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ABSTRACT

The objective of this study was to investigate how two application lessons at the end of an earth science curriculum contributed to two different types of classroom: generative and authoritative. This study used Vygotsky's views to interpret earth science learning in the elementary classroom. The research questions were: How do fifth grade students' discourse enhance their conceptual understanding of erosion during an inquiry-based earth science unit? Do certain types of inquiry-based science activities lend themselves to generative (making meaning) and authoritative discourse? What are the common elements of these lessons that lead to this type of discourse? How did the learning environment facilitate the students' explanations? This naturalistic study took place over a one-semester long study on erosion. Key informants were eight fifth graders. The contribution of classroom discourse and expertise to conceptual understanding differed between the two focal groups. Group 1 used essential expertise to sustain generative conversations, maximizing their learning opportunities. Students in Group 1 got along with one another, rotated assigned roles and jobs, and were able to start their own generative conversations. Members of Group 1 asked generative questions, connected stream table events to real life situations, and involved everyone in the group. Group 2 engaged in a predominance of procedural discourse and had fewer learning opportunities. Group 2 had two dominant personalities who developed a conflict over roles and jobs, keeping their peers out of the conversation. Students in Group 2 had generative conversations, but these were not sustained due to the lack of acknowledgment of peer expertise and the starting their own generative conversations. (Author)

The Connection between Conversation and Conceptual Understanding

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Abstract

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This naturalistic study took place over a one-semester long study on erosion. Key informants were eight fifth graders. The contribution of classroom discourse and expertise to conceptual understanding differed between the two focal groups. Group 1 used essential expertise to sustain generative conversations, maximizing their learning opportunities. Students in Group 1 got along with one another, rotated assigned roles and jobs, and were able to start their own generative conversations. Members of Group 1 asked generative questions, connected stream table events to real life situations, and involved everyone in the group. Group 2 engaged in a predominance of procedural discourse and had fewer learning opportunities. Group 2 had two dominant personalities who developed a conflict over roles and jobs, keeping their peers out of the conversation. Students in Group 2 had generative conversations, but these were not sustained due to the lack of acknowledgment of peer expertise and the starting their own generative conversations.

The Connection between Conversation and Conceptual Understanding

Introduction

This study was a naturalistic study in that I did not attempt to manipulate the research setting (Patton, 1990). Guba (1978) defines naturalistic inquiry as "a discovery-oriented approach that minimizes investigator manipulation of the study setting and places no prior constraints on what the outcomes of the research will be" (p. 67). The research study took place in a classroom where interactions had no predetermined course established by me. Qualitative methods were suited for this study since, "The point of using qualitative methods is to understand naturally occurring phenomena in their naturally occurring states" (Patton, 1990, p. 41).

This study involved observing and interviewing students in a fifth grade classroom in an elementary school in a small Midwestern city throughout a semester long unit of science instruction. Students conducted investigations on specific earth science concepts using the National Science Resources Center/ Science & Technology for Children (NSRC/STC) (National Science Resources Center, 1997) unit *Land and Water*.

This semester long study, conducted in fall 2000, examined the classroom discourse among fifth grade students engaged in inquiry-based science and the development of their understanding of earth science concepts centered around erosion. Social interaction between teacher-child and child-child has been looked at in detail for all ages of students. Some studies have focused on models of instruction that include collaborative grouping and have children assume specific roles and responsibilities (Bianchini, 1997; Cohen, 1994; Richmond & Striley, 1996). More research needs to be conducted that will elucidate connections between science classroom discourse and children's science ideas. Studies about the nature of whole class and small group discourse in a science classroom examining how students offer evidence and explanations are thus called for. The research questions that guided this study were:

- How do fifth grade students' discourses enhance their conceptual understanding of erosion during an inquiry-based earth science unit?
- Do certain types of inquiry-based science activities lend themselves to generative (making meaning) and authoritative discourse? What are the common elements of these lessons that lead to this type of discourse?
- How did the learning environment facilitate the students' explanations?

