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Teaching and Assessing Science For Understanding: Managing the Accountability Dilemma

The authors report on findings from a year-long study of how teachers determine student understanding and why they employ the instructional and assessment strategies that they do.

Introduction

In the United States, science teachers are challenged by the National Science Education Standards (NSES) to "select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners" (National Research Council, 1996, p. 30). Such pedagogies, broadly based on the notions of constructivism and teaching for understanding, encourage teachers to be flexible and to shift the pace and focus of instruction on a daily basis to meet the needs of students. These reforms acknowledge that students construct their own understandings of any given content focus. Assessment practices in a classroom oriented towards understanding must provide ongoing information that allows a teacher to be responsive to individual needs (Perrone, 1998). In a classroom where instruction has been differentiated to meet the needs of individual students, formative or ongoing assessment becomes a critical factor in understanding how to adjust instruction as students begin to achieve the desired understandings. In such a classroom assessment becomes "ongoing and diagnostic … today's

means of understanding how to modify tomorrow's instruction" (Tomlinson, 1999, p. 10)

Paralleling the NSES reforms, there is also a strong pressure on teachers to prepare students for national and state standardized tests. Hardy (2004) indicates that there is strong public support for the current political pressures on schools to ensure their students will achieve high test scores. The general public response to the vision defined by the No Child Left Behind Act has been favourable (NCLB, 2001). The No Child Left Behind law now requires that by the year 2007 states determine student achievement in science at least once in each of three grade ranges (NCLB, 2001). Scores on these tests are seen as general indicators of student progress and comparisons of national, state, district and, sometimes, individual school scores are used to evaluate the quality of schools and the effectiveness of specific programs and teachers.

Inevitably, the effects of these national testing regimes are being felt at the classroom level where teachers feel compelled to 'teach to the tests'. However, such teaching is built on different premises about student learning,

pedagogy and assessment than teaching for understanding. The emphasis when teaching to the tests is likely to be towards knowledge acquisition rather than knowledge construction, direct rather than flexible pedagogies and summative rather than formative assessment practices.

Analysis of student learning should serve as the basis of instructional planning.

Herein lies a fundamental dilemma for teachers as they try to accommodate these countervailing pressures, to teach and assess for understanding *and* improve student performance on standardized tests. Teachers are being asked to be accountable in two ways: to students (and their understandings) and to the public and to school boards (for improving overall student test scores). We call this the accountability dilemma. Wilder and Shuttleworth (2005) also refer to the dilemma that teachers address daily as they attempt to meet the vision of the NSES by providing opportunities for

inquiry based learning and also meet the demand of state and federal testing programs for content coverage. In this study we examine how five teachers from one school district managed to teach for understanding in the face of this dilemma. We report on the findings of a year-long research project investigating how these teachers determined students' understanding and why they employ the instructional and assessment strategies that they do. Our research question is: How and why are teachers teaching and assessing for understanding within the context of the accountability dilemma?

Background

Constructivist learning theory asserts that learning is an active process of constructing meaning and that knowledge cannot be transferred as a complete assemblage from one individual to another. From a constructivist perspective, students are understood to use prior knowledge and understandings to build new knowledge and understandings. Constructivism, as a theory of how learning is achieved, does not delineate a blueprint for action on the part of teachers. However science teachers, using a constructivist referent, are called upon to provide opportunities that challenge students' existing knowledge and help them develop new understandings of the world around them. Much has been written about strategies that teachers might use if they are teaching for understanding, often using constructivism as a referent (Brooks & Brooks, 1999a, 1999b; Llewellyn, 2005; Prawat, 1989; Tobin & Tippins, 1993; Windschitl, 1999, 2000; Yager, 1996). What is clear is that, if instruction is designed using the tenets of constructivism, there must also be a concurrent shift in strategies

for assessing student understanding (Holmes & Leitzel, 1993).

Many science reform initiatives have centred on the need to teach science for the understanding of concepts rather than for simple recall of facts without meaning. A conceptually-oriented view of teaching includes the attributes of focus and coherence, negotiation, and analysis and diagnosis (Prawat, 1989). It is this third attribute that science teachers, in particular, would recognize as being critical to the progress of their students. Analysis of student learning should serve as the basis of instructional planning. Ongoing assessment of student understanding by the teacher provides information about the obstacles students are encountering while negotiating their way toward conceptual understanding. Wiggins and McTighe (2005), for example, encourage teachers to adopt a process of backwards design in creating curricula materials focused on teaching for understanding. They challenge teachers to "gather lots of evidence along the way" and explain that "the assessment of understanding should be thought of in terms of a collection of evidence over time instead of an event" (p. 152).

