

*Towards a Transforming Constructivism:
Understanding Learners' Meanings
and the Messages of Learning Environments*

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ABSTRACT: This article is based on the ideas and material presented at the invitation to deliver the 17th Annual University of Calgary Faculty of Education Annual Distinguished Lecture. This lecture honors the work of a member of Faculty whose research contributions have been judged to contribute significant new insight in the field of Education. The article presents the foundations of research and thinking that have inspired work to deepen knowledge about the value and use of constructivist approaches in research, teaching, and learning. The article deepens the discussion by presenting additional ideas designed to produce a *transforming constructivism*. A transforming constructivism goes beyond taking into account learner conceptions or ideas in the teaching/learning dialogue. It incorporates thinking about the *cultural and social messages presented within the environments of learning* that also must be taken into account to build a more complete story of the ways that the learner constructs meaning. Illustrative dialogue on children learning about the topic light is presented from my book, *What Children Bring to Light: A Constructivist Perspective on Children's Learning in Science*, (1994). The article presents findings and further work that has extended and deepened understanding by featuring the messages of science learning environments in the account of learner construction of ideas.

RESUME: Ce mémoire est fondé sur les idées et le matériel qui ont été présentés pour répondre à l'invitation de la XVII^e conférence annuelle extraordinaire de la Faculté d'éducation de l'Université de Calgary. Cette conférence rend hommage au travail d'un membre de la Faculté dont on a reconnu que ses contributions à la recherche ont apporté un aspect nouveau hautement considéré dans le système scolaire. On y présente les sources mêmes de la recherche et de la réflexion qui ont servi d'inspiration au travail, afin d'approfondir la connaissance sur la valeur et sur l'emploi des

démarches constructivistes dans les domaines de la recherche, de l'enseignement et de la formation. L'analyse fouille le sujet en présentant des idées supplémentaires conçues pour susciter une *évolution dans le constructivisme*. Le concept d'une évolution dans le constructivisme ne s'arrête pas simplement à prendre en compte les conceptions ou les idées des apprenants dans la confrontation « enseignement/apprentissage mais, va bien au-delà. Il intègre une réflexion sur *les messages socio-culturels présentés dans le cadre de l'apprentissage* qui, elle aussi, doit être intégrée pour constituer et peaufiner un article sur les différentes manières utilisées par un apprenant de comprendre un sens. Tiré de mon livre *What Children Bring to Light: A Constructivist Perspective on Children's Learning in Science* (1994), un dialogue d'enfants illustré qui apprennent le thème « lumière », y est présenté. Le mémoire se termine avec les résultats et un travail supplémentaire qui permet d'élargir et de creuser la compréhension en assimilant les messages du contexte d'apprentissage de la science, à la réalisation des idées de l'élève.

Introduction

My original interest in *constructivism* emerges from a background in elementary and junior high school teaching. Like all teachers I have a strong desire to understand how to help students have more successful and enjoyable experiences in learning. And by successful and enjoyable experiences in science, I mean that they learn how deeply satisfying it is to understand and grasp a concept thoroughly, not just for examinations that they must take, but that their experience of science learning is one that gives them continuing interest in the field, makes them feel that they are competent learners, and, when they do not understand at first, they may ask questions that guide instructors to explain what they are having difficulty with. The truth is that for many students, as they move from the elementary program, science learning is not always an enjoyable experience. And so many students turn away from science learning at the earliest opportunity. There is a poem, by Walt Whitman that beautifully expresses the ennui that students may feel. I have used it in the beginning of my book, *What Children Bring to Light: A Constructivist Perspective on Children's Learning in Science* (1994):

When I heard the learn'd astronomer,
When the proofs, the figures were ranged in columns before me,
When I sitting, heard the astronomer where he lectured with
much applause in the lecture room,
How soon unaccountable I became tired and sick,
Till rising and gliding out I wander'd off by myself,
In the mystical moist night-air, and from time to time,
Look'd up in perfect silence at the stars.