Theoretical Framework

The theoretical basis for this study is provided by the social constructivist work of Vygotsky, and situated and distributed cognition. Vygotsky (1978) noted that young children's representations often reflect that they know more about an object than what is actually perceived; young children name and designate more than represent. Young children's representations are symbolic in nature and are not exact copies of objective phenomena. Children take the meaning of their drawings to be an object that is similar to the observed, not as representation or symbol of the object (Vygotsky, 1978). Barnes and Todd (1995) state that the essence Vygotsky's point is that things that are learned in the social sphere later become internalized. "Language is first used for communication with others, but these social encounters with others produce the need to check and confirm thoughts. In this way social experiences affect the course of individual development" (p. 137). Thus, discourse plays a role in conceptual change.

Situated cognition and distributed cognition or learning provides additional frameworks in the social constructivist view of thinking and learning. Lave (1988) argued that learning as it normally occurs is a function of the activity, context, and culture in which it occurs (i.e., it is situated). This contrasts with most classroom learning activities which involve knowledge that is abstract and out of context. Distributed cognition is another perspective from the social constructivist framework. Human beings have a bounded rationality according to Simon (1981). There is only so much we can remember and there is only so much we can learn. The distributed cognition perspective states that learning is a part of living, a natural consequence of being alive and in touch with the world, and not a process separate from the rest of life. What learners need, therefore, is not only instruction, but also access to the world in order to connect the knowledge in their head with the knowledge in the world. Education should be a distributed lifelong process by which one learns material, as one needs it. Distributed cognition (Norman, 1993) is a necessity in response to the limitations of the human mind. Roy Pea (1993) locates the conceptual basis of the idea of distributed intelligence in work on the ecology of perception which has focused on what everyday objects "afford" to their users through their design as artifacts. The "affordances" provided by the objects are tools that carry intelligence in them. These tools that contain ideas might include stream tables and other artifacts used in inquiry-based science instruction.

Classroom discourse, often in the form of small and large group discussion, can be dialogic or monologic in nature (Nystrand, 1997). Such discourse is "structured by tension…as once voice 'refracts' another" (p.8). Wertsch and Toma (1995) described monologic discourse as when the univocal function is dominant. During monologic discussions teachers prescript both the questions they ask and the answers they except, as well as the order in which they ask the questions (Nystrand, 1997, p. 12).

In an attempt to apply theoretical frameworks related to discourse, science educators have taken notice of the multiple facets of discourse, including conceptual understanding as expressed in discourse, types of discourse in science classrooms, and the nature of argument. Researchers have studied student conceptual understanding in the context of classroom discourse at the elementary (Varelas & Pineda, 1999), middle (Varelas, 1996), and high school levels (van Zee & Minstrell, 1997). Keys (1999) examined written discourse as an indicator of student conceptual change. Others have focused on the nature of teacher questions and response strategies (Tobin, 1984; van Zee & Minstrell, 1997). However, these studies did not discuss or examine the types of discourse, the roles, and the intents of students present in science classrooms.

Discourse also serves two functions in science education: generating meaning and conveying meaning. Mortimer and Machado (2000) referred to these functions as generative and authoritative, respectively. Lotman (1988), argued that functional dualism is characteristic of all texts. In his opinion, texts have both univocal and dialogic functions, where the univocal focuses on conveying meaning and the dialogic on generating meaning. The nature and the function of the discourse can determine the extent to which classroom discourse is inquiry-based, which is a critical characteristic of science education (National Research Council, 1996; 2000).

Methods

Instructional Context of Study. During a 16-lesson inquiry-based unit on erosion using the Land and Water (National Science Resource Center, 1997) curriculum module, the children explored the physical attributes and properties of erosion using stream tables as models. Investigations involved adjusting the amount of water flow, the incline of the stream table, growing vegetation in the soil, and constructing their own structures such as dams and landscapes to alter the interaction of water with the soil materials. In all 16 lessons the children were encouraged to draw and/or write in their science journals, but were not given specific instructions about how, when, or what to draw in their journals. In addition, students were interviewed before, during, and after the Land and Water unit about their conceptions of erosion and how the stream table influenced their ideas.

Participants. Key informants included 8 fifth grade students participating in a one-semester unit on erosion. Their elementary school is situated in a diverse socio-economic area in a medium sized Midwestern city, and their teacher is working to increase inquiry in her science instruction.

