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ABSTRACT

This study examined intermediate and middle school level classrooms to describe the relationship between teacher and student understandings of inquiry-oriented instruction. Student understanding of the nature of science within the context of this instruction was also examined. Twenty-seven students from grades 4-6 were interviewed to evaluate their knowledge in a topic selected by the teacher, their understanding of the nature of science, and their perceptions of specific teaching practices. Results indicate a consistency between teacher perceptions and student perceptions of inquiry-oriented instruction. Students valued teacher explanations, questioning, and solicitation of student ideas. The uncertain state of knowledge that arose from lengthy exchanges leading to inconclusive results was generally acceptable to students and was consistent with teacher intentions to solicit student ideas and to generate discussion among students about science concepts. Students differed with respect to how often they questioned the relevance of instruction but all agreed that questions of relevance would be greeted with respect and, in some cases, even encouraged by their teacher. It was concluded that student understanding of the nature of science led to a meaningful interpretation of classroom experience of inquiry-oriented instruction. Implications for science teaching are discussed. (JRH)

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Do students understand the objectives behind inquiry-oriented teaching practice? If a teacher says the objective of a science lesson is to investigate a problem, do students understand the relationship between that objective and related objectives for learning science concepts and facts? How are students prepared to understand inquiry-oriented instructional objectives? In pursuit of the perennial goal of increasing the inquiry-oriented nature of science teaching, the authors examined what students in three different classrooms understood about the nature of science and the inquiry-oriented instruction of their teachers.

Research on science teaching generally sidesteps what teachers are doing not only to carry out the instruction but also to communicate to students the meaning of inquiry-oriented instructional objectives. Reviews of the literature on inquiry-oriented teaching revealed that studies generally concentrated on student behaviors and products and excluded descriptions of teaching practice that lead to those behaviors and products (Shulman & Tamir, 1973; Hofstein, & Lunetta, 1982; Flick, 1995). The National Science Education Standards (NRC, 1995) have the implicit assumption that inquiry-oriented teaching practice will be a part of every classroom that aspires to address the standards. The standards also explicitly state the goal of communicating the nature of the scientific enterprise as part of science education.

At the conclusion of his review of the literature on teacher and student understanding of the nature of science, Lederman (1992) emphasized that research should go beyond studying teacher and student knowledge to examine the intentions behind instruction and student understanding of that instruction. The lingering problem was that even if teachers were knowledgeable about the nature of science and that knowledge influenced their teaching, would students understand the instruction as being a significant part of learning science?

This study examined intermediate and middle level classrooms to describe the relationship between teacher and student understandings of inquiry-oriented instruction. Further we examined student understanding of the nature of science within the context of this instruction. The study took place in the classrooms of three teachers who were part of a larger program of instructional intervention.

Integrated Science Concepts (ISC) is a four-year program designed to improve teacher knowledge of science, the nature of science, and recommended teaching practices. An evaluation component of ISC is to examine effects on students of teacher practice as influenced by project inservice sessions. Teaching behaviors that include more inquiry-oriented instruction were tracked against student perceptions of these changes. If students don't perceive inquiry to be taking place or don't understand the relationship between this type of instruction and teaching science knowledge and skills, then its effectiveness is compromised. This study incorporated three data sources to derive a picture of inquiry-oriented teaching practice: (a) video tape of teaching episodes, (b) survey data establishing the teacher's perspective of his/her own instructional practice, and (c) interviews with selected students in each of the classrooms. Student interviews also established student understanding of the nature of science and its relationship to inquiry teaching.

Subjects and Procedures

Three teachers from the first-year cohort of 16 teachers in the project were selected to participate in an examination of their teaching as influenced by the ISC project. Selection was based on evaluations of classroom video tapes, level of participation in project workshops, and willingness to cooperate in the complex logistics necessary to solicit parental and student informed consent to conduct video-taped interviews. As part of the cohort, these teachers filled out the Constructivist Learning Environment Survey (CLES) (Taylor, Fraser, & White, 1994) and the Science Teacher Beliefs Instrument (STEBI) (Enochs & Riggs, 1990) at the end of the first year of inservice activities at the same time student data were collected. These teachers collaborated with the authors in the design of interview protocols used with members of their class whom they selected. The video-taped interviews were conducted during school time and lasted about 30 minutes. Simple classroom materials used during instruction prompted student thinking about science concepts. All interviews were conducted in classrooms unoccupied at the time of the interviews.

The pseudonyms of the teachers selected for this study were Mr. Lesh, 6th grade; Ms. Haver, 5th grade; and Ms. Braeburn, 4th grade. The teachers selected students for interviewing based on the criteria of providing a cross section of conceptual understanding of the science subject matter and an approximately equal distribution between males and females. To keep the research blind to the perceived achievement of the students, teachers provided an indication of student achievement after the interviews and analyses were completed. The distribution of interviews across classrooms is shown below:

	Boys	Girls	Totals
Lesh (6th)	3	4	7
Haver (5th)	5	4	9
Braeburn (4th)	6	5	11
Totals	14	13	27

The interviews were organized around topics designated by the teachers as being most appropriate for their relationship to the content of project inservice activities and of most interest to them in terms of feedback on their instruction. The teachers also discussed materials used during instruction from which props were selected for the interviews.