Walt Whitman (1965, p. 86)

Walt Whitman's poem exemplifies a dilemma and a concern for science educators. Here is a student, attracted to a lecture, interested in and wanting to know about astronomy, yet when confronted with the instructor's systematic presentation, "the proofs, the figures," he becomes "unaccountably tired." He is sickened and leaves. And in this leaving we feel the learner's profound sense of relief. For some science educators, though, this student's experience is not counted as valid. Isaac Asimov, one of the greatest popularizers of science, argues that in this poem, Walt Whitman is "talking through his hat, but the poor old soul didn't know any better" (1985, p. 169). In Asimov's view, Whitman ignores the beauty and sense of wonder that can be gained through the study of science, suggesting that those who cannot stomach the presentation are missing out on the true splendor and wonder to be gained in a study of the universe. In his view, an accumulation of factual knowledge in science is the best way to attain an appreciation of the amazing patterns and beauty in the universe. According to Asimov, "the poor old poet never knew what a stultified and limited beauty he observed when he looked up in perfect silence at the stars" (p. 169).

I believe that Whitman makes, through this poem, an important comment that needs attention. For, if we carefully listen to this person's experience, it may become a window, enabling us to become more wide-awake to the learner's experience, understand how it is that aspects of the nature of the process of this student's education in science have turned him away. To understand students' difficulties and frustrations in learning science, we must understand how our own assumptions about learning science may cause problems for students.

Something very different happens when we learn science as compared to other school subjects that sometimes cause students to disconnect at the secondary level. This has become of great concern to me and is the foundation of my research program. I have become committed to research work that helps students realize that scientific

concepts can be within their grasp, work that might encourage students to persist and delight in learning science. In the late 1980s a rich literature emerged in the area of learners' ideas in science. This literature emphasized the ideas that students hold about science phenomena and about learning science. Much of it was built upon some of the original research and thinking of Piaget, one of the first to consider learners' conceptions of phenomena.

Most of this work examines the ideas that children have about the physical world (Piaget 1929, 1974a, 1974b). Piaget interviewed children about their views concerning phenomena. However, most of these interviews were in isolated clinical settings, not naturalistic settings, the places where learning took place. I found this to be a great lack in the methodology of the literature and began to build a research program that would expand the methods used to conduct research on children's learning to include observations and interviews with students *in action* in classrooms in order to form rich, qualitative analyses of learning about phenomena. As a former elementary and junior high school teacher, I was interested to know why, some children grasp ideas quickly and joyfully, while others may struggle and become discouraged when learning science.

I began to work with children to study not only the ideas that they hold, but also how it is that they learn, because there is something different and more challenging about learning science. I was looking for something more than just the documentation of ideas. I was looking for features of the learning experience that move children to real engagement with science in school and for factors that influence the ways that learners put ideas together to achieve not only success in understanding, but the real enjoyment they should be experiencing in learning.

When we teach science, we are asking learners to accept initiation into a particular way of seeing and explaining the world and sometimes to step around their own personal ideas about phenomena and accept the world of publicly accepted scientific ideas. In school science learning the child not only develops an understanding of ideas about the natural world, but conceptions of the nature of knowledge in science. We might call these discipline-referenced ideas about learning. The child also has a set of ideas about his or her own learning – a preference for a particular kind of learning, for examples or ideas about how learning best takes place. I have discovered that a profile of learning must also

include sets of self-referenced beliefs – ideas about self as science learner (Shapiro, 1989, 1990, 1992, 1994a, 1994b, 2006).

Of course science is not the only form of knowing. There is artistic knowing, for example, verified by emotion and feeling. There is spiritual/religious knowing. This knowledge is verified by revelation and sometimes dogma. And there is scientific knowing. This knowing is verified by evidence, logical argument, and observation. We need to help the learner value all of the kinds of knowing that he or she can experience as a human being. But sometimes the kind of knowing we come to in science is not conveyed as one of the ways of knowing, but the only way that the world is viewed. Without helping the learner to value the unique contribution of science ways of knowing, the learner can come to devalue their own ideas and feelings and may learn, as a result of school science, a conception of themselves as science learners that can develop, tragically, into a conception of self as science learner that ranges from a sense of great competence to one of despair or even total failure.

This research integrates two bodies of theory: theories of self and self-referencing, and socio-cognitive views of knowledge construction. Many researchers are beginning to build models of learning that integrate the personal and the social with cognitive, motivational, affective, and classroom context components, and more recently, physical features and aspects of learning. These studies recognize that student beliefs, perspectives, and self-judgements can profoundly influence learning, by influencing feelings, thinking, and achievement. The research present here has significant implications for professional development (Shapiro, 2002, 2004, 2006, 2010) and for other fields of inquiry such as Environmental education (Shapiro, 2012).