Data Analysis. Within case analyses (Patton, 1990, Stake, 1994, Yin, 1994) were used to identify patterns in children's discourse in the two groups observed for this study. Videos of individual lessons were reviewed independently and coding categories emerged from the data. The videos were mapped and relevant parts were transcribed. Triangulation was achieved by comparing children's journals, interview answers, and field notes to the video transcriptions of classroom discourse. Individual case studies were prepared for all eight participants in the study documenting progress in their conceptual understanding of erosion.

Data Sources/Evidence

Participant observation, discourse from group interaction while conducting investigations, student interviews (both individual interviews and group focus interviews), artifacts (worksheets, posters, and drawings), and field notes were the primary sources of data for this study.

Videotaped discourse. Every lesson of the 16-lesson *Land and Water* unit was videotaped. Each focal group had a separate camera recording their actions and their discourse. These videotapes were then mapped to determine which portion of the lessons should be transcribed. After transcription, the discourse was then coded and analyzed for different types of discourse, generative and authoritative.

Student interviews. The eight focal group students were each interviewed four times. Interviews were conducted before the erosion unit began, after five lessons of instruction, after ten lessons of instruction, and again at the conclusion of the unit. The two focal groups were interviewed twice, after ten lessons of the unit and at the conclusion. These interviews were then transcribed, coded, and analyzed. Categories emerged from the data and then were matched against other data sources for purposes of triangulation.

Artifacts. Student science journals, posters, worksheets, and drawings were collected during the entire unit of instruction. These artifacts were examined and compared to other data sources to see whether a connection could be made to discourse during lessons and answers given during interviews. These data sources helped to clarify some answers given by students and provided an additional window into their thinking about the process of erosion.

Field notes. Each of the two focal groups was observed for the entire unit of instruction by a participant observer. Field notes were taken during each lesson. The observers then met frequently to discuss the two groups and draw comparisons to how the teacher interacted with the two groups and how group members interacted with one another.

Types of Classroom Discourse

Generative Discourse

Generative discourse denotes classroom talk between group members that provided an opportunity to discuss new meaning or understanding. Analyzing the classroom discourse that occurred in this study, I determined that the following steps characterized generative discourse in focal groups:

- Generative conversations usually started with an observation or a generative statement of an occurrence in the stream table.
- The classroom teacher or a student would validate a group member's idea or observation.
- Another idea would be posed that built upon a previous idea or extended the parameters of the idea.
- Generative conversations were sustained with the teacher or a focal group member asking a generative question or statement. A generative question is a question that prompted the sharing of a personal theory or called for an interpretation of something that occurred. A generative statement served the same function as a generative question.

- Sustained generative conversations survived procedural sidetracks. After a student or the classroom teacher engaged in a procedural matter (see above for procedural subject matter), the conversation returned to a discussion about the science content.
- Sustained generative conversations occurred when the majority (three or more members) of the group or the entire group took part in the discourse.
- Generative conversations may involve the appropriation of a fellow group member's or the teacher's idea about erosion or the observed phenomenon.

This study found that two of the lessons conducted during the *Land and Water* module created the most opportunity for generative and authoritative discourse. These lessons involved the application of knowledge and giving students the opportunity to show what they had learned. These two lessons, the construction of a dam and the construction of a landscape of their own design respectively, had the students generate a plan for the design of these structures discussing the options based upon what they had learned in previous lessons. The construction of the structures continued generating ideas and the discourse demonstrates that students were throwing out ideas and that these ideas soon began to build upon one another. The groups, after the construction and testing of their designs was completed, gave presentations to their peers. During the presentations the discourse switches to an authoritative mode. The time for generating ideas or making meaning has been replaced with discourse that conveys that meaning to others. The "others" were not there during the construction of knowledge. It was up to the group to provide some context to the "others." But their peers had also constructed their own structures, so meaning was easier to convey in this situation.

Authoritative Discourse

Authoritative discourse occurred when the members of a group reported the results of a stream table investigation to their classroom peers. Even though all five groups in the fifth grade class performed the same task, each focal group had unique problem-solutions or results to report. Since each group witnessed an entire investigation, the team members assumed the role of experts as they communicated information about their design. These conversations, when groups communicated results, took on an expert-novice relationship.

