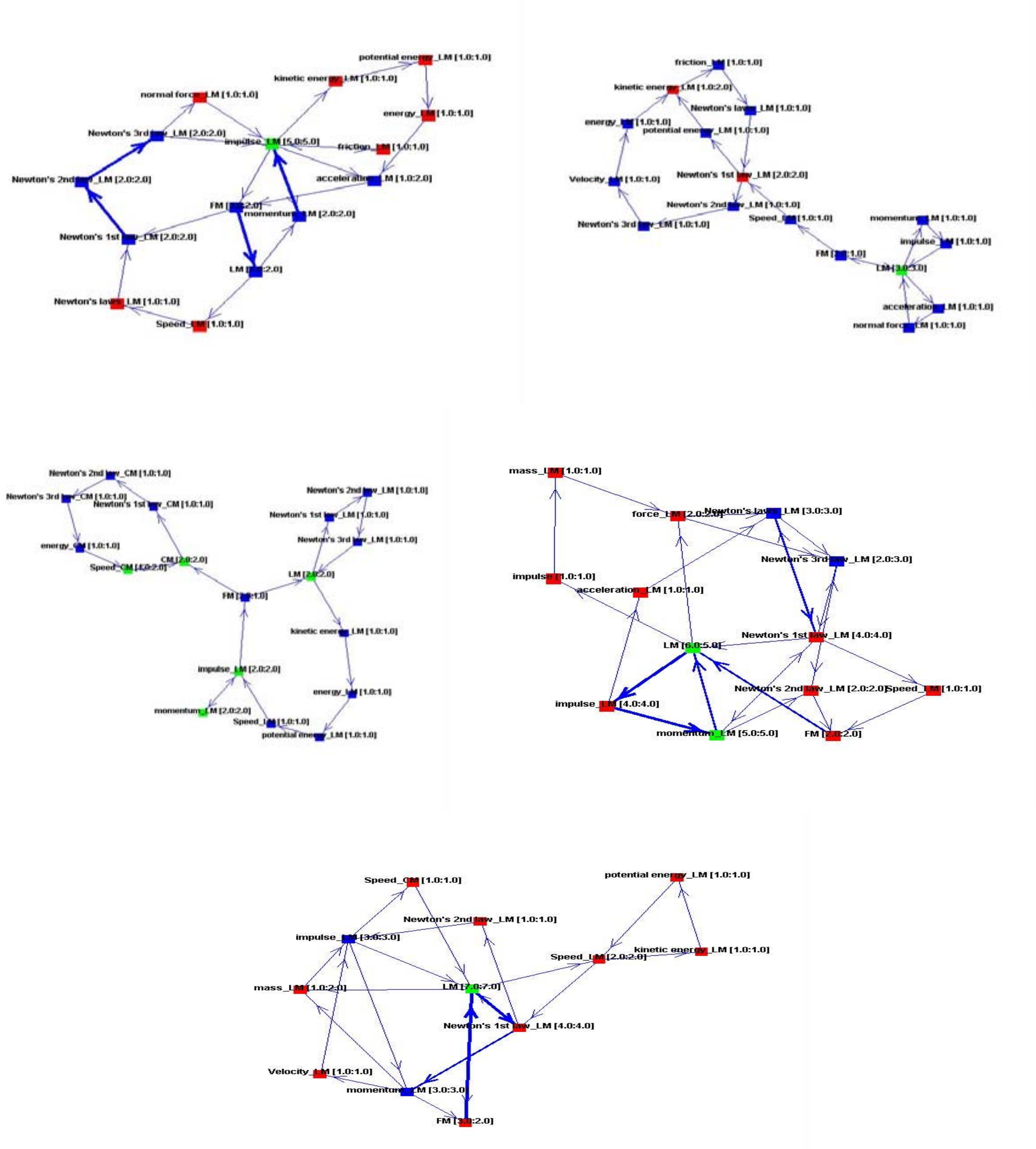

Figure 2. Combined Navigation Patterns for Group Members in Helium, Oxygen, Sodium, Zinc and Argon Groups