The interview protocol was designed to investigate three areas of student understanding considered significant in describing and evaluating classroom instruction from the perspective of students. These areas were (a) student knowledge in a topic selected by the teacher, (b) student understanding of the nature of science, and (c) student perceptions of specific teaching practices considered significant to the goals of ISC project. Interview protocols had to be tailor made for each of the three science topics, however, a standard set of questions were developed for probing perceptions of teaching practice and understandings of the nature of science. As an example, the protocol for Ms. Braeburn is described below followed by the standard protocols.

Example Interview Protocol

Ms. Braeburn selected her study of seasons and the relationship of earth and sun as the interview topic. Her collaboration provided internal validation for the subject matter section of the protocol. She provided following basis for the interview: (a) The seasons result from the uneven heating of the Earth's surface due to the tilt of the Earth's axis relative to its path around the sun, (b) The sun provides all the energy for our weather, and (c) Air that is warmer than the air around it will rise, or float, above the cooler air. The classroom materials included a globe, flashlight, and tennis ball for discussing day/night, summer/winter, and global weather patterns. The interview protocol was:

What causes the seasons?
Why does it get cooler in the winter and warmer in the summer?
How does the tilt affect our seasons?
How do we get day and night?
Why do we say that the sun creates our weather?
Explain why this card stays on this upside-down glass of water. Why doesn't the water fall out?
Why doesn't the water in the cup push the plastic cover and air out of the way and fall out?

Students were asked about the nature of science within the context of the teacher-selected topic and also within a context established by three sets of National Geographic pictures used in a uniform way with all students. While each picture was related to a story dealing with science content, the students were only asked to respond to the pictures as a stimulus for talking about the nature of science. The general line of questioning listed below was validated against the literature on teaching the nature of science (Lederman, 1992).

Introduction

General questions about how scientists learn about the teacher-selected topic of the interview to this point. This is used as a transition to specific questions probing their understanding of the nature of science.

Processes & Activities of Scientists

What do scientists do?

Fallibility of Scientists

Can they be wrong? Why?
Are there disagreements among scientists?
Why is this true, if they are looking at the same kind of information?

Validation and Proof in the Practice of Science

How would scientists resolve their differences?
Would it be possible for scientists to gather all the information necessary to learn everything there is to know about something? Would the scientists then be considered correct and no one would prove them wrong?

Respect for Scientists

Is it OK that scientists are wrong sometimes?

The last portion of each interview was devoted to questions concerning student perceptions of recent teaching practices. Questions were designed to focus student attention on key elements of classroom practice found in the CLES and STEBI. The interview protocol focusing on instruction was validated against the literature on inquiry teaching (Flick, 1995) and the content of the CLES and STEBI.

Introduction
What are some typical things that go on in your science class?
Relevance of Instruction
Is it OK to ask the teacher "why do we have to learn this?"
Teacher Actions
What does your teacher do that helps you learn science?
Expressing Ideas
Do you ever discuss your own ideas in class and tell the teacher what you are thinking?
What does the teacher do when you express your ideas?
Does this help you learn about the activity?
Peer Discussion
Do you ever talk to other students about science during science class?
Do you learn some things from other students when you talk to them during class?
Do you learn as much from other students as you do when you talk or listen to the teacher?

Students were assured in the informed consent that no one would listen to these interview recordings until school was out for the summer. We also explained that their comments were to be used to improve teaching and that their teachers were interested in hearing what they thought about classroom instruction.

Analysis and Results

Results are presented in three parts. First, we used survey results to describe teacher perceptions of their own inquiry teaching practice. These perceptions were compared with an analysis of a video taped lesson by each teacher. These data established the intentions, and to a limited extent, the instructional behavior of teachers designed to lead students in inquiry-oriented instruction. Second, we analyzed interview data concerning student understanding of the nature of science. This established the ability of students to understand the purpose of inquiry-oriented teaching. Finally, we analyzed interview data concerning student interpretation of instruction and compared that with teacher intentions.

CLES and STEBI data were tabulated for all 16 teachers as a means of contrasting the teaching characteristics of the three teachers selected. Individual teachers varied within particular subscales, but there were no clear trends across the 16 teachers. The two elementary teachers were above one standard deviation from the mean on the CLES and the two STEBI scales while the one middle school teacher (Mr. Lesh) was very close to the mean on all three scales. In Mr. Lesh's view, students had less of a role in determining curriculum and instruction as compared to the perspectives of Mrs. Haver or Mrs. Braeburn. The lower scores for Mr. Lesh on both scales of the STEBI can be attributed to responses that indicated he has less direct effect on what students learn than the elementary teachers expressed through their responses. For instance, on the following item, Mrs. Braeburn and Mrs. Haver answered "strongly agree" while Mr. Lesh marked "disagree."