Understanding Constructivism

I know that when many educators begin to consider what is meant by *constructivism*, they see in it, an important referent point from which to discuss significant features of their practice. To begin to further clarify what a constructivist perspective means, I'd like to start by sharing a story. The purpose is to begin a consideration of what constructivism looks like in practice. The story example will show the important ways that teaching with a constructivist perspective involves the interplay between learner ideas, teaching, and actually researching learners' ideas in practice.

One cold Sunday afternoon, just before spring, I went to Fish Creek Park in Calgary to join a city park sponsored nature walk titled, "Signs of Spring." Congregating around the designated meeting place, participants smiled at one another. We chatted and observed our surroundings as we waited. We were a group of 12: six mid-aged adults, four children, and two seniors. Our naturalist arrived, clipboard in hand and greeted us warmly. She introduced herself as Katy, and explained that we would begin our tour by walking up to the river's edge. She turned and, setting a quick pace, beckoned to us to follow. As we brushed past a large leafless tree, one of the children in the group pointed high up and while still walking, asked, *"Whose nest is that?"* Katy turned and looked to where the child was pointing. *"Well,"* she said, and stopped. She spoke directly to the child. *"If I were to just tell you the name of the nest, we'd just keep going by and, you wouldn't learn anything about it, would you?"* She paused. *"Let's gather around. What can we say about this nest? What kind of bird do you think would build this nest?"* One of the adults remarked with a laugh, *"It would have to be a fairly big bird! Those sticks are big."* *"And messy,"* said another. *"Yes,"* remarked Katy. *"What else do you notice?"* We paused. *"Look over here,"* she directed. We looked around at the back of the nest to observe a very large opening. *"That must be the nest of a very big bird,"* an older gentleman remarked, *"to be able to get through that hole."* *"Look!"* shouted one of the children, and our attention was drawn to a large magpie sitting impatiently in the next tree. He held a large stick in his beak. *"A magpie!"* she exclaimed. *"It's waiting to put more sticks in the nest!"* *"That's exactly right,"* nodded Katy. *"This is the nest of a magpie. And we have learned something about their nest and who made it, haven't we? Now let's go down to the river to see some of what is returning for spring for us there."* We followed Katy just a few meters to the water's edge and noticed several different birds in the area, birds in the air and large birds on the water. *"River gulls,"* remarked one adult. *"Actually they are seagulls,"* said Katy, *"even though they are on the river, they are all more accurately called seagulls. Take a look at the larger birds on the river over there."* She pointed. *"Canada Geese,"* remarked one of the adults. We watched them for a few moments. *"That's right,"* said Katy, *"this group arrived just this morning and are feeding."* *"How can you*

tell the male from the female?" asked another adult. "Well, now that is an interesting question," smiled Katy. "You actually cannot tell from the markings. The male and female are the same. We cannot pick up the birds to check them anatomically. But there are some behaviors we can observe that will help us. Let's watch them carefully." And all 12 of us crouched quietly along the river's edge to observe. *"Well, I think that big one closest to us is a male,"* said one of the little boys. *"And why do you think so?"* asked Katy. *"Well, 'cause the men are always bigger,"* he responded. The adults in the group chuckled. *"You know that is a good idea, but you know that is not always the case in the animal world,"* Katy said. *"Sometimes the females are bigger and that is often true in the bird world. We may be able to observe some behaviors, however."* She put her binoculars up to her eyes. *"Look at that one near us,"* said one of the adults. *"It seems to be watching us, bobbing up and down. Almost as if to threaten us."* One of the parents added, *"It has placed itself in between us and the birds that are feeding. Seems like protective behavior."* Katy nodded, *"Yes, that is very likely the male, that is typical behavior that I have seen in the geese."* *"Have you watched geese a long time?"* asked a child. *"Yes, for many years,"* she responded. *"I think you have discovered the secret of the geese!"*

