Tensions Between "Transmission" and "Discovery" in 2 K-1 Science Classrooms

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Abstract: At a time when inquiry is recommended as the best way to teach science, many researchers and practitioners describe science instruction using this term. As we discuss in this article, what is taking place in inquiry-based science classrooms may be more complicated than this category suggests. We propose a useful way of thinking about and describing science instruction is in terms of tensions between teaching as "transmission" and "discovery". The tension represents an *ideological dilemma* (Billig, Condor, Edwards, Gane, Middleton, & Radley, 1988) in education. In our focus on the dilemmatic nature of teaching and learning, this paper illustrates how teachers improvise a balance between organizing K-1 students' science learning through transmission and discovery through their use of discourse strategies and instructional approaches.

Introduction

The idea for this paper emerged out of the challenge we faced in describing the kind of teaching that took place in two kindergarten-first grade science classrooms. In these classrooms, students were working on long-term science projects, doing hands-on activities, asking questions, and wondering about science; their teachers were designing activities meant to spark students' interests, listening to students' questions and ideas, and learning alongside their students about how to connect children's experiences with science content and processes. The students and teachers were engaged in good, some might even call it exemplary, elementary science instruction. However, when it came to describing what was actually happening in these conversations and activities, we found it difficult to categorize because when we looked closely, we found it involved a combination of different approaches. It was neither pure child-centered science instruction, with an emphasis on children discovering concepts and processes, nor was it traditional science instruction, with a focus on the transmission of information. The teachers did what they thought was appropriate for the students at any particular moment and while this is good educational practice, we found it difficult to describe theoretically because as educational researchers, we tend to dichotomize.

At a time when inquiry is recommended as the best way to teach science, many researchers and practitioners describe science instruction using this term. According to the *National Science Education Standards*, inquiry involves,

> "making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations" (National Research Council, 1995, p. 23).

In some ways, the teaching in the classrooms described in this article resembles scientific inquiry. But what does this label actually tell us about the instruction in the classrooms? We propose a useful way of thinking about and describing inquiry-based science instruction is in terms of tensions between teaching as transmission and discovery.

Brown & Campione (1994) described the middle ground between "didactic instruction and untrammeled discovery" somewhat paradoxically as "guided discovery". As they emphasized, the role of the

teacher in this type of instruction is not clear. The teacher needs to make moment-to-moment decisions about how to teach and what to say to students; she needs to be sensitive to students' developmental levels and recognize the potential in what they say and do. These general suggestions for how teachers should teach belie the depth of knowledge teachers need to draw upon when working with students.

A goal of this paper is to contribute to discussions of inquiry-based science teaching by describing how teachers guide students' science learning. We aim to do so by presenting two illustrative scenes from K-1 classrooms in which students are engaged in a version of inquiry-based science. This analysis is not meant to be representative of how these teachers teach or suggestive of how teachers should teach. Rather it is meant to begin developing the notion of a tension between transmission and discovery as a generative way of describing more completely what teachers in inquiry-based science classrooms are doing when they teach.

Conceptual Framework

Our thinking about the tensions between transmission and discovery approaches to teaching/learning is informed by social psychological analyses of *ideological dilemmas* (Billig, Condor, Edwards, Gane, Middleton, & Radley, 1998).

Billig et al. (1998) introduced the notion of ideological dilemmas to describe tensions rooted in ideology that permeate Western culture. Such dilemmas include those between freedom and control, competition and cooperation, and excellence and equity. The ideological dilemma between teaching/learning through transmission and discovery has played a major role in shaping educational practice and discourse over the past century. John Dewey (1938) described this dilemma in contrasting traditional (transmission-based) and progressive (discovery-based) approaches to teaching respectively:

> "To imposition from above is opposed expression and cultivation of individuality; to external principle is opposed free activity; to learning from texts and teachers, learning through experience…" (p. 19)

For the purposes of this paper, the use of the terms "telling" and "didactic instruction" refer to the transmission of scientific information. In transmission models, teaching involves the delivery of sets of facts by an expert. Using this conception of science, the teacher assumes the responsibility for telling students scientific facts and information. In radical discovery approaches to science teaching, students construct scientific knowledge for themselves.