> When a student does better than usual in science, it is often because the teacher exerted a little extra effort.

For items on both scales that were worded in the negative, Mr. Lesh responded less extremely than the other two. For instance, Mr. Lesh disagreed while Mrs. Braeburn and Mrs. Haver strongly disagreed with the following statement:

> Effectiveness in science teaching has little influence on the achievement of students with low motivation.

Discussions with these teachers concerning the content of student interviews and analysis of a video taped lesson did not suggest major differences in the way these teachers conducted class. All three lessons engaged students in small group, hands-on activity. Mr. Lesh's 6th grade examined rocks and developed rules for classification, Mrs. Haver's 5th grade wrote out observations of flowers, and Mrs. Braeburn's 4th grade constructed a tower with straws. They each conducted focused discussions about the purpose and nature of the small group work with clear expectations for the activity. From the frequency and open-ended nature of questioning, both Mrs. Braeburn and Mrs. Haver left more of the content of the class in control of the students while Mr. Lesh conducted a more convergent lesson designed to use Venn diagrams in the topic of classifying. In this sense, the 6th grade class was expected to understand a more well defined idea than either the 4th or 5th grade class.

Student interviews were transcribed and coded corresponding to the subsections of the interview protocol as shown above. For instance, that portion of the interview dealing with instruction was coded for the categories (a) relevance of instruction, (b) teacher actions, (c) expressing ideas, and (d) peer discussion. The nature of science protocol was coded for (a) processes of science, (b) fallibility of scientists, (c) validation and proof of scientific results, and (d) respect for scientists and the scientific endeavor.

We first present an analysis of student interview data dealing with their understanding of the nature of science. It is reasonable that student perceptions of the work and thinking of scientists would be consistent with their views on the nature of inquiry teaching. Students who think that ideas in science are based on empirical evidence would presumably think that activities in class are important for evaluating empirical evidence in support of scientific ideas. Conversely, students who do not view science as involving investigative processes would not see a connection between classroom investigations and learning ideas in science. The analysis has been broken into to two parts, (a) the fallibility of scientists and (b) how scientists get new ideas. The latter category synthesizes two interview categories involving the processes of science and validation and proof in science.

Student Understandings of the Nature of Scier ce

Students tended to perceive scientists as fallible human beings. They had little trouble imagining that information in science could change and that scientists could be wrong, after all "nobody's perfect." But, if enough time and effort were expended on a problem, would scientists know a correct, infallible answer?

I: So if some additional scientists studied those maps and satellite pictures and used their calculations, and were very, very careful, would they be able to tell us exactly how the seasons work?

B1M*: Not exactly, I mean there always could be something they missed even no matter how careful they are.

I: I see. Later on if other people were studying weather and-

B1M*: They could prove something wrong or say this isn't true because this and this.

I: Would those people who showed the new information, would they be correct, or could they possibly be wrong?

B1M*: They could also be wrong. They could have made a mistake somewhere around there and since they made the mistake then the other people could be right or they could have a point of something.

Mistakes were not the only reason that knowledge in science was less than certain. Students expressed the view that science is limited and tentative because "everything is always changing." If changes in the environment are an impetus for scientific study, then these changes can also be a source of inexact knowledge. This can be thought of as the "You can't hit a moving target" view of science.

B4F: Something is always wrong. You're never gonna learn everything exactly. Everything is always changing. They could study the hurricanes over and over and over again, and think they have everything correct, everything right, that they know everything there could be about hurricanes, but I know that they wouldn't know everything, because there's more to learn. There's hardly anyone that could learn it, I don't think there ever could be anyone.

H4M*: No. There's nothing that ever has to be something, or, is going to be the same.

I: Why is that true? Why is it?

H4M*: Because everything in the world is always changing. Everything is always changing. There's not a moment that something is not changing.

L4M*: Ya, cause they could have like studied different parts of (the rock). They could have studied like that half the rock and they could have studied that half, and they could have been different. (If scientists don't study exactly the same part of the rock, then they could be mistaken because all parts are not the same.)

Other sources of change affecting the tentative nature of scientific knowledge included advances in technology (it is always improving so more is learned), scientists get smarter as they get older (and therefore improve on the knowledge of years ago), and scientists simply correct the mistakes that earlier scientists made.

Knowledge is tentative because there is too much to learn as was mentioned above. However, students saw major limiting factor was that there weren't enough scientists to study all the necessary parts of nature. This can be thought of as the "brute force" view of science. To get more knowledge you need more scientists. The implication was that if there were enough scientists, science concepts would be more exact.

H2F*: Because, they can't keep track of really all fish in the world and every different one needs different things. Same with the people in there. Every person needs different things to stay alive and to keep healthy.

I: So, no matter how long these scientists kept working on this, they could never possibly work out what's most important for the diet of these particular fish right here?

H2F*: Well, maybe, but, there's, but if the fish, well, if some of the fish lay eggs or something then, and they kept getting bigger and bigger, the fish population there, they probably couldn't. And if there was only a couple scientists.