Constructivism, as a set of beliefs about knowing and knowledge, can be used as a referent for teachers to determine the learning potential of a given classroom situation. A constructivist view of learning has consequences not only for how one views an understanding of science content but also for how the role of a teacher is perceived. According to Duit and Treagust (1995, p. 52), under this orientation, "the teacher is viewed as a facilitator of knowledge and not as a person who transfers knowledge to the brains of students." Teachers need

to decide what experiences should be provided in order to facilitate learning and how the learner can represent what is already known to give meaning to the new experiences. Brooks and Brooks (1999a) identify five principles that teachers who are interested in creating constructivist classrooms need to understand: "teachers seek and value their students' points of view, classroom activities challenge students suppositions, teachers pose problems of emerging relevance, teachers build lessons around primary concepts and big ideas, teachers assess student learning in the context of daily teaching" (p. IX-X).

An important guiding framework for science education in the United States is the National Science Education Standards (NSES), published by the National Research Council (NRC, 1996). This document incorporates standards for science teaching, professional development of teachers, assessment in science education, science content, science education programs, and science education systems. The NSES take the position that if teachers are to be prepared to teach for understanding, they need strong content and content specific pedagogical knowledge. And, importantly, for the purposes of this study, they require a clear understanding of how students learn. While the NSES do not specifically espouse any particular model for instruction, many of the teaching standards proposed in the NSES use language also found in the literature on teaching for understanding and constructivism.

Although the NSES support a variety of performance-based assessments, a countervailing trend in both the political and educational arenas is towards a greater use of standardized

test scores as a measure of student achievement. The most common purposes of state testing are accountability for the schools and school districts, instructional improvement, and program evaluation. A less common purpose is student diagnosis and placement. Widespread testing for accountability purposes has increased following the 2002 enactment of the federal *No Child Left Behind* legislation. Throughout the United States, there are state tests for students in mathematics and language arts, tests for science and social studies achievement are being developed and many states now have high school exit exams. In 1995, Ryan and Miyasaka reported that multiple-choice tests were the most common format (70%) for state tests, with other formats such as performance assessment (28%) and portfolios (18%) less evident. By contrast, within the classroom, nonmultiple-choice testing formats were predominant (Barton & Coley, 1994).

> **We have to make connections between ideas if greater meanings are to happen.**

In summary, teachers are working within a complex and contradictory teaching and assessment milieu. The widely lauded National Science Education Standards (NSC, 1996), drawing on research into teaching and learning science, advocate a range of classroom, performance-based, normative as well as summative, measures to assess student understandings. The popular standardized testing movement draws from a different set of theoretical assumptions about teaching and learning

and school reform. This movement has resulted in the widespread administration of external, summative, uniform multiple-choice type tests. In their classrooms, teachers are responding to both pressures. While employing mainly nonmultiple-choice techniques to monitor understanding, they are also preparing students to sit for multiple-choice state tests. This study of classroom assessment practice examines how teachers manage to inhabit these two assessment worlds, and how they balance the dilemma of having to account to different groups in different ways.

Research Design and Procedures

This data for this article were collected by the first author as part of a year-long qualitative study of five science teachers from the Sonora Foothills School District—Ms. Springer, a multi-age teacher of grades one through three, two fifth grade teachers, Ms. Frederick and Mr. Gorman, a sixth grade teacher, Ms. Richardson, and a tenth grade teacher, Ms. Cornette (district and teacher names are pseudonyms). The Sonora Foothills District had a declared policy of implementing the NSES as well as improving student scores on state and national standardized tests. Multiple methods of data collection included observational field notes, teacher journaling, and semi-structured interviews. During the course of the study, Adrienne worked alongside the teachers as a participant observer (Adler & Adler, 1994). The data were reported in the form of individual case studies, incorporating lesson vignettes and teacher reflective commentaries. The case studies were analysed to identify common themes about teaching for understanding.

Yin (1994) defines a case study as "an empirical inquiry that investigates a contemporary phenomenon within its real life context" (p. 13). In this study, the contemporary phenomenon was teacher perceptions of student understanding within the real-life context of the science classroom and the political and profession pressures that teachers were experiencing. The study fell into the category of a collective case study as several cases were studied jointly in order to inquire into the phenomena of teacher perceptions. Individual cases were chosen with the belief that understanding them might lead to a better understanding of a larger collection of cases (Stake, 1994). We see the analysis of these cases as a small step toward understanding on a general level the strategies teachers use to assess student understanding and their success in doing so.