In the story of Katy's work with this group, we see a very good example of constructivist teaching and learning. I would like to use the example to identify some of its key features. We can see that Katy does not simply give information – she is not merely giving the group answers to their questions. She *skillfully guides* participants to construct their own meanings by encouraging them to engage in the process of observation and discussion and to consider what she has learned. Participants make observations. They give expression to their ideas and hear the ideas of others. They began to integrate the new ideas that Katy contributes into their already existing knowledge frameworks. Katy introduced participants to several new ideas to add to these frameworks. In doing so, she taught us so much more than the answers to our questions. She engaged us in the process of learning with others. And in the end, the enjoyment of everyone at the park was palpable. There was not one person in the group who did not express extreme disappointment when the teaching came to an end. I was so taken with Katy's work with us that I asked if I could speak with her about her philosophy and approach after the field trip. It did not surprise me that Katy had never heard the

term, constructivism. What she did know about was what she called "*some of the principles of interpretation*" from her education as a park naturalist, and, she said, "*my own realization that when people get a chance to engage with the environment in the same ways that naturalists do, they enjoy it more.*" Katy was helping participants learn something about how to learn.

Science educators are faced with a dilemma. We see the importance of taking account of the learner's perspectives in teaching and learning, but teachers may also find themselves torn, valuing both objectivist and constructivist positions. We know the scientist's perspective and want the student to grasp it. Sometimes we want them to simply accept scientific views as true. At the same time, we want to understand the student's ways of organizing thinking about ideas and see it as a vital aspect of our work to help the learner to develop ways of thinking about phenomena. Yet, we are faced with a perceived need for efficiency. It is faster to assert the correctness of one viewpoint, usually the scientific one, and the wrongness of the other, usually the student's. But what is the cost? What is lost? The approach of telling uses the familiar "*tabularasa*" metaphor – the idea that knowledge can be written on, transmitted, or transplanted to a person's mind, as if the mind were a blank slate to be filled. In fact, we know that information memorized only for a test is poorly retained and is rarely regarded as useful or satisfying knowledge from the student's point of view. Despite the fact that the "blank slate" view of the learner is not well regarded, it is still the perspective underlying practice seen most often in school settings. Look at what was gained in this story. We enabled deep experiences of learning. We learned what to look for, and to come to conclusions for ourselves. We looked intensely at the phenomena before we chose labels or made judgements. We experienced great joy in the experience of talking about our ideas and the opportunity to listen to and consider what other learners in the group had to contribute. Perhaps someone spoke up who had never contributed before. What a significant experience that would be! This does not mean that we should not, at times, tell students what it is that we want them to think about, or observe, or are hoping they will consider true. But through this story we learn to value and recognize that *learners have ideas of their own* that profoundly influence learning and they use these ideas as frameworks to integrate new knowledge. An educator working with constructivist values wants to know what learner ideas and questions are, how

students integrate new ideas with existing ones, and what kinds of learning opportunities facilitate their efforts to do so.

Constructivism is a philosophical position on the nature of knowledge that focuses on the importance of the interplay between what the learner brings to the experience of learning and what it is that the individual is being asked to learn (Driver, Guesne, & Thiebergen, 1985; von Glasersfeld, 1986; Kelly, 1955; Shapiro, 1994a, 1994b). Traditional or objectivist orientations to knowledge are contrasted with constructivist perspectives in that they focus on the outcomes of learning only. A focus on the outcomes of learning may seem a worthy goal, but when it is the only goal, its interest is, not in what students learned, only in how they performed on a test, or in how one population compares to another. There is no real concern for, or way of valuing personal growth, progress, difficulties or successes of individual students. A completely objectivist emphasis on outcomes disembodies learning from learners. Constructivist perspectives, in contrast, focus on the interplay between the ideas and thinking of the learner and the subject matter – learners are encouraged to grasp ideas. In the development of science concepts, educators become more concerned with the ways that students *are engaging in making learning their own* and how they might more effectively help them consider scientific ways of thinking about phenomena. David Fisher (1991) provides a very useful framework that compares fundamental ideas in the objectivist and constructivist perspectives.

Figure 1. Contrasting objectivist and constructivist epistemologies.

