SMALL GROUP SCIENCE TALK IN A DESIGN-BASED CLASSROOM: AN EXPLORATORY STUDY

This paper describes an exploratory study in which middle school students learnt science through small group collaboration in a design-based classroom. The science talk of two groups of students with similar post-test performance was analyzed to examine their discourse patterns. It was found that although the groups had performed similarly on the post tests, they differed in the quality and extent of their science talk. While one group had more constructive science talk than the other group, students from both groups, in general, engaged less in deep science conversations and were more focused on completing specific tasks such as reading and writing text-based information. This paper discusses implications for collaborative science dialogue in teaching and learning of science.

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Inquiry approaches to science education such as project-based (Marx, Blumenfeld, Krajcik, & Soloway, 1997) and design-based learning (Kolodner *et al.,* 2003) encourage students to learn collaboratively in small groups. Collaborative learning rests on the socio-cultural premise that social interactions mediate learning (Rogoff, 1990; Vygotsky, 1978; Wertsch, 1985). Learning involves the construction of shared meaning in a social context, and language is an important tool mediating and regulating one's own and other's activity (Vygotsky, 1978; Wertsch, 1985).

Peer collaboration in technology-enriched learning environments presents a valuable opportunity for students to encounter, critique, negotiate, and integrate diverse ideas to construct a coherent understanding (Linn & Slotta, 2006). Small group collaboration can help learning through mutual engagement (Barron, 2000) and converging through clarifying and confirming (Roschelle, 1992). However, it is not simply the presence of a partner or the sheer amount of talk but certain kinds of talk that benefits learning. Students' conceptual understanding has been found to improve when peers offer arguments, examples and exchange high-level questions and explanations (Coleman, 1998; King, 1990; O'Donnell, 1999; Webb & Farivar, 1999).

However, collaborative learning also poses challenges. Students focus on completing the task rather than the science content (Coleman, 1998), and display little evidence of questioning and connecting their ideas with each other's (So, 2007). Students are likely to share factual information rather than offer deeper explanations (Arvaja, Häkkinen, Rasku-Puttonen, & Eteläpelto, 2002). There is inadequate student engagement in dialogue that involves critical reflection, evaluation, negotiation, and extension of each other's ideas (Liu & Hmelo-Silver, 2007; So, 2007).

Research in science education has emphasized viewing science as an inherently social activity, and to encourage students to *talk science* through analyzing, constructing and sharing an understanding of scientific phenomena, instead of simply reading and listening to science texts

(Lemke, 1990, p.1). In this exploratory study, we investigated how students construct knowledge of science concepts when they work collaboratively in technology-rich science classrooms. We analyzed student dialogue of two groups to understand the extent and quality of science talk, as students worked with a design-based curriculum, CoMPASS (Puntambekar, Stylianou, & Goldstein, 2007). Additionally, we studied student dialogue over time to better understand how students' science talk changed with increasing familiarity with the content. Examining the depth of students' science discourse could enable us to provide appropriate support to foster a constructive dialogue among students as they learn science through inquiry.

Method

Participants

Two groups of sixth grade students from a Midwestern private school participated in this study. Group A comprised of two boys and a girl, while Group B comprised of two girls and a boy.

Instructional Setting

This study focuses on students' small group interactions when they used CoMPASS to learn about Inclined Planes and Pulleys, two types of Simple Machines. CoMPASS is a design-based science curriculum with a hypertext system and design challenges comprising of hands-on activities to help middle school students learn about Simple Machines (Puntambekar, Stylianou, & Goldstein, 2007). CoMPASS contains two representations: text and concept maps which show interconnections between concepts (Puntambekar *et al.,* 2007). For the Inclined Plane unit, students were presented with a challenge to design the best ramp to lift a pool table into a van. The challenge in the Pulley unit involved designing the best pulley system to lift a bottle of water. To complete the challenge, students brainstormed predictions and questions, used CoMPASS to conduct research to inform their designs, and finally engaged in hands-on investigations. We were interested in examining students' science talk when they used CoMPASS during the first unit on Inclined Planes and compared it to their final unit on Pulleys, specifically whether they explored relationships between science concepts, and connected the text to their challenge.