These graphics represent all of the different texts about various concepts that groups visited and which, therefore, had the potential to be brought up in the group discussion. For members of the Helium group, navigation within the topic of linear motion primarily focused on impulse and transitions between impulse and momentum. Darker lines in the graphics indicate multiple transitions among concepts. Impulse and momentum are two highly related concepts that students needed to understand and be able to apply to the design for their Stop the Car exploration (see Figure 2). In contrast, members of the Oxygen group did not focus on any particular concepts and visited most of the concepts in linear motion only one time, rather than focusing on concepts they needed to understand to complete the exploration (see Figure 2). Since these graphics represent combined navigation patterns of all students in a group, this means that only one member of Oxygen visited the concepts of momentum and impulse, which were essential concepts for their exploration. The navigation patterns for members of the other three groups, Sodium, Zinc and Argon, showed varying degrees of focus on the concepts that were important for the challenge, including momentum and impulse (see Figure 2). Nevertheless, none of these three groups' navigation behaviors showed only one visit to the concepts of momentum and impulse, as did that of the Oxygen group.

Group Discourse

As explained above, there were both boys and girls in each group of three students, and the goal of meeting in small groups was to discuss how concepts informed students' design for their hands-on exploration and to develop questions about concepts that they didn't understand for a whole class discussion. There were differences in the types of talk that occurred in each of the groups (see Figure 3).

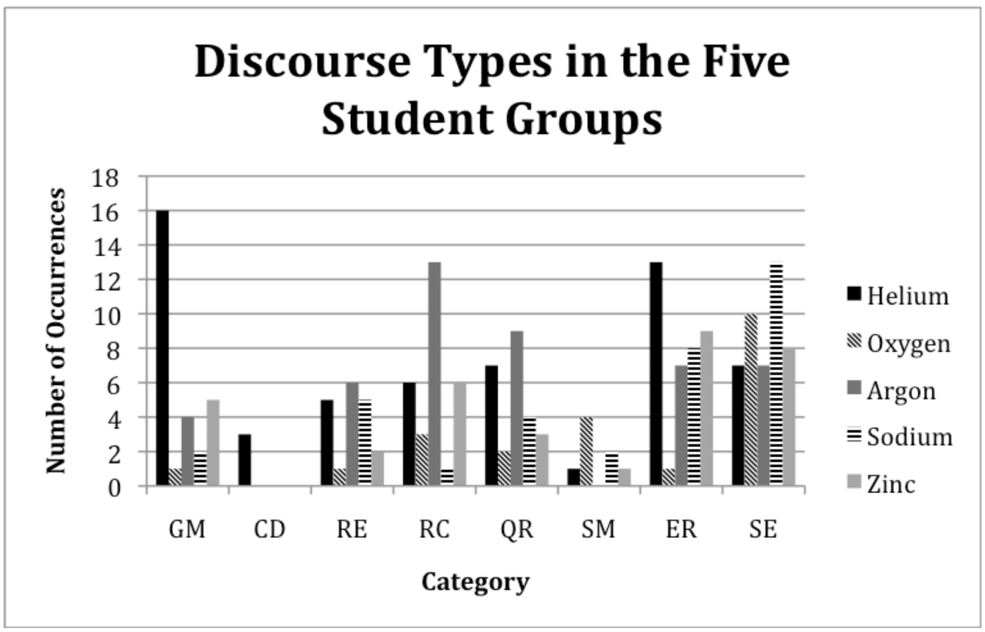

Figure 3. Number of Occurrences of Different Discourse Types in Each Group

Figure 3 represents the number of utterances that were coded with each of the eight identified discourse types for each of the five groups. Viewing the comparison of the groups' discourse in this way reveals some interesting and significant patterns. In summary, the Helium group members differed from the other groups primarily in their much more frequent use of group meaning making discourse (GM) and in that they were the only group to develop questions for the whole class discussion (CD). To reiterate, the group meaning making code (GM) focused on recognizing one's own lack of understanding of a concept and sharing this with the group, checking the understanding of other group members and challenging science ideas articulated by other students. The Argon, Sodium and Zinc groups all had various positive exchanges, such as elaborated science reasoning (ER), talking about the application of concepts to the current exploration (RE), and question raising (QR). Nevertheless, the members of these groups lacked discourse in which they identified any lack of understanding in themselves or other group members, challenged ideas, or identified specific questions to raise in their whole class discussion. The Oxygen group only shared the information that they read on CoMPASS at a surface level (SE) without elaborating on the science and had many misconceptions (SM) without being aware of any lack of understanding.

Discussion

In this study, we examined how students collaboratively made sense of information presented in multiple documents in a hypertext system to learn about science concepts in preparation for their hands-on inquiry. Our goal was to examine the kinds of discourse that appeared to help students develop a more sophisticated understanding of physics concepts and determine what kinds of support could be provided to improve their discourse and learning.