Research on effective teaching and learning shows that complete reliance on telling students science content does not lead to understanding (Bransford, Brown, & Cocking, 1999). However, not stepping in to guide a student at a critical learning moment may lead to confusion or frustration on the part of the learner. As Loughran (2002) writes, there exists a dilemma with "when to tell or not tell" (p. 197).

Analytic Perspective

Taking a situated approach to understanding teaching and learning, our analysis considers how the teachers designed classroom activities and attempted to engage students in science conversations and activities (Lave & Wenger, 1991). To document how teachers and students participated in the scenes, we examined how they used talk, materials, and gestures to *position* (Goffman, 1981) themselves and others to participate in classroom science activities. All speech positions speakers and hearers to take on particular roles in an interaction, for example as a principal actor in a story, an over-hearer, or as part of an audience. The emergent *participation framework* or set of participant positions that open up when an utterance is spoken shapes how one is able to engage with the topic being discussed or the ongoing activity (Goodwin, 1990).

Furthermore, as suggested by Billig et al. (1998), the strategic use of talk, gesture, and pauses are important communicative resources used by teachers to "ensure that (children) 'discover' what they are meant to" in classroom interaction (Billig et al. 1988, p. 54). For this reason, the scenes were transcribed to document classroom participants' uses of talk and interaction. Our analysis differs from Billig et al. (1988) in that it focuses on the actions of the teachers *and* students in order to examine how students contributed to the management of the tension between transmission and discovery in classroom interaction.

Tensions between Transmission and Discovery: Two Classroom Scenes

Background

The scenes presented in this paper are from a larger corpus of videotaped classroom data collected as part of an ethnographic study of teaching in long-term science projects. In that study, science instructional activities were videotaped over the course of one school year.

Our purpose is not to provide an exhaustive description of the science instruction that took place in these classrooms. Rather, it is to illustrate a tension we noted between supporting students' discovery learning versus the transmission of science content, and to discuss the usefulness of this idea for understanding inquiry-based science teaching and learning. As we discuss in our presentation of the scenes, the teachers appear to manage moments that we, as researchers, view as involving a tension between teaching through transmission and discovery as a routine part of their classroom practice. Their decisions about what and how to teach were made on the spot, but were also informed by their ideas about good pedagogical and scientific practice. The focus of our discussion is on describing what they did in these moments to guide students' science learning.

The scenes used to illustrate this tension come from two kindergarten-first grade classrooms in a laboratory school at a large university in California. As a laboratory school, the school has a long and rich legacy of progressive education. One of the early principals of the school studied with John Dewey and progressive educational values are still evident in official descriptions of the school's pedagogical philosophy. On their website, the school's learning environment is described as "rich in real-world experiences and thought-provoking activities to help children develop the ability to think creatively and use and question a variety of sources of information."

Forty-four students from the two kindergarten-first grade classrooms combined classes for science instruction. Ms. Gold (1) taught students in a monolingual English classroom and Ms. Mendéz taught students in a bilingual Spanish-English classroom. Ms. Gold and Ms. Mendéz had worked together as a team for five years at the time of the study; a third member of the team assisted with instruction in both of the classrooms. As a team, the teachers planned science activities together and organized science projects over the course of the year. The classes would meet together at least one day a week for science instruction. Teachers organized instruction so that students would work at different activity centers, work in small groups with or without a teacher, and participate in whole-class discussions.

The two scenes are from the students' early study of physical science. Specifically, classroom instruction focused on investigating the characteristics of three states of matter: solids, liquids, and gases.

Scene 1: Learning Science through Experimenting

The focus of this scene is on the tension between transmission and discovery when helping young students learn science through experimentation. This scene takes place at the end of September and students have been investigating the characteristics of solids since the beginning of the month.