Objectivist (Traditional)	Constructivist Epistemology
1. REALITY exists "out there" independent of the observer.	1. REALITIES are constructed as experience = the relationship between the observer and the observed.
2. ABSOLUTE TRUTH about reality is available to us.	2. TRUTHS are relative to the frame of reference of the observing systems.
3. KNOWLEDGE consists of verifiable facts about the worlds, people, etc.	3. KNOWLEDGE is constructed as a product of social and individual assumptions and is developed through language.

4. MEANING resides externally in symbols and combinations of symbols.	4. MEANING is constructed both internally and socially as processes of interpretation.
5. PROCESS OF KNOWING is through categorization and conceptualization.	5. PROCESS OF KNOWING is an ongoing process of interpreting present events from within the observer's interpretive framework.
6. SCIENCE is a method for discovering truth and reality.	6. SCIENCE is an interpretive process through which observers test consensually derived distinctions for their utility.
7. CAUSALITY is linear. That is, under specifiable conditions, if X occurs and Y follows, then X may be said to be the cause of Y.	7. RECURSIVITY. Each element in a system provides conditions of operation for other elements in the system.
8. PERSON. Behavior is fully determined and could be explained if only we understood all relations between all variables.	8. PERSON. Behavior is indeterminate. People have agency and have choice, constrained by recursive relations between self and the environment.

Fisher (1991, p. 15)

Constructivist thinking applied to education has been of great interest to educators, who often comment on the ways it helps in the renewing of their thinking. Its focus is on learning not only as rational and logical, but also an emotional affair. The literature on constructivism has been rampant with misinterpretation and misunderstanding. Sometimes the phrase is used to sell textbooks or it may be used as the basis for research articles without explaining what is meant by the term. As a catchword in education, constructivism has been used in such a wide variety of ways that there has been much confusion regarding its meaning and domains of interest. It has been referred to as a philosophical position, an epistemology, a form of research, a learning theory, and even a model of learning. The term itself contains an important root metaphor, which is at the heart of the constructivist viewpoint: Knowledge is *constructed*. It is constructed by individuals and

by groups. The constructivist paradigm departs from traditional approaches in its view of such ideas as the nature of reality and knowledge, the purposes of knowing, the role of the learner and of learning, the role of the teacher and of teaching, and the organization of the classroom and of the curriculum and its evaluation. Because it does so, it also is a way of challenging the nature of knowledge to be acquired by learners and the ways in which it is best acquired.

In an analysis of constructivist theories of learning, Swift (1984) argued that it is useful to consider a continuum of thought within the constructivist tradition. He analyzed differences in constructivist stances taken by researchers in terms of the degree of individuals' active participation in knowledge construction. In this analysis, the Piagetian perspective occupies a conservative position on a proposed conservative-active classification continuum. Those who place greater emphasis on consideration of learners in general and features of social participation in knowledge construction are placed on the conservative end of the continuum. Constructivists who focus on the development of individual or personal meanings are placed on the radical end of the continuum.

In the search for a theoretical framework for studying individual children learning in classrooms, I discovered George Kelly's (1955) evolving personal construct theory. Its primary emphasis is the importance of the individual's interpretation of the events of the world, and is used in a variety of social science settings in which the individual's meaning making behavior is of interest. Kelly advocated use of research attitude and suggested tools to engage individuals in conversation regarding their interpretations of events. I have used some of the tools he suggested and developed others to study how individual children's ideas change and grow as they interpret and construe events in their learning environment.

Kelly (1963, 1969a, 1969b, 1970) explicitly rejected a view of change in persons in terms of "push theories based on stimuli" or "pull the theories based on needs." He envisaged change in persons not as a result of external forces bearing upon the person, but as a result of the ways the person reconstrues situations. Kelly's approach not only takes the individual into account but asks the individual about his or her ideas concerning that meaning of experience. If one is to change, Kelly suggested, one must first become aware of the ways one is construing of the world. Then, one must decide that it is worthwhile to make the effort to change.

When I first became interested in the constructivist philosophical position on knowledge, I recognized its remarkable potential for dealing with children and their thinking in ways that I believed in. But because the use of the term causes so many different ideas about its meaning, I originally chose not use it and to focus my research on children's ideas and meaning construction. The challenge and focus of the research became, primarily, to develop case study descriptions that would demonstrate characterization of the interweaving of individual meaning making approaches and constructs about learning with the outcomes of learning, in an effort to help us see the learner in a different way.