The many instances of group meaning making (GM) by the Helium group, as evidenced by challenges to one another's ideas as well as an awareness of members' incomplete understanding of concepts in order to develop questions for the class discussion (CD), seemed to support the development of their conceptions of impulse. This outcome aligns with the findings of Asterhan & Schwarz (2009), in that students in the group that challenged and questioned their conceptual understandings showed greater learning gains than groups that only engaged in explanation construction. Further, this group also navigated among goal-related concepts in the hypertext system (see Figure 2). As described above, the Helium group was also the only group to move from a low to a high level conception of impulse. In fact, all three group members received the maximum score on the impulse question. Conversely, the Argon, Sodium and Zinc groups all remained at a middle level understanding of impulse, despite the fact that these three groups navigated to goal-related concepts (see Figure 2), which may have been facilitated by the representation of the relationships among concepts made visible by the concept map (Rouet, Potelle, & Goumi, 2005; Gerjets, Scheiter, Opfermann, Hesse, & Eysink, 2009). Additionally, these students engaged in elaborated science reasoning (ER) throughout their group conversations. However, our results indicate that although students from these three groups navigated to goal-relevant concepts and engaged in elaborated science reasoning, their discourse showed a lack of evaluation of understanding and question development by the group and did not appear to help students form a more sophisticated understanding of impulse. In contrast to the other groups, the Oxygen group started out with and remained at a low level conception of impulse. The Oxygen group did not focus on goal-related concepts (see Figure 2) during their navigation and group members focused primarily on reporting surface information (SE) from individual texts in the system. This group did not elaborate on conceptual relationships or evaluate alternate conceptions and misconceptions about the concepts. Therefore, according to the review of effective collaboration by Nussbaum (2008), it is not surprising that this group did not make substantial learning gains given that they did not evaluate student ideas and used few elaborative and metacognitive strategies. Although we only had five groups, and thus cannot make causal claims, the results indicate that conceptual understanding may be facilitated by helping students to not only just talk science but also by supporting them in helping each other to evaluate understandings and collaboratively develop questions with an explicit connection to the goal.

Implications for Practice

The results of this study suggest that the ability to evaluate what they knew and use metacognitive processes to assess conceptual understandings before going into the hands-on exploration seemed to help students develop a more advanced conception of impulse. Although the structure of the hypertext environment may have helped students to be aware of conceptual relationships, most groups could have benefited from support of evaluative and metacognitive monitoring strategies to help them think about which concepts they did and did not understand. This finding is consistent with that of Wiley and Bailey (2006) in that most groups exhibited a lack of engagement in evaluation of the text content. Mercer and Littleton (2007) raise a salient point that students often "work *in* groups but not *as* groups" (p. 26), emphasizing that students are focused on individual activities rather than working together on the task at hand. They further add that students are seldom taught how to engage in productive discourse and are often asked to "discuss this in your group" (p. 67). According to them, students need to be supported for productive collaboration. One way to support this productive discourse may be through prompts in the hypertext or hypermedia system, another through norms for discourse, such as those suggested by Mercer and Littleton, and third, through teacher support of collaboration by prompting evaluation, monitoring, elaboration and question development in group discourse. When integrating multiple digital or traditional text-based resources into their inquiry units, teachers should focus not only on helping students to explain what they have learned but also place just as much emphasis on supporting students to help them develop questions about what they don't understand.

Although having students read individually before meeting with their groups may facilitate increased discussion of scientific concepts (e.g., Smith, Sullivan, & Puntambekar, 2009), students attempting to make sense of multiple documents while collaboratively conducting scientific inquiry need help to monitor and evaluate their understanding of the text content. They also need support to actively challenge others' ideas and conceptions, and use metacognitive strategies to successfully identify questions that can then be shared with the class as part of the inquiry process. While our coding rubric allowed us to identify that these kinds of group meaning making and question development processes appear to be important to developing conceptual understanding, it only allowed us to identify these processes at the level of the individual utterance. However, future research will involve the identification of these kinds of discourse processes in more groups and look at the relationships among these processes within the group collaboration as a whole as well as identify relationships among the contributions of individual students. Since collaboration is an essential part of learning through inquiry, supporting groups to engage in discourse that stresses evaluation, monitoring, and question development may help them make connections among activities by encouraging them to actively think about what they are learning from each part of the inquiry process.

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