Data sources and analysis

Of the six groups in the classroom, we selected two groups for this study based on their similar post-test performances. Students were administered post-tests at the end of the Inclined Planes and Pulley units. The post-tests were developed by the CoMPASS project in consultation with physics experts, to assess students' understanding of science concepts and the relationships between concepts. The Inclined Planes test consisted of nine multiple choice and one open-ended question, while the Pulley test consisted of 11 multiple choice and two open-ended questions. Students could obtain a maximum of 14 points on the Inclined Planes test and 17 points on the Pulley test.

We collected and transcribed audiotapes of students' small group interactions. The data consisted of approximately 213 minutes of audio and 99 pages of transcripts. We qualitatively analyzed students' interactions by coding each utterance as a unit of analysis. We modified and applied a coding scheme that was developed for an earlier data set. The final coding scheme consisted of 17 codes (see Table 1). Two researchers independently coded 10% percent of the transcripts and achieved an inter-rater reliability of 82.46%. Inter-rater differences were resolved through mutual discussion. We computed the proportion of student talk in each of the coding categories to determine the extent of science talk (see Figures 1 and 2).

Table 1

Coding Categories for Student Talk during CoMPASS

Coding Category	Explanation	Example
Connection between Concepts (CC)	Explicit mention of a link between concepts	"Work depends on force, affects. Do you think we should go to gravity? Because gravity could affect the friction."
Clarification to group member (CM)	Clarification of the concepts or the challenge	"The more distance, well distance and long are the same thing. The more distance."
Examples of concepts (EX)	Coming up with a novel example	"Or like two pieces of wood rubbing together. The friction starts the fire."
Quantitative Talk (QT)	Quantities, Numbers, Equations, Formulae	"Why do you have to multiply by one hundred percent?"
Making Predictions (MP)	Making prediction about the challenge	"Wait. Wax paper would be the best."
Student Misconception (SM)	Misconception about science content	"No 'cuz wax paper has like a ton of friction."
Asking for clarification (CQ)	Asking for clarification about science concepts	"Um, wouldn't power be the same thing as force?"

Connection to the Goal (CG)	Doing something in relation to the challenge	"The more efficient the inclined plane. So we do not want too much friction."
Abstract-Concrete (AC)	Connecting an abstract scientific concept to a concrete real world feature	"And takes doing the work. So friction is really with the sand paper."
Note Taking (NT)	Talk about writing something down	"Yeah. The longer board. Just write that down."
Looking for Definitions (LD)	Looking for definitions of concepts	"Now let's find the definition of 'work'. Go back."
Looking for the Right Answer (LA)	Looking for answers to questions generated by the group	"Okay. Now we need some load right?"
Navigation Talk (NG)	Any talk with regard to navigating on CoMPASS	"Click the blue efficiency."
Reading Aloud (RA)	Reading aloud from CoMPASS	"Friction reduces eh, efficiency."
Paraphrasing (PP)	Restating the text in one's own words	"Friction is a type of force."
Reference to Questions (RQ)	Referring to questions generated by the group	"Let's see. I'm, I'm just reading the questions."
Off-task talk (OT)	Talk not related to the goal	"How do you spell rich?"

Results

We analyzed and compared the science talk between two groups that had similar post-test scores. The total post-test scores of Group A on the Inclined Planes test and Pulley test were 34 and 32 respectively, while that of Group B was 32 on the Inclined Planes test and 28 on the Pulley test. After averaging the individual post-test scores of group members, the mean score of Group A was 11.33 for the Inclined Planes test and 10.66 for the Pulley test, while that of Group B was 10.66 for the Inclined Planes and 9.33 for the Pulley test. We were interested in exploring patterns of science dialogue over time in these two groups to understand how students constructed their science knowledge. Selecting groups based on similar learning outcomes enabled us to investigate the processes underlying their learning outcomes.