One of the most profound insights for me has been the observation of the persistence over time of these approaches and the affirmation of George Kelly's assertion that not only do children come into the classroom with prior ideas about the phenomena we are teaching them about, but that individuals are, even before coming to us in the classroom, deeply engaged in their own efforts to make sense of the world. Some of these approaches are very similar, but for each individual, there is uniqueness – and we must recognize that we ask them to interact with ideas in a particular way in the classroom. In this work there is a very important focus on the nature of personal meaning making, not a focus on individualized instruction, but on the strategies and approaches used to construct meaning.

The Need for New Research Approaches in Science Education

My program of research then, is an attempt to contribute new methods to study and investigate meaning construction in science education, and thereby, new insights. I developed a research methodology and framework to include interviews with students and observations of learners in action to build ways to provide in-depth and situated qualitative analysis of learning experiences.

The creation of qualitative profiles of learners' personal frameworks for learning gave an opportunity to explore relationships among these features, the children's success in acquiring ideas and thought, and the ways children learn in collaboration with others in school settings. I have also maintained a longitudinal component in this work, in that I have been able to maintain contact with the students to see how their ideas in science and ideas about themselves as learners have developed and changed over time. And through the work I have attempted to

develop some ways to help teachers to think about what they are doing to assist learners to construct meaning in classroom settings.

*What Children Bring To Light: A Constructivist Perspective
On Children's Learning in Science*

My book, *What children bring to light: A constructivist perspective on children's learning in science*, presents this research to educators and curriculum developers. The research has been an attempt to characterize individuals' meaning making goals and processes to try to understand not only what the learner is trying to accomplish when they are learning science in terms of product outcomes, but also how these are related to their personal constructs of science, that is, about what it means to learn science. There are entire constellations of features that influence what the learner will pay attention to when learning about a topic in science.

To illustrate these, I selected six very different children for the study, three boys and three girls. Two of the children selected were considered by their teacher and peers to be high to average achieving and very well established socially and emotionally. Two students were considered by teachers and peers to be achieving at an average level and well established socially and emotionally. Two of the children were having serious difficulties with their school program and were having difficulties socially and emotionally in the classroom setting. All of the children were in the same grade five classroom a middle-class neighbourhood in a mid-sized western Canadian city, studying the topic, light. I'd like to present some material from my research tapes that show some of the children in the study. I will focus on one of the students to illustrate the approach and some of the findings of the work. Her name is Donnie.

Light is a topic typically presented early in the elementary school curriculum. "Light and shadows" is a unit commonly presented when children are 7 to 8 years old. The mechanism of vision is often studied in conjunction with the study of human body systems when students are 9-10 years old. Such concepts as light movement in straight lines, the nature of light reflection, refraction, light travel through various media, the light spectrum, and color mixing are typically studied in limited detail by students in Grade 5 or 6 (ages 10-12 years old). Light is studied in greater depth in the secondary school Physics program, but not all students will select Physics as a topic of study.