Authoritative conversations took place only twice during the *Land and Water* module. On two separate occasions, students were given the opportunity to apply their knowledge of erosion. Students planned and built a dam for the Lesson 12 of the module, and designed and constructed a landscape for Lessons 15 and 16. After their investigations, groups were asked by the teacher to explain their designs to the rest of the class. This explanation included a demonstration when the group poured some water into the stream table to test their design, providing an opportunity for the rest of the class to witness the integrity and success of each group's design.

Results/Conclusions

Group 1

Lesson 12

In Lesson 12, the students constructed a dam to control a flood control problem in the fictitious town of Gaveo. All members of the group were present. Since this lesson presented the students with an open-ended scenario, it was similar to Lesson 16.

Jessica:	I was thinking we could build it right there or….
Carol:	Or with popsicle sticks.

Tony: Why right there? The town is right there. So why make it right there? The water is coming from down there and you don't put it on the bottom.

Tom: I know and then it is just going to flood right there. It is just going to flood back here. We don't want that to happen.

Jessica: I was thinking when she was talking about the sticks, I was thinking we might build like a wall around this part for part of it. So it would keep the water from washing off of it. And then…

Tom: Yeah, but that would separate the town.

Shirley: Are you guys doing OK?

Jessica: It is already separated by the water.

Tom: They can always swim across.

Tony: Yeah, it can't go back up. Water can't go up.

Jessica: I know but…

Tony: It always goes down.

Jessica: I know but we could make it there and there just to protect that. Just to keep the water…

Tony: But what if it made a stream down there? It would be going through the town.

Tom: I think we should make it like up here because it would stop it faster I guess.

Tony: But it would be washed away faster.

Jessica: Oh yeah you're right!

Tom: It is slow.

Tony: But it would be….I had an idea how we could make it there.

Tom: Above Gaveo.

Jessica: Oh we could build it right here. But we could take the popsicle sticks and build it around.

Tom: Yeah we could build it like that. But then it wouldn't pop out.

Tony: I thought we could make like here's a popsicle stick and here is another and here is another and we make them in back too. And then we put, if we could wrap the sand she is giving us and then stick them in front.

Jessica: Oh, let's make sure, it is like mud….

Tony: Yeah.

Jessica: Slapped against it. We could ask the teacher for clay.

Tony: Investigator!

Tom: I have one question.

Jessica: OK, I am going to ask the teacher about the materials.

Carol: We need to answer these questions.

Tom and Tony do not acknowledge her comment.

Jessica: She told me to ask Mr. McDonald. So ask him if we could.

Tom: Who?
Carol: Mr. McDonald.
Tony: I am not the investigator.
Tom: Oh yeah.
McDonald: Jessica, just go ahead.
Jessica: We were wondering if we could, Tony had the idea of taking like popsicle sticks and seeing if we could use a little bit of water to make like the dirt hard and put it against the sticks?
McDonald: Well, if they give you water to use in your materials, you can certainly use the water.
Jessica: OK.
McDonald: Your only limitations are the things that you are given.
Jessica: OK.
McDonald: If you are given water, then you can use it that way if you want to.
Jessica: OK. Tony, is that how we are going to do it?
Tony: I guess.
Jessica: We need the spoon.
Tony: Yeah, we need the spoon.
Carol has gone to get the materials.
Tom: Where are the toothpicks?
Tony: We don't have toothpicks.
Carol: Yeah, we are supposed to have toothpicks.
Tom: Yeah like popsicle things. Do we have some of those?
Tony: Give it Tom. OK, Tom start packing it up.
Jessica: You start packing it up now.
Carol: When is my turn?
Tom: Let's leave it [the channel they have dug] like that, then we will have more room for the dam.
Tony: No. We can't. It says to do it like we have in other lessons.
Jessica: We never made it like that, did we?

Carol did not take part in the generative conversation of the group. While they decided how to construct the dam, where to place it and what materials to use. Carol was instead concerned with when it was her turn and with fetching materials, and she had fewer utterances than the other members of the group. No one in the group made an effort to involve her in the conversation. Carol was not applying her knowledge, which was the major focus of the lesson. Group members who did not participate in the conversation could not generate new knowledge through interaction, either because they lacked confidence or because the rest of the group did not acknowledge them.

Jessica, Tom, and Tony all suggested materials or possible designs for the dam. Jessica and Tom deferred to Tony and his expertise of design and generation of ideas. Jessica even came up with the idea of using water to pack some dirt around the structure. The teacher only stopped by to check on the students to see if they needed anything. This was a student-student generative conversation.