An overall analysis of the transcripts revealed three broad themes that captured the nature and extent of group dialogue during the two units. The first theme was *procedural talk,* which involved activities such as reading aloud, paraphrasing, navigating, taking notes, referring to group questions, looking for definitions and specific answers. The second theme was *science talk,* which involved students' misconceptions, connecting concepts to each other, generating novel examples, abstract-concrete connections, offering questions and clarifications. The third theme was *connection to the goal*, which involved making predictions and connecting the science concepts in the text to the design challenge.

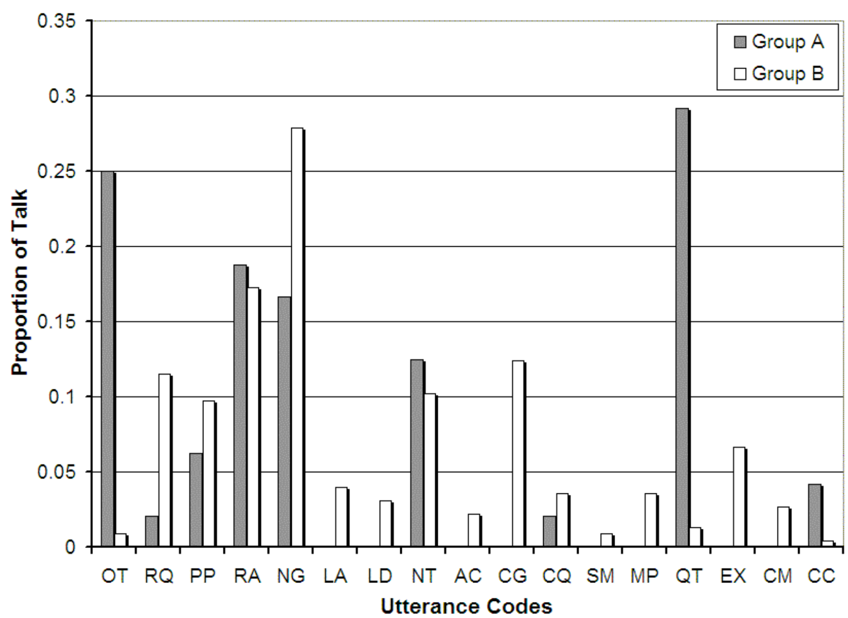

***Figure 1*. Proportion of students' science talk during Inclined Plane.**

As shown in Figure 1, Group A had 25% off-task talk, a large proportion of their overall talk. However, while on task, members focused mainly on procedural talk such as reading aloud the text on CoMPASS (18.75%), navigating to concepts (16.66%), taking notes from the hypertext (12.5%), and talking about formulae and equations (29.16%). Deep science talk such as drawing connection between concepts (4.16%) and questioning each other about science concepts (2.08%) was rare. Although CoMPASS was meant to facilitate research for the challenge, members neither made any predictions about their design, nor did they connect the text to their challenge by talking about their design. Members also did not connect scientific concepts to concrete real world features, generate novel examples, and offer clarifications. A majority of their group work was spent on tasks such as reading, writing, and navigating rather than interacting about science content.

As shown in Figure 2, analysis of science dialogue in Group A during the Pulley unit revealed that members continued to have off-task talk, which accounted for 28.87% of their overall conversation, still a large proportion. While on task, members engaged in procedural talk such as referring to their group questions (9.15%), reading the text (4.92%), navigating to concepts (7.74%), taking notes from CoMPASS (7.74%) and looking for specific answers (3.52%). Although they had a greater focus on finding answers to specific questions during the Pulley unit as compared to the Inclined Plane unit, members also exchanged a considerable proportion of questions (16.19%) and clarifications (20.42%) about the science content, and drew connections between the science text and their challenge (4.22%). This is in contrast to their discourse during the Inclined Planes unit, where they shared fewer questions (2.08%), and the exchange of clarifications and connections between science concepts and the challenge was absent. During the Pulley unit, the group dialogue also revealed some misconceptions (7.04%) as members grappled with important science concepts such as Mechanical Advantage. However, student dialogue involving relationships between concepts (0.7%), making predictions about the challenge after reading the text (0.7%), connecting abstract science concepts to real world features, and generating novel examples, was either rare or absent.