I: There would be too many fish?

H2F*: Yes. But, if they kept being that many fish and there were a lot of scientists they probably could, but they wouldn't know exactly.

Students saw disagreement among scientists as appropriate given that there was so much change in the world. Scientists would have trouble studying the same thing. However, if scientists did study the same thing over a period of time and agreed on the results, then they would probably be correct in their conclusions.

I: Could they possibly be wrong about how the clouds form or how the seasons work?

B2M: They could be but it'd be sort of unlikely how they all agree on it. Through all the years they figured out that that was it and all of them got together and they figured out - they come to a conclusion and okay, that's how they would figure out.

The idea that scientists could maintain an enduring conclusion was a minority view. Given that technology improves and scientists find new things in the environment, an obvious question was, Where do scientist get their new ideas? Students generally associated this idea-generating process with a vague notion of thinking about a problem.

B2M: It's just the different ways (scientists) look at it. Some people, like I did before I even studied it, that rain just came and it got sucked up somehow and came again. Now I understand a little more.

I: And how does that happen? How do we end up thinking that Jupiter has more moons that it did before?

H3F: Because I think that people go up there and think.

When pressed to consider where new ideas came from, students linked thinking, experimenting, and sharing ideas with other scientists. Examining the source of ideas was not easy for them to put into words.

H4M*: I don't know. Depends on what the scientist is thinking. Like, "should I do this or this to test it out." Or, "Why should I test it out?"

B5F*: I think they do a lot of research and they have to do a lot of experiments and they have to try over and over again until they get it just right. If they don't get it right one time, they have to try again and again. They research something then they try it out....I think stuff like from other people like if they got together and what other people do and how other scientists work. They research how other people before tried to come up with stuff and they try to use that.

I: Where do scientists get their ideas?

H6F: From other scientists sometimes.

The nature of these new ideas or their relationship to the work of scientists was not clear. The relationship among experimenting, data or evidence, and new ideas did not come up in the discussion. A few students did use the term 'theory' and applied it to the work of science but this was rare.

I: How is it that scientist's can be shown to be wrong? How does that happen?

H5M*: Well, they can develop a theory, and then when they try it, it doesn't turn out the way they said it would. Or, they can have theories and prove it, and, then, later someone has another theory and proves that, and, they try them together and somehow it clashes.

L6F: Okay, how do I come up with a theory. Well you just like, you examine everything and you just think okay, so what happened, how did this happen. You think of all the possibilities and everything and you just think of one natural possibility that sounds really, can't think of the word, really-

I: Believable.

L6F: Ya, I guess. That sounds like somebody is gonna be able to agree with.

B11M: Maybe because there's day and night and since there's the sun, maybe they just wonder, ya know, and maybe they get feedback from maybe other scientists and hear ideas and maybe can put together their own ideas and then they send probes out and figure out if it's true or not. If it's not, it's not and it's sort of a guess and check sort of thing.

Generally speaking, students put a human face on science and considered these people to be fallible. The process of investigating, making mistakes, and being corrected fit with their view of how science worked. They also considered scientists to be social and willing to share information and get feedback from each other. However, just as there was little discussion about the role and nature of theories, there was little specific discussion about what scientists do when they investigate or experiment. The processes of science were not operative terms during these interviews. Even so, the tenor of the discussion suggested that these students would recognize the purpose of instruction that promoted social interaction for the purpose of sharing ideas in science and examining agreements and disagreements about experimental results.

<u>Student Perspectives of Mr. Lesh's Teaching</u>

We now turn to interview data concerning how students perceived instruction that was intended to be inquiry-oriented. The student interview data are presented for each teacher and compared with each teacher's view as expressed through responses to the CLES.

Statements that Mr. Lesh's students made during clinical interviews were generally consistent with responses he made on the CLES and observations via video tape of his classroom teaching. Lesh's students said that they typically "find out" about things in class. Finding out was operationalized as discussion with explaining and doing activities. The term "activity" mean a wide variety of things from "doing experiments" or "hands on stuff" to "watching a video." Notice the emphasis on classroom talk. Mr. Lesh's talk eventually emerges as a significant feature in student perceptions of his teaching.

L5M: Well, it's usually the hands on stuff like when you do experiments with him. Sometimes the reading, but it's easier to understand when you do experiments.

L6F: ...for instance, right now we're finding out how the earth is formed and stuff like that. We're just finding out, we're looking at other things. We're looking at videos and stuff like that, that explain like volcanoes and how they explode and stuff. We just study things. We look at them and we just talk about them and stuff.

L3F: We read out of (science books) sometimes, but most of the time we just talk...like at the beginning of the year we talked about and did activities on planets and stuff; the universe. We just talked and did activities.

Students said that during classroom talk there were opportunities to express their own ideas and engage in peer discussion. This took various forms that included discussion in small groups and speaking out in the whole class.