Lesson 15

For the penultimate lesson of the *Land and Water* curriculum, the students designed their landscape. Tony and Tom were the only members of the group present, while Jessica and Carol were absent. This was the only lesson where two members of this group were absent at the same time.

Tom:	Oh, I got a great idea.
Tony:	Man, we need more land than this.
Tom:	I need a toothpick to do this.
Tony:	We are going to need more land than this if we are going to have hills. Like right here.
Tom:	Keep it up like that, we will make a little stream running right through here.
Tony:	Oh yeah!
Tom:	When it is closed in here I will show you. It is a great idea.
Tony:	Oh, we could make a ditch right here.
Tom:	I am making a ditch go right there and it will pour off into there.
Tony:	Oh yeah.
Tom:	Make a pit right here. Make a little pit and then make it come all the way around here and the water comes right here.
Tony:	Make a dam right here. I will do it.
Tom:	And then we will put toothpicks around it. And put all of this…
Tony:	Let's ask the teacher because she doesn't want…
Tony [to Shirley]:	Can we make like a stream and it will go right there?
Tom:	The stream would go right there.

Shirley:	You can make whatever you think would be the best for your design.
Tony:	OK.
Shirley:	Now when you decide what hole [cup] you want to use when you pour the water. This is the cup you are going to use to put the water in first and then pour it for your test run.
Tom:	We really need to make the sides tight right here so that the town doesn't cave in and go in.
Tony:	That's tight.
Tom:	Yeah like that.
Tony:	Oh, we need to make this up. Put this up. We need to make a dam right here.
Tom:	Smash that up.
Tony:	We need to make a dam right here. Oh yeah we can do that with the sticks.
Tom:	Make this part deep.
Tony:	OK.
Tom:	Make it go like that all the way along.
Tony:	Man that is great.
McDonald:	So you are going to have like a stream there?
Tony:	Yeah and then we might have like a dam right over here and maybe right here we make it.
McDonald:	So you are going to have a stream. Are you going to put any hills in other than what you've got?
Tony:	Probably and we might have like, we don't exactly know where we are going to put the plants.
Tom:	We can put these right here.
Tony:	To make the dam?
Tom:	Yeah.
Tony:	We are going to need more soil then.
Tom:	No it won't be a big dam we just need it like that so we have gates around the town. We can put a boulder right there so there is no overflowing.
Tony:	Put it like right there.

Tom and Tony listened intently to one another during the planning phase of their design. Each boy contributed ideas and made compromises when the other person wanted to include an element from an idea. Tom showed his expertise for design and building during this lesson and Tony deferred to his ideas. Both boys showed equal leadership expertise as each took responsibility for getting the other person involved as they designed their landscape.

Since this was an application lesson, an opportunity to show prior learning, both boys showed that they had learned about erosion. The boys decided to regulate the flow of water by using the cup with the small hole, keeping the stream table flat (and not incorporating slope), and diverting the flow of water with their channel (to reduce the force and impact of water). The two boys also used plants in their design, as well as hills and rocks, to reduce the impact of the water on the land. While they had not stated that erosion was a process, they have incorporated four components mentioned in the hierarchy.

In order to prevent erosion the group decides prevent all of the causes of erosion. They decide to divert the water away from their "homes," not to slope the stream table, place rocks and plants into the soil, and to have a cup at the mouth of the stream table that will restrict the flow of water to slow it down. They have applied their prior experience and use it to generate new ideas.

This section presents an example of authoritative discourse from Group 1 during a presentation made to the rest of the class about the landscape they designed.

Lesson 16

Shirley again facilitated. Shirley chose Tony to be spokesperson. The next lesson was an opportunity for the group to test their landscape designs.

Shirley:	We are just going to go in numerical order. Team one will be first. The rest of you come over here.
Tony:	I am the spokesperson.
Jessica:	I am the moderator so I can choose.
Shirley:	OK, ready? Tony you are the speaker. Would you just fill us in a little bit on why you designed it the way you did?