At the start of the activity, Ms. Mendéz refers to the students as "really awesome scientists" positioning them as scientists who are engaging in the premier scientific activity (i.e., experimenting). As "scientists", the teacher suggests that the children have a different relation to the activity than they ordinarily would assume as "students". Scientists actively seek out knowledge and engage in experimenting in order to discover and test ideas. An experiment is defined as "an operation carried out under controlled conditions in order to discover an unknown effect or law, to test or establish a hypothesis, or to illustrate a known law" (Merriam-Webster's Collegiate Dictionary, 1993). By framing the activity in terms of students as "scientists" who are going to do an "experiment", it is clear the teacher did not intend the activity to be about the transmission of information to passive recipients.

Ms. Mendéz is seated on the rug with ten students who are tightly gathered around a jar filled with water. The teacher prepares to pour sand from another jar into the water jar. She has asked one student to keep his finger on the water jar to mark the current level of its contents so they can monitor what happens as they add the sand. Before she begins pouring, Ms. Mendéz asks Sylvia for her "prediction" (2):

1	Ms. Mendéz:	Can you see? Leon has his finger (on the jar). What's your prediction?
2	Sylvia:	Um, the water's gonna with the other rocks at the bottom it's gonna turn a little higher.

The teacher then pours the sand (and a few rocks) into the water jar. As the solution settles, Ms. Mendéz directs the students to look at Leon's finger and number of students note the solution is "rising":

35	Ms. Mendéz:	Why is it rising?
36	Bradley:	The rock and the sand are pushing it up.
37	Ms. Mendéz:	(slowly) The sand and the rocks-
38	Clara:	I KNOW WHY because the stuff is on the bottom and the water is getting higher and higher.

In response to Ms. Mendéz's question about "why" the solution is rising, Bradley suggests the rock and sand are "pushing" the water and making it rise. Clara then proclaims loudly that she "know(s)" why" the water level has risen. Her declaration along with her intonation, increased volume, and facial expression suggests that this insight was authentic for her; this is a kind of "discovery" to which the teacher was leading. Like Bradley, Clara links the addition of the sand and rocks to the increased water level. However, whereas Bradley's explanation refers to the actions (i.e., "pushing") of the rocks and sand, Clara's explanation refers to the relative locations of the "stuff" (rocks and sand) and the "water" in the jar and suggests a relation between them ("the water is getting higher and higher").

After eliciting these possible explanations, Ms. Mendéz pours more sand into the jar and directs the students' attention to Leon's finger.

50	Ms. Mendéz:	Look at Leon's finger. Now look at the jar and tell me where the sand is at.

Students note that the level of the solution has increased. At this point, Ms. Mendéz attempts to conclude the experiment by summarizing for the students what has been found:

58	Ms. Mendéz:	So WE KNOW then that matter occupies space.

From the teacher's perspective, the experiment is now complete; she has just stated what they have learned. Let's consider how she formulated this claim. She begins by prefacing what is now known with "so…then" which suggests what will follow is a consequence of what was observed in the experiment. Ms. Mendéz then states emphatically and with increased volume that "we", an inclusive pronoun that refers to her and the students, have the knowledge that "matter occupies space".

Following Ms. Mendéz's summary of what has been found in the experiment, a couple of the students ask if they can put their fingers on the jar now that Leon has removed his finger:

62	Charlene:	Can I do it?
63	Ms. Mendéz	You can do it.
64	Marissa:	I want to do it!
65	Ms. Mendéz:	You ca- you want to do WHAT? HERE'S our experiment. So this is what I want you to do.

At line 63, Ms. Mendéz agreed to let Charlene put her finger on the jar. Then, at line 65 she started to agree to let a second student "do it" as well, but then hesitated and changed her mind ("You ca- you want to do WHAT?"). The tone of her question (at line 65) along with its increased volume and emphasis on the word "what" suggest the teacher is surprised by or is feigning surprise at this request.