In the interest of brevity, in this article we present a full account of one of the cases, that of Ms. Joan Springer. While we do not claim that the case is representative of all five cases, it does capture most of the issues which emerged during this year-long study. The case includes an introduction and narrative vignette (Polkinghorne, 1995) of one of Joan Springer's lessons, narrated by Adrienne, followed by a reflective commentary on the central issue of teaching for understanding, narrated by Joan. The case is followed by a discussion of the issues emanating from this and the other four cases, supported by excerpts from the other cases where appropriate.

The Case of Joan Springer

Ms. Joan Springer was an experienced elementary school teacher, having taught in kindergarten - sixth grade classes for the last 28 years. She was also a teacher leader in the

Sonora Foothills District in the area of staff development and, for several years, helped teach a requisite class for all new teachers that covered Madeline Hunter's Essential Elements of Instruction (Gentile, 1988; Hunter, 1979). During the five years previous to this study, Ms. Springer taught a multi-age, first through third grade, class.

Within her multi-age classroom, Ms. Springer worked to build a sense of community among her students. When in her classroom it was very common for me to observe older students helping younger ones without prompting; sharing their knowledge and understanding of various concepts and helping the younger ones learn basic skills. By adhering to the multi-age concept that students learn best by learning from many different people in many different ways and with the help of many classroom visitors and volunteers, Ms. Springer managed to balance the range of needs presented by her multi-age students.

The following case study story focuses on one of Ms. Springer's lessons in a unit on electricity. Although this was actually a unit in the third grade curriculum, all the students in the room participated in the lesson. I observed the case study story lesson close to the beginning of the electricity unit. During most of the lesson I sat with the students and scripted as much of the conversation between students and teacher as possible. When the students were assigned to work in their learning groups my role changed from observer to participant and I was no longer able to record the students' comments. Immediately after the lesson, I left the classroom and wrote as many of the students' words as I could remember in my own journal. I also recorded my impressions and questions about the

lesson so that I would later be able to discuss them with Ms. Springer. Within a day or so after my observation she sent me her journal notes, including her thoughts about what she perceived to be a dilemma posed by the electricity unit as a whole. Later, when we had an opportunity to talk about it, Ms. Springer related the difficulties she was experiencing as she tried to maintain the integrity of her multi-age program while, at the same time, planning for appropriate science instruction for all of the students in her classroom.

Teaching Vignette: "Atoms Get Recycled"

Students entered Ms. Springer's class as soon as the bell rang. Class began with the students reciting the "Pledge of Allegiance" and then singing the class song. Ms. Springer told her students that she would be reading them a story about electricity before they started on their 'theme' (science) project for the day. She told them that the story would be about electrons traveling around making light and heat. The electrons would also be traveling thorough wires during the story.

The students sat on a rug and listened quietly as Ms. Springer read. Immediately after the story was finished, they raised their hands to make comments. A third grader said, "I'm thinking about yesterday and I think atoms get recycled."

Mrs. Springer responded, "Atoms get recycled? What a wonderful concept and good thinking. What did the electrons in the story do?"

Another student answered, "Electrons go differently. Only one atom jumps. Then it dies and another one jumps."

"What else did you learn from the story?" Ms. Springer asked the class.

Again a third grader answered. "I learned that at the power plant they send out a whole lot of electricity and when it gets to our houses it lights the lights."

"That fits into what I want to talk about today," Ms. Springer replied. "We are going to add sources of electricity to our web." Ms. Springer frequently used a concept map or web design to illustrate how various parts of a lesson interrelated. At this time she pointed to the web that had been started the day before. "Sources are where electricity comes from. There are three places. One is the sun. Do you remember the others from yesterday?"

"Water," answered one student.

"Wind," another said.

"What did I ask you to write about yesterday? What you think about electricity?"

This time a second grader began to get in on the discussion. "Could we read what we wrote?"

Another second grader joined in with, "I learned that when electrons jump we get electricity." Several students shared the comments that they had written in their journals on the previous day after seeing a Bill Nye movie about atoms and electricity. Many repeated the idea that electrons jump from atom to atom.