Tony:	We… should I tell them about the cup?
Shirley:	Everything.
Tony:	We chose the cup with the small hole because we thought the water would go slower than the three hole because that would go everywhere and erode a lot of soil. With the bigger hole it could erode faster too quickly so we just chose the little hole. We did not slant the soil because that would help erode the soil because the water would go quicker. We made the stream so that the water would not really erode anything, it would just go around the town.
Shirley:	It is like a natural valley maybe?
Tom:	We made it.
Shirley:	You were nature?
Tom:	Yeah.
Tony:	We bulldozed our hill just in case, it won't happen probably, in case water comes up here there and the water shoots up over here. And then the sticks are for having the water go around it. And we had the grass right there so if any of the water went back then it would go back here and we would have protection.
Shirley:	Why do you have three homes on the natural land bridge let's say and then you have the green house up on top of the mountain.
Tony:	I don't know why they have theirs there but I put mine up here because none of the water will get up there.
Jessica:	He is the Grinch.
Tony:	The water will not go up there.
Shirley:	Tom?
Tom:	That is the decoration. If this goes down there…
Shirley:	What is down there Tom?
Tom:	The toothpicks. Yeah instead of it eroding away the soil right there it would just hit right here and go off and then it would not erode away soil like if that did happen.
Shirley:	Tom, since you were here for the design phase, why did you choose to put your house in the middle?
Tom:	Well, we wanted to test those spots to see where it would run.
Shirley:	So as the landscape architect you were doing testing to see what would be a better place?
Tom:	Yeah.
Shirley:	The underground houses.
Jessica:	Just in case the water would go over it and not wash it away.
Shirley:	I want you to be able to see the water. Ready? OK, let's watch it. See how it is going to the left? Looks pretty good to me.

Tom:	It worked.
Shirley:	Is it bouncing off the rocks at all?
Jessica:	No, not really.
Shirley:	Does anyone remember what it would be called if it was so saturated it couldn't fill any more. Remember the groundwater? Nice job.

Shirley allowed the group to present information concerning their design to the rest of the class. She asked some questions but allowed Tony and Tom to present their thoughts on the design. The design for the landscape worked with none of the houses succumbing to the water. Students were the experts here and controlled the majority of the conversation.

Group 2

Lesson 15

All members of the group were present, as they planned the design for their landscape during this lesson. Notice how Bobby's role changed throughout the discourse.

Charlotte:	OK, what hole do we want? The big hole, the medium hole, or the three hole?
Bobby:	The three hole.
Susan:	We are going to make a big hole.
Bobby:	Let's dig a trench in it.
Charlie:	What do you mean by that?
Bobby:	Like dig a hole for the water to go down.
Charlie:	Yeah, that is what I was thinking.
Bobby:	And then like build a land bridge.
Charlie:	Yeah.
Bobby:	And put our houses on the land bridge.
Charlie:	Make a hole and then make like a patch of land over the top of it.
Bobby:	That is what we would have to do for the houses.
Charlie:	Yeah.
Bobby:	Do you want to do it?
Charlie:	Yeah, plus you gotta add different stuff like grass around it and stuff.
Bobby:	If we wanted to we could outline the tunnel with grass.

Bobby:	We are not using that.
Charlotte:	Then we are using, we are using rocks.
Bobby:	We don't know that for a fact.
Charlotte:	Well, we have rocks.
Bobby:	OK.
Charlotte:	Rocks, sand and humus. OK are we using hills and valleys?
Bobby:	Yes.
Charlotte:	Hills or valleys?
Bobby:	Valleys.
Charlie:	Well, give me the spoon.
Bobby:	Read the instructions Charlotte.
Charlotte:	Wait.
Susan:	Carefully remove...
Charlie:	Hey, Charlotte?
Charlotte:	Yes.
Charlie:	Can you go get one big hole because of what we are doing?
Bobby:	Yeah.
Susan:	I'll go get it.
Charlotte:	Go get it. I'll read.
Charlie:	Can I tear this out now?
Bobby:	Huh?
Charlie:	Huh?
Bobby:	Yeah, don't make it all the way down to the bottom.
Charlie:	Oh, OK.
Shirley:	All of you, did you decide what kind of cup you wanted to use?
Charlotte:	Well...
Shirley:	Susan wanted to know. Did you discuss that yet?
Bobby:	Big hole.
Charlie:	Big hole.
Shirley:	Everyone in agreement to that?
Charlotte:	I don't care.
Shirley:	OK, you have to find the red dot.
Charlotte:	OK.
Shirley:	Remember you are only allowed to do one cup.
Charlotte:	OK.
Bobby:	Do we read the book first or do we do this?
Shirley:	Use this [the worksheet].
Bobby:	So we don't even read the book?
Shirley:	You were almost doing it basically. Make sure whoever is the reader goes through all of these steps to make sure you didn't miss one before you do your test run.
Charlie:	That hole is pretty big.
Charlotte:	It is almost like using dam.
Charlie:	We wanted a slight slant.
Charlotte:	Wait.