From Ms. Mendéz's perspective, the point of keeping a finger on the jar was to be able to see the change in water level before and after the sand and rocks were added to the solution. This was a critical part of the experiment because it was meant to make the process under study visible. That students want to put their fingers on the jar after the sand and rocks have been added suggests they may have a different view of the activity. One explanation may be that they have not understood what they were meant to learn from the activity. Other explanations might be that the students are interested simply in putting their finger on the jar or that they

might want to experience for themselves an aspect of the experiment by doing this critical activity of placing their finger on the jar even though the experiment is over. While any of these explanations may be correct, our focus here is on how the teacher responded to these requests. At line 65, Ms. Mendéz emphasized her view of the activity stating, "HERE'S our experiment", which along with her attempt to move on to another activity suggested the activity is over.

This scene illustrates what we view as a tension between transmission and discovery in teaching young children science through inquiry. To help students see and understand what she thought was important in the experiment without simply telling them, Ms. Mendéz used a few different strategies. First, the teacher set the stage for discovery by determining what the students "as scientists" would be testing in their "experiment". She also was responsible for selecting, setting up, and manipulating the materials (jar, water, sand, and rocks). The metaphor of acting was purposely invoked because there was a certain amount of staging on the teacher's part involved in this discussion. The teacher had an idea of what she wanted the students to see in the experiment and she designed the activity and proposed particular roles for the students to take in order to accomplish this goal.

Ms. Mendéz then proceeded to lead the students through the activity. One discourse strategy employed here was the use of *directives*. A directive is defined as a linguistic act "whose function is to request a non-linguistic response" (Sinclair & Coulthard, 1992). Specifically, she told the students when to look and where to look in order to guide their perceptions (line 50). By directing the students to notice the increase in the water level, the teacher did not have to tell them what changed; they would see it for themselves.

In concluding the experiment, Ms. Mendéz summarized what had been learned from the activity and phrased it in such a way as to suggest that this meaning was shared with the students. Her summary is notable because it is she, the figure with the most authority in the scene, who makes a claim about what the entire group knows. It is also worth pointing out that this summary is not stated in the language of the children—"matter" "occupies" and "space"—are sophisticated concepts and words for kindergarten and first graders. This leads one to question the degree to which the students recognized this idea as something they now know.

Lastly, at the end of the scene, the teacher addressed the possibility that not all of the students may have followed the task as intended. Her response was to label explicitly their activity as an "experiment", which suggested both how the activity and the students' participation in it should be understood.

One of our aims in presenting this scene was to describe how Ms. Mendéz led her students towards particular scientific ideas (line 58) and engaged them in scientific processes (lines 1 and 5). The teacher faced (though not necessarily consciously) a dilemma at the end of the activity that may be familiar to many science teachers—to tell or not to tell. By presenting a close look at what Ms. Mendéz did in this scene, we hope to suggest that thinking in terms of a tension between transmission and discovery draws attention to the complexity involved in inquiry-based science teaching.

Scene 2: Learning Science through Hands-on Activities

The focus of this scene is on the tension between transmission and discovery when helping students see what is relevant in a hands-on science activity. In it, a group of five students investigate liquids at a liquids table. On the table, there are different types of liquids including shampoo, molasses, and oil. This scene takes place in October and the students have been studying the characteristics of solids since the beginning of the year. Immediately prior to their work at the liquids table, the students investigated solids at a similarly organized solids table.

As the students begin their work, Ms. Gold says to the students, "All of you are chemists. You are going to start mixing all the different liquids together. See what you come up with." In this way, the students are positioned as scientists, specifically chemists who are investigating the properties of materials and what happens when you combine them. As Ms. Mendéz did in Scene 1, Ms. Gold suggests a relation between the students, the materials, and the activity wherein the students-as-chemists are expected to be active investigators as opposed to passive recipients of information.