"Do you remember what I said we were going to do next?" Ms. Springer then asked. "Each person is going to do an individual report and each group is going to do a project as a group. Your reports can be about any part of our electricity web that you are interested in. The web includes the words atoms, sources, how it works, and safety centered on the word electricity. In order to write about one of these four parts we need to have a little more information about atoms. Can you understand

about electricity if you don't know about atoms?"

"No", a third grader replied.

Ms. Springer continued with a brief discussion of the structure of atoms. "So we have to learn about atoms. Look at the back of your hand. Do you see little sections? These are like cells and they are made of molecules. Molecules are made of atoms. They are very, very tiny. You can't see them with just your eye. Do you remember what an atom looks like?"

A third grader answered quickly, "Atoms have a nucleus inside and that is made of protons and neutrons and electrons around the outside."

Another question from the teacher, "And if electrons jump from atom to atom in a circle that is closed what do we have?"

A third grade student answered, "A circuit, electricity."

Ms. Springer then explained to her students that atoms are invisible to us and students would have to take the scientist's word for the fact that they exist. "This is one of the things that has to be taken on faith." She then showed the students a diagram of an atom. "It is just like you have described. Look how much space there is between the nucleus of an atom and the electrons. Atoms make up your body and your body is 99% space."

"Take a minute before we go on and write about an atom in your journal. You little ones can draw and then put labels on the parts. The second and third graders need to write some sentences. I'd also like you to write about an "aha" moment that you had from the video, something that you now understand because you watched it. What were some of your "aha" moments?"

The students' responses included "energy takes lots of power," "a turbine makes water to electricity" and "I want to find out about kinetic energy so I understand it."

"How long do you think it will take to understand all there is to know about electricity?" asked the teacher.

A first grade student who had been silent during rest of the conversation didn't wait to be called on. "All your life!"

After a few minutes had passed and all the students had added something to their journals Ms. Springer continued with the lesson by giving directions for the remainder of the class period. "OK, when you're done with your journals

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you are to get in your learning groups and start working on your reports. You can also talk about your project with your group if you wish." "Remember that you older students are responsible for your own reports as well as working with the younger kids when they need help." Students were also instructed to decide on a group project with each student to be given a task appropriate to his or her grade level abilities and interests. Each group was composed of four students including at least one third grade, one second grade and one first grade student.

At this point in the lesson I stopped scripting the dialogue and began to help various children find books that they wanted to use. A third grade girl asked me for help in locating informa-tion about how a hydroelectric dam worked. Together we found a book with a good picture and accompanying diagram with an explanation. I let her explain the process to me until she became frustrated with trying to understand how turning the turbines created energy that was stored in what looked like a big battery in the diagram. I reminded her of what her classmate had said earlier about it possibly taking a lifetime to understand everything about electricity and suggested that she did not need to understand every detail in third grade in order to do her report. She was visibly relieved and confided that she had been to a hydroelectric dam with her family and after this report she would be able to explain to them just how it worked.

As I continued to circulate around the room I had other opportunities to ask the students about what they had learned or were in the process of learning. One group, whose project was going to be about electrical storms, shared the following insights with me. A third grade student related that "electricity comes from storms and atoms, electrons jump from atom to atom making electricity"; another third grade student shared that "atoms are electricity, they are so small that we can't see them but scientists can and they know they are there"; the second grade member of the group explained "atoms are electricity, they jump through a wire to the light bulb. The one first grade student in the group had been following the direction of the older students during their project activities. He had spent most of the time carefully drawing a picture of an atom including a nucleus with electrons in a ring around the outside. When it was his turn to share his learning he smiled at me and said, "I love atoms. I'm do-ing my report on them. They are very

small. I have to use my imagination to see them."

The lesson illustrated by the case study story raised many questions in my mind about how Ms. Springer made assessments of what the students had actually learned during the course of the lesson. She and I discussed these questions and others by an exchange of journal entries and in follow-up conversations. In addition, during the field study, I was able twice to question Ms. Springer extensively about her background in teaching, the strategies that she finds most useful in teaching science and her perceptions of what her students understood during the lessons that I had observed. The following commentary was constructed almost entirely from Ms. Springer's words during our conversations and interviews. It represents her own reflections on her teaching and on the methods she relies on to determine what her students are accomplishing.

Joan's Reflective Commentary

"I can't," is rarely heard in my classroom. I have tried to create a classroom culture in which all the children feel like they can do whatever they are asked to try. I'm finding that the longer I teach multi-age the more that is happening. We are a group for a long time and it is important to create a sub-culture of sharing that encourages each student to support the others as they learn. One of the things we have made a point of is that our information or knowledge should not be kept a secret. It should be shared so we can all build on it.