Bobby: Go get us some popsicle sticks. Charlotte? Can we build like sort of land bridge and…?
Charlotte: Well yeah, we can but…
Bobby: We aren't going to make it all the way across, are we?
Charlie: See that would be sweet.
Charlotte: Yeah but…. [reads the directions]. We already did all that.
Bobby: Let's put dirt on the bottom.
Charlotte continues to read the directions.
Charlotte: So we can use whatever we want. Give me that spoon. And here is a straw too. I am making soup.
Charlie: But we don't want them to see the popsicle sticks.
Bobby: I can see it.
Charlie: But we don't want them to though.
Charlotte: We can use humus, rocks, sand.
Bobby: Do you want to put a rock down here?
Charlie: No.
Bobby: OK.
Charlie: Can we stick our houses on it?
Charlotte: Wait.
Bobby: No first we have to design the whole thing.
Charlotte: With our houses and stuff.
Charlie: First of all where do we want to plant this big guy?
Charlotte: We could set it right here and…
Bobby: That would defeat the purpose of digging a trench.
Charlie: Yeah. Why don't we set it right here?
Bobby: Why don't we do nothing.
Susan: Why don't you just put a little rock in there?
Bobby: We don't have to do it do we?
Charlotte: We don't have to.
Charlie: First of all…
Shirley: When your whole design is done you know using whatever you are using and you are ready…
Charlie: Mrs. Morrow?
Shirley: Yours home are up there. Wait a minute. You have to draw it first then you pour this water into here. This is your cup of water. Then you are going to do this last when everything is done.
Charlie: Mrs. Morrow, I have a question. Can we make this hole a little bigger so a straw could fit down there?
Shirley: What else could you do?
Charlie: Stick it on the bottom.
Charlotte: So we can use anything?
Shirley: You can use anything or you can use nothing. You can use all of it.
Charlie: Can someone hold this up here like that?
Shirley: No.

Charlie: Ahhh.

Bobby showed that he could generate ideas for the construction of the dam. Charlie even validated some of his ideas, but Bobby had control over the conversation. Susan and Charlotte were ignored and had no part in the suggestion of materials. Susan and Charlotte were confined to the procedural roles of reading, retrieving materials and recording information.

Much like the previous example, this was a generative conversation for only two members of the group. Charlie asked Charlotte to go get a certain cup and Susan responded that she would perform the function. The girls were both marginalized and pushed out of the conversation. It was the boys who generated the ideas and made key choices for the design of the dam.

Lesson 15 showed that the group could have a generative conversation. However, the participants in that conversation bear closer examination. The boys spawned ideas while the girls were spectators for most of the lesson. If all members of the group did not take part in the creation of ideas, can the conversation be called generative? Using the criteria outlined in the introduction to this chapter, generative interaction was sustained when a majority or all of the members took part. Lesson 15 then cannot be classified as a generative conversation.

Lesson 16

During this example, the group presented their landscape design to the rest of the class. Bobby served as the spokesman for the group.

Shirley: Team 2, get yourselves set.
Charlie: Mrs. Morrow, we are going to have to switch this to this side.
Bobby: I will hold the cup.