After the teacher leaves, the students become thoroughly engaged with mixing the different liquids in cups that have been placed on the table for this purpose. When Ms. Gold checks on their progress, she asks them

to "start thinking about the differences between your experiences" with the solids and liquids. She leaves the table and returns a few minutes later to ask what differences they have found:

54	Bradley:	Liquids always separates.
55	Ms. Gold:	Liquids can separate? How do they separate?
56	Bradley:	(nods head in agreement)
57	Javier:	No, you cannot separate.
58	Bradley:	(inaudible) something. No, you can mix them together with your own hands but if you just pour them together they separate.
59	Ms. Gold:	If you pull- how can you separate? Where are they separating?
60	Bradley:	You know? It looks like they're not, but they are like in different categories really close together.
61	Ms. Gold:	Close together.
62	Harshad:	Ms. Gold?
63	Ms. Gold:	What?
64	Harshad:	Once you've already poured one and you pour the other they just go on top of each other.

One of the differences between liquids and solids Ms. Gold wants the students to identify is that liquids are not as easily separated from each other as compared to solids. In response to Bradley's and Harshad's descriptions of separating liquids (lines 55 and 59), Ms. Gold poses the following challenge to the students:

70	Ms. Gold:	…Are you ready for my question? Actually, I'm going to ask you to do something for me. I'm going to ask you now, in this other cup that you have, separate your liquids, please. Separate the molasses, separate the oil, and separate the shampoo for me.
71	Emma:	(looks at Ms. Gold as she walks away) Ho::w?
72	Sofie:	We're just supposed to separate the liquids?
73	Students:	Yeah.
74	Bradley:	What?
75	Javier:	Ho::w?
76	Emma:	This is going to be hard.

When Ms. Gold says "Actually I'm going to ask you do something for me" she indicates that she is about to make a change in her plan for the lesson. She decides to follow up on Bradley's claim and poses the challenge of "separat(ing) the liquids" to the students. The tension between transmission and discovery that emerged in this episode specifically involved engaging students in hands-on activities so they can discover and notice things and helping students to see what they think is important within a limited amount of time. Ms. Gold managed this tension by strategically posing a challenge (line 70) rooted in the students' experiences with the liquids and initiated by an observation made by one of the students. Her question focused the students' activities and led a few of them to wonder out loud about the plausibility of separating liquids.

Ms. Gold again leaves the table. When she returns, she sees that the students have not separated the liquids. Emma, still perplexed by the teacher's question, asks, "How, how could that be?" Ms. Gold states that Bradley said, "You could separate liquids." She then asks the students:

90	Ms. Gold:	Can you separate the liquids?
91	Students:	NO.
92	Ms. Gold:	Could you separate the solids?
93	Students:	YES.
94	Ms. Gold:	(pauses and holds out both hands palms up)
95	Emma:	AH HA! THAT'S THE DIFFERENCE! (points at Ms. Gold) You can't- you can't separate liquids, but you could separate solids.

Emma's "ah ha!" moment, when she identifies "the difference" between liquids and solids, is an interactional achievement. Specifically, Ms. Gold's questions were designed to lead Emma (and the other students) to focus on whether liquids and solids can be separated. In turn 94, Ms. Gold pauses and waits with her

hands raised as if waiting to receive what the students have found. Emma then puts the questions and their answers together and declares the difference to which Ms. Gold was leading.

Immediately after Emma's declaration, Bradley expands on his initial comment that liquids can be separated to say that "actually you can…" separate liquids "if you have certain kinds of liquids" that don't mix together. Following his line of thought, Ms. Gold asks the students to identify "which liquids do not mix easily":

105	Bradley:	Like (reaches for a bottle of oil)
106	Ms. Gold:	Which liquids did you find out that don't mix easily? Like what? What is that? (points to the bottle of oil)
107	Bradley:	I don't know (laughs).
108	Ms. Gold:	What is this? (reaches for the almost empty bottle of oil) What was this? (holds up the bottle)
		…
112	Emma:	(reads the label on the bottle) Wes::son
113	Ms. Gold:	But what is it?
114	Emma:	Wesson
115	Ms. Gold:	This is, but-but what is it?
116	Emma:	Oi::l
117	Ms. Gold:	It's oil!
118	Bradley:	That's what I was trying to get.
119	Ms. Gold:	Oil and water do not mix easily.
120	Bradley:	I know. That's what I was trying to s-
		…
122	Ms. Gold:	So you are saying that some liquids you can separate but others you can't? Is that what you're saying?
123	Bradley:	(nods head affirmatively)