The science dialogue in Group B during the Inclined Plane unit showed that members were off-task for only 0.88% of their conversation, a negligible proportion of overall talk (see Figure 1). Members engaged in some deep science talk by questioning each other about science concepts (3.53%), making predictions about their challenge as they read the text (3.53%), generating novel examples after reading the text (6.63%), and connecting scientific concepts to concrete features (2.21%). Although there were some misconceptions (0.885%), members offered clarifications about concepts and the challenge (2.65%). A sizeable proportion of talk was about navigating on CoMPASS (27.87%), reading the text (17.25%) and paraphrasing it (9.73%). The group talked about looking for answers to questions (3.98%), definitions of concepts (3.09%), and taking notes (12.5%). Along with a considerable proportion of reference to their group questions (11.50%), these instances might imply a focus on looking for and writing down text-based material with little discussion of that content, but members did connect science concepts to their challenge (12.38%). Thus, Group B not only discussed navigating to concepts based on the questions they had brainstormed, but also generated some examples, predictions, clarifications, questions and connected the text to the challenge.

As shown in Figure 2, during the Pulley unit, Group B continued to focus on referring to their group questions (32.92%), navigating (18.93%), reading aloud (9.87%), looking for definitions (2.88%) and taking notes (4.11%). Members engaged in some deep science talk by connecting science concepts to each other (5.76%), and to the challenge (3.7%), drawing connections between science concepts and concrete features (2.46%), raising questions (8.23%), and offering clarifications to each other (19.34%). While some misconceptions (5.76%) emerged during this unit, students did not generate any novel examples or make predictions about their challenge while reading the text, unlike the Inclined Plane unit where members constructed examples and predictions during their exploration on CoMPASS.

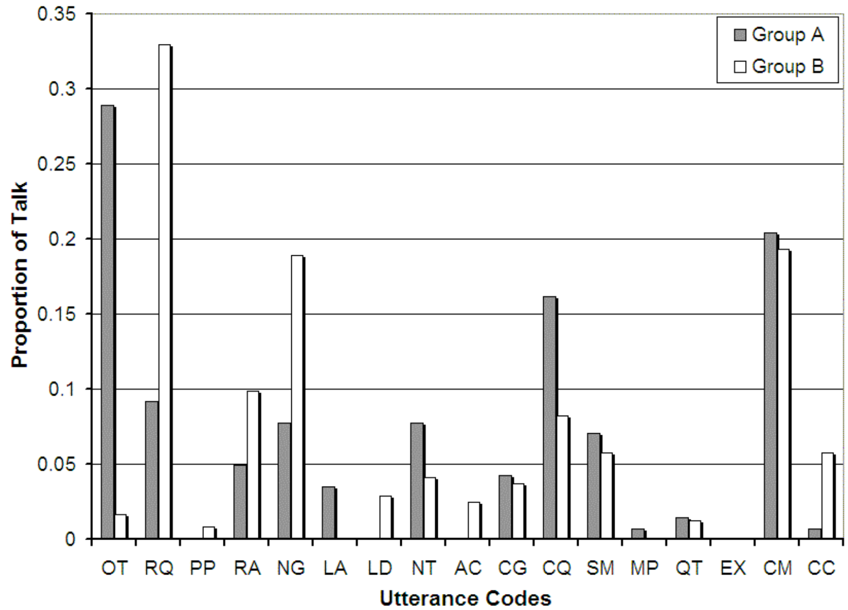

***Figure 2*: Proportion of students' science talk during Pulley**

Discussion

In this study, we compared science dialogue of two groups and found that although the groups performed similarly on the post-test, they differed in the extent and quality of science talk. While Group A had a substantial proportion of off-task talk during the first and final units and a greater focus on procedural talk, Group B were on task for most part of their dialogue and engaged in some deep science talk. One reason could be that small group interactions during CoMPASS may not be the only factor to have influenced the learning outcome. Since students had participated in a challenge and a whole class discussion prior to being tested, their learning outcome could have been influenced by these different activities, instead of their research on CoMPASS alone.