When I am introducing a new science topic or unit I like to use a "web" type diagram, much like a concept map. It traditionally includes

the parts of the topic we are going to explore and what I want the students to find out. I use the same idea of a web to help the students build bridges between the different units that we work on. My students build mental bridges not only from unit to unit but also from year to year. The kids will make statements to each other like "... remember last year, how we did that? Well this is how it fits."

Another thing that I think is useful for teaching is a clear understanding of Bloom's Taxonomy of critical thinking skills. The ability to use that taxonomy to ask questions and elicit responses is critical for discussion within my multi-age group. I expect responses at a higher level of thinking from my older students than from the younger ones. I try to deliberately phrase questions so that each child will have to stretch his or her thinking.

I think it is vitally important that I am aware of my students' existing beliefs and understandings. We have to make connections between ideas if greater meanings are to happen. If students don't have a base to connect with, learning doesn't take place. As a teacher I have to know if everyone is on the same track or someone will get lost along the way while I am going on and on. You need to help students get back on the right track as soon as you can so they don't get lost. You have to talk with kids all the time to see what they understand. I try to check for understanding constantly by talking to my students, watching them work and asking questions. Sometimes I am very methodical about checking at specific stages in a long-term project. Typically my questions might be "What is ...?; How do we know that ...?; Where do we go from here ...?" With my multi-age kids a younger one might not know how to answer each

question but will benefit from having the correct answer repeated and explained by an older child.

I am not a proponent of standardized tests as a means of determining how well my students are doing. I don't think the format provides a fair test of what children can do. To me, understanding is when students demonstrate they know the concept or skill by correctly performing it in a similar but not exactly the same way. This could be through conversation or demonstration. They are successful when they can bring the learning back and apply it to a different yet similar situation or build onto that learning to go to the next step. I think that levels of understanding are different. What one person understands at an early stage should deepen and expand with more experiences with the same or similar concept.

The most effective way for me to assess the progress of my students is to listen to them on an individual basis. Final assessments come from presentations and projects. Even when there are group projects, each student is expected to complete an individual component on his/her level. Overall, I think my students understand a great deal about their lessons. People ask about multi-age all the time. They don't understand how you can teach a first grader and a third grader at the same time. I wish they could see the students' presentations. First graders might stand up and say a few words about plants while third graders explain photosynthesis. This year, during presentations to parents, one of my students announced that he didn't wish to share his report. Instead, he talked about how everything is connected. He clearly was able to build bridges between topics he had discussed in class. This was just an ordinary kid that

loved what we had been doing and was involved in his own learning.

Discussion

The purpose of the study was to describe how and why teachers are teaching and assessing for understanding within the context of the accountability dilemma. The data, exemplified in the above case of Ms. Springer, included observations of the teachers' instructional and assessment strategies. In analyzing the data, we identified commonalities of thought and action across the five case studies. We found that it was not possible to separate teachers' practices into two disconnected sets of actions, one being of instruction and the other of assessment. In each case study, assessment of student understanding was embedded in instruction, as was instruction, in some instances, embedded in assessment. As we analyzed the data we were able to identify themes that were both specific to each individual teacher's practice and common among all of the participating teachers. The themes included the link between teaching and assessing for understanding, the tension between professional and political assessment expectations, the preference for informal information on student achievement, and teachers' capacity to manage a dilemma of pedagogical choices.

The link between teaching and assessing for understanding

The outcomes of this research confirm that each of the teachers in the case studies developed their own perceptions of their students' understanding by using a number of different assessment strategies. These strategies were embedded in their individual practices of instruction as well as assessment.

As a result it was difficult to separate their instructional strategies from their assessment strategies.

The study teachers were observed using a wide range of techniques, including journaling activities, questioning strategies, group projects, one-on-one interviews, concept maps, activity reports, and student presentations to determine their students' levels of understanding during and at the end of the instructional units. As exemplified in the "Atoms Get Recycled" vignette, teachers frequently used information gained from these sources to adjust their instruction in order to meet their students' needs. Prawat (1989) identified teaching for understanding by its "highly analytic and diagnostic nature" (p. 324). Just as Ms. Springer encouraged her students to explore their ideas about atoms, the other study teachers favored a facilitation role over a transmissionist role. In the process of facilitation they used the analysis of student understanding for instructional decision making such as the addition of alternative activities to aid the progress of students with different learning styles. Ms. Springer employed this strategy when she added activities to her electricity unit because some of the students were having trouble understanding the concepts she wanted them to learn. Another of the study teachers, Mr. Gorman, employed a similar strategy when teaching a lesson on Bernoulli's principle.