L5M: Oh ya, (students express their ideas) a lot. ...Mr. Lesh tries to help them explain. He tries to explain it to them, but usually we do something to explain what they ask. A lot of times when they ask, it's usually during an experiment that we're doing. Sometimes during greeting.

L3F: We have groups. There's groups and you work with them and you have your own paper, but you work with them. If you have a question or anything, you're supposed to ask whoever is in the group.

This was consistent with Mr. Lesh's views expressed on the CLES that students learn to communicate through discussion with other students and during class. Mr. Lesh restricted student "questioning" and "complaining" about instructional activities but "almost always" allowed students to discuss science ideas with each other as a part of science class. The following is a paraphrasing of statements from labeled sections of the CLES using Mr. Lesh's responses:

> Learning to speak out
> In the process of being in my class, they learn that it is almost always OK to ask "why do I have to learn this?" But it is only sometimes OK to question my teaching strategies or complain about activities that are confusing. While it is almost always OK for student to express their opinions, it is only sometimes OK for them complain about things that they think are preventing them from learning.

Learning to communicate

Students almost always get a chance to talk to other students about solving problems, explaining their own ideas, and asking each other questions about what they think.

However, not as obvious from Mr. Lesh's perspective was his central role as the mediator of information and ideas in the classroom. Generating understandable explanations was, from the students' point of view, the most important thing he did in helping them learn science.

L4M*: (Mr. Lesh) Explains stuff like gives us an easier explanation. ...like takes the explanation, the video that he gave us, and like made it so we can understand it like using smaller words or recreating their explanation to something we would understand.

L6F: He explains it, he, well, Mr. Lesh makes it seem so easy... He makes it so that we understand it... It's the words he chooses and the way he lets us look at things.

L1F: Well, the teacher, he gives us films, and we take notes on what we hear. He learns things and then he tells them to us about how like maybe this was formed by volcanoes and that kind of thing, and he teaches us, and I think he does a very good job too.

L5M: Well, usually he'll take a break and talk about something we had just read about and tell us more about it that the book doesn't explain.

Mr. Lesh was central to the process of mediating ideas and processing information. Students felt that they learned from others in their class but they also stated that student attention was inconsistent and sometimes students did not listen to their peers. They looked to Mr. Lesh to create an atmosphere for sharing ideas and provide feedback on their thinking.

L1F: Ya, sometimes, but it's hardly ever that anybody has any (ideas to express) because they're here to learn, so they let the teacher teach.

L4M*: He says something about it like, "Very good," like he or she was right and he talks a little about what they said about. (Or) if they're wrong he says something that it kinda has something to do with the idea, but it's the right idea that they could have been thinking about but not what they were.

In one anecdote, a female student explained the relationship between using Mr. Lesh as a mediator of student thinking and students' own thinking. She was conscious of the value of his verbalized thought but was also aware that at least she was using that information to help her think on her own.

L6F: ...we don't use his mind, we use our own. We try to think of what happens like how things do things and we use our own minds. We don't just use his, it's like taking advantage of his mind 'cause he knows everything 'cause he's the teacher. It's kind of like we just, we think on our own. We just learn from our own minds and from each other.

Students were silent concerning their possible input with respect to the content of the class. While Mr. Lesh seemed to express the position that his students were to be, to a large extent, responsible for their own learning, his students did not directly express the view that they were contributing to their own learning. As we shall see, the elementary students were far more confident and outspoken about their role in their own learning. This result is contrary to the way Mr. Lesh expressed his position on the relevant section of the CLES:

> Learning to learn
>
> Students sometimes help me plan what they are going to learn and which activities are best for them. While students often help decide how much time they spend on activities, they only sometimes help me assess their own learning.

<u>Student Perspectives of Mrs. Haver's Teaching</u>

Mrs. Haver's students found her class "fun so that we aren't bored." Student perceptions were focused on the materials they can "fiddle with." Learning science in her class was finding out what happens as a result of manipulating materials.

H7F: Well, she lets us fiddle with the stuff. And, let's us play with it and try to find out what kind of stuff the thing does... it like helps you, like, learn like what, how this stuff works and stuff. And, like what happens if something occurs. Like if you mix vinegar with baking soda or something.

H6F: Sometimes, most of the times, she hands out stuff and we try to make things. Like balloons and see how stuff and just fiddle around with it and see what you can make with it. Stuff like that.

H5M*: Well, what we usually do is that we usually have an experimenting free for all with some rules involved so that we don't short the whole school's power system or something. But, then we go and we talk about what we learn and what caused that and then we back to experimenting with our new knowledge to see.

Student statements support Mrs. Haver's views of her own teaching that imply students have a clear voice in the curriculum and instructional strategies. It was equally clear from the interviews that she selected the topics and provided specific materials. However, they were able to play a key role in deciding how materials were to be used and even how much time they spent on the topic. Paraphrasing from the CLES expresses Mrs. Haver's position:

> Learning to learn
>
> Students often help me plan what they are going to learn and which activities are best for them. Students often help decide how much time they spend on activities and often help me assess their own learning.