We also observed that in technology-rich science classrooms, students may not spontaneously and adequately engage in deep science conversations. Moreover, comparison of group discourse between the first and the final units revealed that while the dialogue in both groups showed some changes over time, in that the members exchanged more questions and clarifications, and explored more connections between science concepts and with the design challenge in the final unit, the group dialogue continued to be predominantly focused on procedural talk and even off-task talk in one of the groups. The Pulley unit was conceptually more complex than the Inclined Planes unit, and despite greater familiarity with some of the science content in the final unit, the two groups generated lesser novel examples, abstract-concrete connections, and predictions as compared to their focus on navigating, writing and looking for specific answers.

Both groups in this study, in general, devoted a greater proportion of their talk to specific tasks such as reading text, navigating to concepts, and taking notes. Students discussed the science to a lesser extent, and engaged less in processes such as questioning, explaining, and generating examples which have been found to benefit learning (Coleman, 1998; King, 1990; Webb &

Farivar, 1999). Thus, the nature of talk in both groups seemed to be predominantly procedural instead of connecting the text with their design challenge and discussing the science concepts and relationships. It is also interesting to note that neither groups offered any deep science questions and explanations. The questions and clarifications exchanged in the dialogue were mainly about the meaning of concepts and procedural aspects of their exploration on CoMPASS and the design challenge, instead of the relationships between science concepts and with their application for their challenge. These findings confirm previous research which has highlighted uncritical science discussions among students (Arvaja, Häkkinen, Rasku-Puttonen, & Eteläpelto, 2002), and a focus on the task rather than the science underlying it (Coleman, 1998).

Thus, while the collaborative exploration using the CoMPASS hypertext system was meant to facilitate the groups' research for their challenge, we found that students seldom explored the connections between science concepts and their challenge, although the CoMPASS hypertext represented these conceptual relationships. One reason for this could be the way in which the task was framed. Our classroom observations and transcripts suggested that the teacher emphasized the goal as finding answers to questions by using CoMPASS as a textbook and taking notes. However, CoMPASS was designed for students to explore relationships between science concepts, and to connect these concepts to their challenge. The Inclined Plane unit was the students' first experience of working collaboratively on a hypertext system, and lack of familiarity with the content and the technological tool could have affected their discourse.

However, the finding that student dialogue did not involve much deep science exploration even during the final unit indicates that small group learning may not progress spontaneously and successfully (Coleman, 1998). Although previous research (e.g. Hogan, Nastasi, & Pressley, 1999; Tabak & Reiser, 1997) has demonstrated the important role that teachers can play in facilitating a science dialogue during small group collaboration, Hogan (1999) has raised concerns about the limited mindful interactions that a single teacher can have with multiple small groups in a classroom. The results of this study suggest that while the teacher's appropriate instructions for the task and an emphasis on constructive science dialogue, especially as the science becomes more complex over time, may be a critical factor in small group collaboration, groups may also benefit from additional external support. More recently, Zumbach, Schönemann, and Reimann (2005) have argued for scaffolding groups by providing feedback about their collaborative behavior. Although real time feedback-based approaches have been investigated mainly in computer-supported collaborative learning, in the future we will look at supporting face-to-face groups over time by feeding back information and encouraging groups to reflect on and review their collaborative interactions.

This was an exploratory study examining science talk in two groups. More research is needed to further explore the progression of students' science talk during the challenge, the contribution of individual members, and the kind of support that will help students.

Conclusions and Implications

In this study, we analyzed collaborative science talk in a design-based science classroom. We found inadequate constructive science talk and a greater focus on tasks such as reading and writing text-based information. Research in science education has emphasized moving away from a focus on completing the task and instead involving students in a mutual science dialogue (Coleman, 1998). Since students may not spontaneously and adequately generate deep science talk, teacher facilitation could encourage peers to engage in constructing critical questions and explanations, as these have been found to benefit learning (Coleman, 1998; King, 1990). With the foray of technology-enhanced learning environments, students may require additional support to interact around technology tools, specifically to generate discourse using the shared information as a referent (Liu & Hmelo-Silver, 2007). In the future, we will look at providing social and material support for constructive science dialogue in small groups.

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