Final assessments employed by the five study teachers included performance assessments, project presentations, one-on-one interviews and student-led parent conferences as well as teacher-generated paper and pencil tests. For example, Ms. Springer had her students complete independent projects on electricity and present their work at a parent gathering. During these processes the teachers often provided instructional feedback comments. Ms. Springer did this while the students were working on their projects. Another of the teachers, Ms. Fredericks, used one-on-one final assessment interviews to teach students the concepts they were struggling with. In these instances the focus of assessment was on student understanding of concepts and the processes of reasoning rather than on the production of 'correct' standardized answers.

The tension between professional and political assessment expectations

The teachers in the Sonora Foothills School District were challenged by the district goal to be "the number one school district in the nation … as evidenced by test scores." At the time of this study, teachers were offered incentive pay bonuses if they were able to meet specific short-term goals in order to make progress towards the district goal. The science teachers who participated in this study often talked about the difficulties in reconciling their preferred instructional and assessment practices and the testing parameters established by the school district.

Teachers felt that they were subjected to contradictory direction about how to determine the level of understanding that students were achieving in their classrooms. In each case they felt they were receiving conflicting signals from the district administration in terms of how to adequately evaluate the progress of their students. Teachers were encouraged by the district to participate in workshops and training including several days of training in Madeline Hunter's elements of instruction, multiple

Teachers' knowledge of science content and science content pedagogy as well as their personal knowledge and experience impacted their instructional and assessment decisions.

intelligences, brain-based learning, multi-age classroom instruction, and the use of performance assessments. Ms. Springer, for example, took a lead role in this program. The district curriculum had been rewritten shortly before this research began. The teachers involved in the curriculum revision used the NSES as the framework for the revision process. One of the study teachers, Ms. Cornette, a high school chemistry teacher worked with colleagues who had had extensive training in using learning cycles to teach for understanding. Many of those opportunities supported practices recommended by advocates of constructivist teaching. At the same time, however, the teachers were being encouraged to develop teaching strategies deliberately focused on raising the standardized test scores.

Within their classrooms the teachers planned for science instruction and assessment in light of these contradictory directions. They fulfilled their responsibilities as they understood them to be in terms of administering standardized tests but most of the teachers did not seem to place much value in the information that might be gained from the test results. In her commentary Ms. Springer dismissed the validity of the mandated standardized tests in determining student understanding and achievement. Another teacher, Mr. Gorman, was also concerned that

scores on "the district tests will [not] correlate very well with the learning and understanding that [his] students have accomplished". However, he did acknowledge that these types of tests were here to stay, as people could understand them easily.

Two of the teachers, Ms. Fredericks and Ms. Richardson, rejected the usefulness of standardized test scores, preferring performance assessments for the final determination of student achievement. Ms. Fredericks administered the district-mandated tests to her students but did not find the resulting scores useful in her determination of student success. Ms. Richardson expressed a willingness to use the test scores as an indicator of student success at some time in the future but did not trust the accuracy with which the scores reflected her student's accomplishments. In her words, "the tests are too picky, too specific in the nature of the questions."

Of all the teacher participants in this study Ms. Cornette was the one most open to using standardized test scores for the final assessment of her students' achievement because she understood these tests to be part of the "real world" and felt she should start preparing her students to be successful when taking them. In spite of her willingness to accommodate the district mandate she did not feel that the tests tested what she taught and preferred other assessment strategies. When the standardized test scores did arrive, Ms. Cornette found them to be unhelpful.

Both Mr. Gorman and Ms. Cornette acknowledged the reality of standardized testing. They reasoned that while, over time, performance assessments might gain public approval, standardized tests are currently viewed by many as reliable and valid measures of

student achievement. They were prepared to comply with the district plan in order to prepare students to be successful on standardized achievement tests that they might have to take in the future. Neither expressed any interest personally in using the test scores to inform their own teaching. Overall, the teacher participants gave only cursory attention to any use of standardized test scores, in spite of the fact that administering the tests and increasing student scores on the tests was a district mandate. Each teacher met the district guideline of administering the required tests. However, as a group, the teachers were not using standardized tests to inform their teaching or determine the level of understanding that their students had achieved.