Rather than agreeing with Emma, Bradley proposed an exception to the general claim that liquids cannot be separated. While he has some difficulty identifying those liquids that do not mix easily, he reaches for the oil bottle suggesting that he thinks oil does not mix easily with other liquids. Ms. Gold tries to get the students to say that oil is one type of liquid that does not combine easily with other liquids. She holds up the bottle and Emma reads its label ("Wes::son"-the brand of oil), but Ms. Gold wants to know what it *is*. When Emma says the word oil, Ms. Gold quickly offers oil and water as a combination that does not mix easily. Bradley states that he knows this and while he does not finish his sentence, it seems that he starts to claim that this was what he "was trying to" say. At line 122, the teacher checks in with Bradley to make sure she understands him and to summarize. Additionally, by phrasing her question to emphasize what "you" (Bradley) are saying, Ms. Gold emphasizes his ownership of the claim.

Teaching using hands-on science activities involves a tension between making sure students see what you, as the teacher, think is relevant and allowing them to see what they see. In this scene, Ms. Gold improvised a balance between transmission and discovery by guiding the students to see certain things and providing them with the opportunity to investigate materials on their own. Importantly, by selecting which liquids were placed on the table, the teacher also shaped the kinds of discoveries the students could make (i.e., including oil on the table). While Ms. Gold seemed to be leading the students to make a particular claim (liquids cannot be separated), she changed direction in response to Bradley's insight. Thus, while the teacher guided the students to make a particular type of discovery, the process was not unidirectional. Bradley's contribution re-directed the conversation by raising an exception based on his experience of mixing and exploring the characteristics of liquids and his reflection on this experience. In addition, by asking Bradley and the other students to provide an example of liquids that do not mix easily, Ms. Gold engaged them in the scientific practice of supporting claims with evidence.

Discussion

Throughout the past century, there have been attempts to organize school learning through discovery or transmission (Cuban, 1988). While this may be an ideological dilemma, in classroom practice as Dewey (1938) and Bruner (1961) emphasize, teaching does not necessarily require making a choice between discovery and transmission.

This perspective was valuable in revealing how the students engaged in a type of guided scientific inquiry. For example, in Scene 1, Ms. Mendéz was primarily responsible for designing and leading the experiment; students participated as active observers of phenomena that the teacher identified and as respondents to her questions. In Scene 2, Ms. Gold organized the activity and selected the materials to be used, but students were unsupervised as they worked with the materials. The tension between transmission and discovery was evident in how the teachers used language to guide the students' actions in the scenes. For example, in both scenes, the teachers heavily guided the students' interactions using directives (Scene 1, Line 50, "Look at Leon's finger" and Scene 2, Line 70, "separate your liquids, please"). The use of such directives served to reaffirm the teachers' authority in relation to the students, but at the same time the content of their statements provided a way for the students to gain access to scientific phenomena and thereby take more responsibility for participating in scientific inquiry. This dialogical relation between transmission and discovery characterized the interactions in both of the classroom scenes.

By describing inquiry-based science teaching in terms of tensions between transmission and discovery, this paper suggests that it is not necessary for teachers to choose between transmission and discovery. Rather, embracing this tension can help teachers listen carefully to students' ideas and observe students' actions to identify clues to their understandings (Ball, 1993). In this way, teachers can figure out *how* and *when* to encourage discovery and to share knowledge more directly with students.

Endnotes

(1) All proper names are pseudonyms.

(2) (…) Parentheses indicates transcriber comments, = contiguous utterances are indicated with equal signs, :: elongated syllables are indicated with double colons, CAPS indicate emphasis, [onset of overlapping talk is indicated with a left bracket, and English translation is written in *italics*.

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