One student described a classroom episode involving a discussion. While the plan was to spend only a half hour on the topic, the discussion stretched to 90 minutes. She talked as though the students would not let her stop the class for recess.

H4M*: Oh, well, we were talking about communities, I think, and we were talking about what makes a community. And we were going spend a half hour on this, and then we were going to have and hour 'til recess. We spent an hour and a half on it. So we got into it. Finally, one kid just put out the answer and we all accepted that.

Students said they regularly interacted with other students during Mrs. Haver's instruction as a way of learning science. A typical pattern involved students being asked for their ideas while Mrs. Haver wrote them on the board. Other students expressed agreement or disagreements with these ideas and a discussion followed.

H9M: She kind of goes with (our ideas) and talks to the class about it, and maybe see what they think about it and stuff like that. And, then we discuss it, and then we may (experiment) or we may not. ...and then each of us came up with that idea. And it's working.

H6F: Sometimes you have arguments. But, like they say some things are a community. And, they say "Naah, it has to be loving." or something. And, so, Mrs. Haver kind of writes up our questions and then we all talk about it and see which is right.

H4M*: Well, it always starts out with a question. And then a comment. And then we get into a discussion. It always happens when we do that. And only when Mrs. Haver stops us do we.

H5M*: Yeah. A lot of times I get ideas and sometimes I forget them. But, everybody gets to say their ideas, and, then, if everybody says "Yeah,

yeah." then we kind of turn to a discussion about that. Or, if it's questionable, we maybe set up an experiment with it.

Sometimes discussions were stimulated in small group settings and students talked among their peers about science. Students generally associated these interactions with activities.

H6F: Yeah. Sometimes when we get materials to play with and stuff, and figure out ways to do, we're in groups. And, yeah, we talk to each other about how to do it.

H5M*: Yeah. A lot of times when we try an experiment, or something, before we do it, we talk about, like, sometimes I say, I use my knowledge that I already have and put that towards the experiment.

Peer discussions were an important way of learning science according to some students. When asked if they learned as much science from talking to peers as from Mrs. Haver, some felt that peers were an indispensable part of the instruction.

H9M: ...But, when you're just talking to the teacher, it doesn't come out with the same idea. It kind of comes out better when you talk with your group and stuff, because then you guys can work together.

H6F: Cause if you're alone with your teacher and just one class, or just you. Then you probably wouldn't learn as much because kids would bring up other ideas.

Mrs. Haver's responses to the CLES indicate a strong intention to let students communicate in class and with each other on a regular basis. She selected the option of "almost always" in the items relevant to communicating and speaking out.

> Learning to speak out
> In the process of being in my class, they learn that it is often OK to ask "why do I have to learn this?" It is often OK to question my teaching strategies or complain about activities that are confusing. While it is almost always OK for student to express their opinions, it is only sometimes OK for them complain about things that they think are preventing them from learning.
>
> Learning to communicate
> Students almost always get a chance to talk to other students about solving problems, about explaining their own ideas, and about asking each other questions about what they think.

Student Perspectives of Mrs. Braeburn's Teaching

Mrs. Braeburn's students have developed an alternative meaning for the term "science class." As a result of a teaching team developing an integrated curriculum, the students didn't identify with attending a class in science. Instead students saw themselves doing the activities normally associated with a science in time blocks reserved for integrated curriculum or in their math groups. One student separated his concept of science ("beakers and stuff") from what happened in school and said that "we don't have all that stuff." He then came to the startling conclusion that as a result "we do more hands on stuff."

B11M: Well in our class I don't really think of it as a science class because it's like we don't have all the stuff, all the beakers and stuff. That's kind of why we don't call it a science class cause it's not really a science class. ...(It's) integrated curriculum. I think it's just different because we do more hands on stuff than I think you wouldn't do; chemistry, we don't do a whole lot of sitting down and listening to the teacher talk and talk and talk. We don't have the science stuff, but we do experiments like the thing with electricity and we did stuff with the weather, we did stuff with the ocean.

This perspective had an interesting effect on how students saw the role and fit of science in the curriculum. With no "class" being identified with "science" students were comfortable with science-like ideas being included wherever possible.

B8M*: We really don't have a science class. You learn about science in any class that we have around here. We learn about air pressure, we do quite a few experiments. Like the thing we just did with the globe we did and things like that. We had some pop cans that we put into a bucket of water. A few sank and a few were still up on top.

B2M: In our math group that's basically where we have most of our science. That and our integrative curriculum. She tries to bring in as much science as she can and it's all around things, it's not one particular thing. We try to make structures out of straws and see how high they can hold up, we're doing something on polymers right now and it's just lots of different things.

This more diffused or dispersed view of science learning was perhaps reinforced by the observation by several students that science was stuff brought from home or from outside the classroom either by the teacher or students. The sense of these interviews reiterated the point made in the previous quote, "(Science is) all around things, it's not one particular thing."