Charlie:	Do you think we should move it to this side?
Shirley:	Yes. I want the… Who is the representative, the speaker who is going to tell us? Bobby, OK, go ahead.
Bobby:	We dug a trench for the water to go down and then we put a bridge over it. It is made out of popsicle sticks and then we covered it up with dirt and then put more popsicle sticks on top of it.
Shirley:	So you have two layers of popsicle sticks under there?
Charlotte:	Two layers of popsicle sticks and then we have dirt under both of them.
Bobby:	After we did our test run we put grass underneath the bridge so the homes would not erode so it would not collapse the bridge. And we put the hose there hoping that the water would go down in it and the water would just go down.
Shirley:	When you were running it today so they know… did you have to move the straw at all? A little bit?
Bobby:	Yeah.
Shirley:	They tried very hard, boys and girls, and it was hard for them to understand this…they wanted their straw to go all the way up to the cup originally. So then we had to discuss how we really could not do that because that would mean that the pipe would go all the way up to the clouds. Keeping in mind if you truly did a test run you probably could not maneuver your straw like that. But you know what they did discover? What was happening, Bobby?
Bobby:	It was eroding the hole.
Shirley:	And what was happening in the straw with the water and the straw? Remember what you told me?
Bobby:	Oh yeah, it was coming back up.
Shirley:	The water can only go in something so much and then it starts flowing. That is what was happening. The water could not come out of the straw underneath fast enough to keep the water that was being poured in.
Charlie:	Another thing the reason why we stuck these rocks here is if this got clogged for some reason then the water came up it would kind of run off of that. Cause if it flooded they would be the first ones to go.
Charlotte:	The first time we did this with one layer we did not have this there and it just flowed all the way out and I don't know.
Charlie:	And another reason is we sat it there to see if it ever got clogged up if it would stay. We have grass under there so it won't erode the sides so that the bridge won't fall.
Shirley:	Ready?
Charlie:	This isn't going to work.

Charlotte:	I know.
Charlie:	Wow, it is clogging up.
Shirley:	Why didn't you slope yours?
Bobby:	Because if we sloped ours and when we poured the water then the water would have gotten so high then it would be eroded.
Charlie:	We are goners.
Shirley:	Wait and see what happens though. You have to remember it is so saturated now that it makes such a big difference. Very good.

Bobby's position in the group can be seen in this lesson. His teammates nominate him to be the spokesperson for the group, due his contributions to the design of the landscape.

This group uses authoritative discourse in presenting their results because the other groups were not present during the investigation. However, their peers have conducted their own investigations using different landscapes and it does not take much to give them some context for this particular group's design. There is some mutual experience communicated during the presentation.

Generative and authoritative discourse together was only found in these two lessons. The elements of these lessons that enabled this discourse to occur were active student planning, an opportunity to apply what they had learned, the ownership of the students in their ideas, and the presentation of that material to their peers. Interviews with the students and discourse from the lessons confirm the ownership of ideas and that applying their knowledge made these lessons different from the rest of the unit.

Educational Importance of the Study

The Inquiry Addendum to the National Science Education Standards (National Research Council, 2000) describes five essential features of classroom inquiry:

- Learners are engaged by scientifically oriented questions.

- Learners priority to evidence.
- Learners formulate explanations from evidence to address scientifically oriented questions.
- Learners evaluate their explanations in light of alternative explanations.
- Learners communicate and justify their proposed explanations. (p. 25)

These two applications lessons, in which students constructed a dam and a landscape of their own design, applies four out of the five "essential features." Students applied their previous knowledge, obtained in the preceding lessons, to figure out a design for their structures. Students made a test run with the one cup of water to test their design or accumulate evidence. Students formulated explanations and fixed their design in light of test run results. Students then communicated with their peers by presenting their design to the rest of the class. This is an expert-novice relationship since each group knows its own design best. The only step of the essential features that was not followed in these lessons is that students did not evaluate their explanations. The students were not asked to write in their journals. This would have given them the opportunity to reflect on their designs and construct new knowledge.

This study has shown that generative and authoritative discourse can occur during inquiry-based science if the essential elements are in place. A satisfactory connection between student discourse and their knowledge of key science concepts occurs when all of these elements are in place. Due to the adoption of inquiry-based science standards and materials in elementary classrooms, the science education research community, as well as elementary teachers, needs to understand students' conceptual understanding of science concepts in inquiry settings and its connection to student discourse. Students' conceptual understanding of erosion and other earth science concepts and its ties to generative and authoritative discourse should be included in this discussion. Since many science curriculum materials still fail to include information for teachers about student conceptions and student discourse (AAAS, 2000, [Online] http://www.project2061.org), studies such as this can inform curricular developers and teachers. This study thus adds to the research literature on students' conceptions in earth science, its connection to generative and authoritative discourse and how certain elements of an inquiry-based curriculum addresses students' conceptions.

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