The preference for informal information on student achievement

The teacher participants in this study assessed student understanding continually during the instruction process and preferred performance type assessments to paper and pencil tests as final assessments. Typically, teachers used assessment strategies at the beginning of lessons to determine what students already knew about a new subject or what they remembered from previous lessons. They embedded assessment in their instruction to determine if students were understanding as lessons proceeded and used various assessment strategies to determine final achievement of understanding.

All of the teacher participants deliberately included strategies to determine the initial understanding of students as new lessons began. Ms. Springer, for example, used concept maps to find out what her students knew about electricity. She referred to

the importance of sharing information, emphasizing that "knowledge should not be kept a secret." Mr. Gorman planned and posed questions about the 'big ideas' of each new unit to find out what students understood at the beginning of the unit and to generate discussion among the students about the new topic. Both Ms. Richardson and Ms. Cornette used daily warm-up activities to begin their classes. Students were frequently asked, in Ms. Richardson's class, to reflect on previous learning or experience and make connections to the new learning. Ms. Cornette asked her students to answer questions directly relating to the lesson taught the day before. All teachers used the student responses to determine the level of understanding that students had at the beginning of the lessons and adjusted their instructional plans accordingly. This strategy is nicely illustrated in the lesson on electricity described earlier, when Ms. Springer posed open ended questions after reading the story about electrons, light and heat.

Each of the teacher participants integrated assessment of student understanding into their instructional strategies. Those practices varied from informal questions during whole class discussions, one-on-one conversations between teachers and students as students were working on individual assignments, discussion of homework assignments, quizzes, and reflective writings. Teachers used information gathered from these sources to inform and adjust their instruction in order to provide opportunities for more students to be successful. For example, in the electricity lesson, Ms. Springer checked students' understanding by asking them to write about their "aha" moments after watching a video. On many occasions, both Mr. Gorman

Given the current political climate, which emphasizes the importance of student success on high stakes, multiple-choice achievement tests, teachers who are striving to maintain constructivist teaching practices are working in an environment that would seem to be counterproductive to their efforts.

and Ms. Fredericks added specific activities to their planned instruction because feedback from student discussions informed them that students had been struggling with specific concepts. Many of the lessons observed in Ms. Richardson's class ended with a review of the day's learning. These question and answer sessions served to inform her of how thoroughly her students had understood the material presented in her daily lessons.

All of the teachers stated that they would prefer to interview each student individually in order to assess their final understanding of the concepts taught in class. Ms. Springer referred to the importance of "listening to students on an individual basis." Ms. Fredericks was actually able to schedule her classes so that she could have those interviews at the end of several science units. She used the product of performance-type assessments as the focus of those interviews. In the case of an electricity unit she had her students build circuit boards and explain the differences between parallel and series circuits. If they weren't sure of the concepts to be assessed she worked

with them in a one-on-one setting until they understood.

Each of the elementary teachers expressed a strong preference for using performance-based assessment in determining the level of student understanding achieved in their classes. Ms. Springer preferred performance assessments including presentations and projects and believed that students demonstrated understanding when they could apply learning in different situations. In the three units of instruction observed in Mr. Gorman's classroom his final assessment of student understanding was embedded in an analysis of a final project. In one case the project involved wiring a model house with series and parallel circuits. Another was constructing and describing the interrelationships in a freshwater ecosystem and a third involved building and flying paper airplanes and explaining how and why variations in design affected the flight of the planes.

The middle and high school teachers also expressed a preference for performance-based assessment. These teachers expressed concern that the district mandated multiple-choice tests did not correspond to the content taught in the classroom and could never accurately test what was learned. There was a clear disconnection between the goals of the teachers in this study in assessing student performance and the district goal of being the number one district in the nation as evidenced by standardized test scores.

During the study the teacher participants implemented assessment strategies that correlated with the suggestions found in the literature on teaching for understanding. The NSES advocate the planning of assessment as an integral part of instruction. According to the NSES, assessments

embedded in the curriculum can serve at least three purposes: "to determine the students' initial understanding and abilities, to monitor student progress, and to collect information to grade student achievement" (NRC, 1996, p. 87). These teachers used assessment for all three of the NSES identified purposes. As illustrated in the vignette of Ms. Springer's teaching, teachers made instructional decisions based on initial diagnosis of student understanding and ongoing analysis of student achievement.