B1M*: Ya, we like take questions and we bring in stuff from home. She asks us questions like, she goes, "Does anybody have any questions," and we ask all our questions so we're all totally clear about it.

B6F: She brings in, like little things in, like today we were learning about trees and she brought in sticks for us to take the bark off and look at and so we can touch it and see how it feels. She talks about stuff and she takes pictures and we learn more about how we do research.

B7F: ...The teacher is up here and she brings in the big stacks of wood, she sets them on the tables and you take one of the microscopes and look inside them. She brings in stuff and she brought this stuff and she showed us stuff and oh god, it's so complicated.

Expressing ideas in class as well as discussion with peers was associated with activities and experiments similar to Mrs. Haver's students. Students describe the context of hands on activity as a time to say what they are thinking and to get feedback from the teacher. Whereas students found Mrs. Braeburn's feedback to be important, they also felt that considerable learning occurred by talking to other students.

B3M*: Usually she brings out an experiment and says, "What do you think will happen." People like give her as much information as you can on one idea.

B4F: If we have a science project and then we talk about what we think is gonna happen. ...She has us all raise our hands. If you say something that is really close or almost on the dot, she'll tell us and she'll tell us even more and give us little hints and it makes us think even more.

Students felt they learned a lot of science from other students. At times, they saw students as being the best source of information when Mrs. Braeburn did not know how to answer their questions. In a broader sense, students said that it was a good idea to have a variety of opinions because this would strengthen their own thinking.

B2M: Ya, I think we learn more than it would be if she just told us what to do things and we didn't exactly talk. It gives us different ideas; different things to think about. If someone gives you a different opinion about things, it's much better than just going with your opinion and proven wrong and you not knowing why. I think it's about even (learn as much by talking to other students). She knows most of the facts, but we just have like little outcomes of it. We figure out well if that's right, maybe this could be right about a different thing. Doing that connects to another thing.

B4F: Sometimes we do, not a lot. I usually don't. I like to keep my ideas in my head just in case it's a good idea. ...Ya, we learn a lot more. It's like what we do when we share and someone has a good idea. She tells us and we take that idea and we use it over and over again. It's pretty fun.

Students expressed the view Mrs. Braeburn's regularly sought student input which was consistent with her own view. Students expressed several ways that their ideas were heard and used in class. They went a bit further by saying that their discussions with each other about the tasks Mrs. Braeburn set for them were as important to their learning as discussions with her. A summary of Mrs. Braeburn's responses to relevant sections of the CLES express her position.

> Learning to speak out
>
> In the process of being in my class, they learn that it is almost always OK to ask "why do I have to learn this?" It is almost always OK to question my teaching strategies or complain about activities that are confusing. It is almost always OK for students to express their opinions or complain about things that they think are preventing them from learning.
>
> Learning to communicate
>
> Students almost always get a chance to talk to other students about solving problems, about explaining their own ideas, and about asking each other questions about what they think.

The students saw paper work as an integral part of science instruction. Far from being a burden, they saw it as constructive. Written work was a guide for what they were going to learn, were learning, and had learned. Further, the paper work was a vehicle for learning about organization.

B10M: ...We study that for awhile and then we have papers that we have to do and stuff. We put it all into like our binders and stuff and then we give it to them (teacher team) and they grade us on how good we were organized and how good we did and stuff.

B5F*: Sometimes we do papers and stuff to see if, to answer questions that we might have. At the beginning of the thing, we write down questions we have and stuff we don't know and stuff we do know and then we try to find out the stuff we don't know during the time we research it. That I think is kind of neat because it's hard to believe more stuff about plants or weather or whatever we're studying than when we came in.

B9F: Ya, she gives us paper work and she gives us tests sometimes. Like she did it with plants and then like she gave us a test at the beginning of the year to show what we know about it. Then at the end when we were finished learning about the stuff she would give us another test and see what new stuff we learned.

"Paper work" can be seen as Mrs. Braeburn's way of connecting students to the learning process that she designed. Her own view of instruction strongly emphasizes a student role in planning curriculum and instruction. A summary from the CLES expresses her position.

> Learning to learn
>
> Students almost always help me plan what they are going to learn and often which activities are best for them. Students almost always help decide how much time they spend on activities, and often help me assess their own learning.

Conclusions

This study of the first of four cohorts revealed a consistency between teacher perceptions and student perceptions of inquiry-oriented instruction. Students valued teacher explanations, questioning, and solicitation of student ideas. Students detailed lengthy exchanges in class leading to inconclusive results about the science topic under discussion. This uncertain state of knowledge was generally acceptable to students, and they said they would be interested in examining the ideas later. This was consistent with teacher intentions to solicit student ideas and to generate discussion among students about science concepts. However, there were differences between the one middle school teacher, Mr. Lesh, and the two elementary teachers with respect to the control of subject matter and the nature of instruction.