The capacity to manage a dilemma of pedagogical choices

Each decision about teaching and assessment required judgments on the part of the teacher about purpose and implementation. The teachers in this study were faced with a dilemma of pedagogical choices. One such dilemma was in determining the level of understanding of science content that their students achieved during and as a result of instruction. When lessons were more heavily packed with content information in the elementary classrooms there was evidence that teachers accepted recitation for understanding. For example, in Ms. Springer's multi-age classroom, there were students who memorized and copied representations of atomic structure as their teacher drew them on the board. These efforts were accepted by the teacher as evidence of understanding.

When lessons were focused on concepts, teachers at the elementary level often used performance assessments to determine the level of student achievement. Mr. Gorman asked his students to wire a model of a house using both series and parallel circuits. Ms. Fredericks had her students build

a circuit board and explain to her how it worked. Mr. Gorman determined the level of understanding of airplane flight that his students achieved by having them construct paper airplanes and analyze why changes in the model resulted in change in flight pattern. Ms. Springer had her students read about food chains and webs and then choose different ecosystems and make drawings of different food webs. Mr. Gorman had his students build mini-ponds in the classroom and watch the feeding process of several organisms at different ranks in the food chain. In each case the lesson focus was on broad concepts and the assessment of understanding was based on student use of the concepts to analyze different situations.

The teachers in this study brought a broad range of knowledge and experience to their science teaching, including knowledge of science content and science content pedagogy. Each teacher made daily decisions about what content to teach, which instructional strategies to use, what level of student understanding of concepts to expect and how to assess student understanding. As they implemented their lesson plans and taught for understanding, they faced a dilemma relating to their individual bases of knowledge and experience. Teachers' knowledge of science content and science content pedagogy as well as their personal knowledge and experience impacted their instructional and assessment decisions.

Conclusions

This research raises some important issues about teaching and assessing for understanding in the context of a complex policy environment. The first issue concerns the importance of recognizing the impact of political pressures on classroom teachers.

Organizing a constructivist classroom based on the principles of teaching for understanding and then recognizing student understanding when it occurs is problematic at best for teachers at all grade levels. Given the current political climate, which emphasizes the importance of student success on high stakes, multiple-choice achievement tests, teachers who are striving to maintain constructivist teaching practices are working in an environment that would seem to be counterproductive to their efforts. Those who are interested in what teachers are thinking and doing as an important component of efforts towards educational reform and those who are teachers of teachers need to fully understand the dichotomous role that teachers have to fill.

The second issue is about the importance that teachers place on connecting teaching and assessment. Assessment of student achievement, as a topic of discussion, has become a focus of political rhetoric as well as a concern among science educators. The political push for accountability frequently eclipses the intent of the NSES and the educational practices suggested by constructivist learning theory and the principles of teaching for understanding. This study revealed that teachers, as evidenced by their daily practices, are advocates of assessment strategies that allow students to demonstrate what they know and focus on the content that is most important for students to learn. When there is a correlation between, and integration of, instruction and assessment, teachers can develop sound perceptions of student understanding, at both the formative and summative stages. As a result they can adjust their instruction according to student needs and develop higher order assessment strategies. Other evaluation

techniques such as the use of external multiple choice style standardized tests may provide quantifiable standards of achievement but the level of learning that they assess may not be consistent with the depth of conceptual understanding that students have achieved. In addition, results of such tests are often not available to teachers during the instructional process and thus do not serve as a tool to inform instruction of the students that were tested.

Finally, we return more directly to the issue of the accountability dilemma and to teachers' capacity to operate within a complex policy milieu. After tracking these five teachers for the almost a year, what strikes us is how competently the teachers were able to deal with the multiple pressures inherent in this dilemma. The five teachers managed to hold these two accountability requirements in a kind of dialectic tension. They recognized the political reality of being held to account by the school board and the public at large through the administration of standardized tests. They also recognized the central importance of a different kind of practical accountability, to individual students and their parents for building student understanding. We found that teachers were able to *both* separate *and* integrate these two kinds of accountability. They wanted students to do well on the standardized tests *and* to develop their understandings. Their day-to-day practice, however, was motivated primarily by a desire to improve understanding, and in doing so they drew information from a wide variety of sources. These sources were mainly informal but also formal (and potentially including, where feasible, available and useful, standardized test scores). We conclude with the observation that the teachers in this study were able to work in a complex accountability milieu by operating with a pragmatic sense of making efficient and effective use of available resources, and motivated by a desire to develop understanding in the students in their care.

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