Mr. Lesh perceived himself as exerting tighter controls on student input concerning curriculum and instruction while Mrs. Haver, 5th grade, and Mrs. Braeburn, 4th grade, encouraged more dialogue about the structure and nature of classwork. Student interviews did not reveal this same distinction. For example, the middle school students, with one exception, did not comment on their ability to effect changes in curriculum or instruction. It appeared to be a non-issue. As one student said of the class, "they're here to learn, so they let the teacher teach." However, one student in Mr. Lesh's class did express discouragement while operating within the instructional guidelines and said that she had not found a way to express her frustration in class.

L3F: We had to draw what we saw there. That's hard because in my rock there's dents and stuff like this and you can't draw that. The really talented people can, but I can't. ...we had to think (hypothesize) what it looked like and you can't really get much from a gray picture with just lines. So it was hard to do that. (What I wanted to do was) actually be able to look at it through the jeweler's loop or something without drawing it first.

She expressed hesitant agreement that she could express this problem in class and that Mr. Lesh would let her proceed in her own way. This was an isolated comment in an otherwise uniform endorsement of Mr. Lesh's teaching practice by the seven students interviewed.

Even though the students expressed a positive view of teaching practice that was consistent with Mr. Lesh, there were some discrepancies across grade levels. The 6th grade students cast their teacher in the role of mediator of information that was not implied in the CLES responses by Mr. Lesh. The 4th and 5th grade students did not make the same observations. While the middle school students were willing to "let the teacher teach," this subtle statement that students were not providing input into class structure and content was not perceived by Mr. Lesh. A logical extension of this view over the next few years of school would be that students rationalize that they actually have less of a role in their own learning than they did in the elementary grades. This view directly contradicts Mr. Lesh's position that students at this age have more responsibility for their own learning. This contradiction between student and teacher perception of the nature of student involvement in the instructional process has direct implications for inquiry-oriented instruction and will be discussed below.

Students differed with respect to how often they questioned the relevance of instruction, but all agreed that questions of relevance would be greeted with respect and in some cases even encouraged by their teacher. There was consistency in the presence and perceived value of activities or hands-on instruction. Teacher actions were usually cast in terms of using an activity as a stimulus for discussion and questioning. Students reported being able to express their ideas in class although they did not take equal advantage of these opportunities. Within the 27 interviews there was no obvious relationship between gender or teacher-perceived, achievement level and student participation in classroom discourse. Students used and valued discussions with peers about science and generally agreed with the statement that they learned as much from each other as they did from the teacher.

Student understanding of the nature of science led to a meaningful interpretation of classroom experience of inquiry-oriented instruction. Interview data showed that these students were able to discuss basic tenets concerning the tentative nature of science knowledge and the importance of experimenting and sharing results. Students did not, however, express much understanding of science processes nor did they say anything about the role of theory and hypothesis in directing the work of science. This selective knowledge about the nature of science may have affected their ability to perceive the broader intentions behind teaching practices designed to engage students in inquiry. For instance, these students would not easily see the relationship between forming hypotheses and collecting data. Data collection was a mechanical process valued as a source of information within the immediate context. Its function in solving a larger problem and the relation of that larger problem to the immediate set of circumstances would not be easily recognized.

Implications for Science Teaching

These results have implications for studying the nature of inquiry-oriented instruction at the upper elementary and middle levels. The participatory nature of instruction as stimulus for class discussion was consistent with student understanding of the tentativeness of scientific knowledge and its dependence on collecting and sharing information about the environment. The data from this study show only that students understood aspects of the nature of science that was relevant to the kind of inquiry-oriented instruction they experienced. These data do not show how students came to hold these views about the nature of science nor do they explicitly show what the teachers may have done to convey specific ideas about the nature of science. It was clear from video tapes, informal discussions with teachers, and survey data, that these teachers valued instruction that stimulated student thinking about science and that they had intentions to teach with relevant objectives in mind.

Evidence from the middle school classroom suggest that students shift away from seeing themselves as directly influencing the nature and content of science class. An implication is that the teacher-student relationship is becoming more formalized with students expecting and even demanding that teachers provide certain kinds of information. There are undoubtedly developmental and social factors underlying this change in perspective. For example, heighten social awareness of middle school boys and girls can influence their willingness to speak out in class. They may non-verbally communicate this disposition and establish expectations that the teacher lead more of the discussion.

All three of these teachers were selected because of their demonstrated knowledge of and interest in constructivist epistemology supporting contemporary views of inquiry teaching. Yet, from the beginning the middle school teacher, expressed a more teacher-directed view of the way these ideas applied to the classroom. Mr. Lesh enjoyed a harmonious relationship with his students indicating he has sensed their desire for a style of teaching different from the elementary teachers. Therefore, developing a deeper sense of what it means to inquiry in science will take a more direct effort on the part of Mr. Lesh. That is, to maintain inquiry-oriented instruction, the teacher-directed content of Mr. Lesh's class will have to shift from particular science content to teaching more purposely about inquiry. In order to develop more direct involvement in the content of science class, students would need to be directly taught about aspects of inquiry including modes of discourse during discussion, the role of theory in making observations and interpreting data, and the long term nature of scientific problems.

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