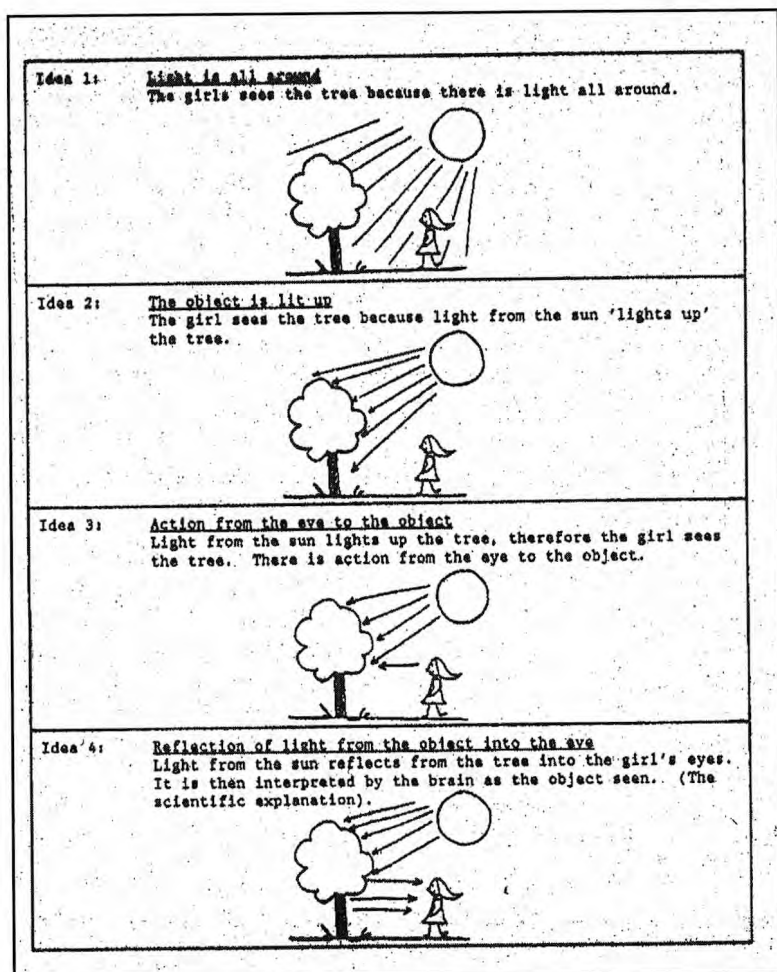


Figure 2. Shapiro, 1994, p. 26.

One of the most interesting aspects of light study is investigating how we see objects. In Figure 2, we see a chart showing the typical responses that children give when asked to answer the question, how does light help the girl to see the tree?

Here we see more prominent views about connections between the light source, the object, and vision. The most prominent idea at the grade five level, the level of my research, is idea number 3. Most students hold

the idea that visible rays of light are reflected not from the source object to the eye (the scientific perspective) but through the person's act of looking at the object. This idea is foundational to the development of other light concepts, such as refraction. What has been of great insight in this research is the finding that most teachers are not aware of the fundamental difficulty that students have in understanding how objects are seen and therefore, why the study of refraction poses such a great challenge for them.

Donnie was one of the high achieving students in the study. She struck me, during my initial settling in time in the classroom, with her incredible enthusiasm for learning and her serious efforts to put ideas together to make sense of what was being presented – she would often mime or mimic the teacher's activities in an effort to follow along with him. What follows is an edited portion from a research tape. This segment documents a part of the children's work that took place some time after the children were given some instruction in a unit on Light in the grade five classroom. They had had several experiences with light beams directed through beakers of water. Light boxes were used as well.

Throughout the unit, Donnie often spoke of the feeling of not quite having all of the information needed to respond during science class. Her statements showed a serious interest and concern with *understanding*, which has a special meaning for her. She believed that all of the other students understood the material when she did not. In fact, this was not true. Her comments about her previous experiences with science echo this sentiment. *"When I was younger I always knew what she [the teacher] wanted, but this year, I don't really understand some things."* In earlier science experiences children are encouraged to develop *sense awareness*, to trust the senses as validating criteria for making observations and drawing conclusions. This focus on awareness and use of the senses was predominant in the early grades, but this year Donnie was being asked to accept on faith insights and ideas that have been put forward in centuries of accumulated and corroborated scientific endeavor. Such insights are very often counter-intuitive or, cannot be personally verified. Students may not grasp ideas when they do not *believe* the ideas being presented. Students have not participated in the process of knowledge creation, therefore, may not understand how ideas are verified or rejected in science. Waterman (1982) studied the epistemological bases of college students' understanding of science and found that even at the university level, a similar lack of belief in ideas presented was due to a lack of understanding by students of the nature

and structure of scientific knowledge. She found that this affected students' abilities to grasp new ideas in science courses.

Donnie often expressed awareness when she did not understand. She readily reflected on her own thinking processes in coming to know. During the first lesson in the program, we discussed the presentation of ideas that were in conflict with her own beliefs about the nature of light.

The Introduction to the Light Unit

The class introduction to the light unit began with a question posed by teacher, Mr. Ryan: "*Who can tell me how we see things?*" Material from the videotape Donnie and I viewed together is indicated as *Video* and the subsequent discussion with Donnie is indicated as *Conversation*.

Video

Leon: *We see things upside down? Like we really see the things upside down but our brain turns them right up again.*

Mr. Ryan: *Okay, that's good. But how do we get the image in the first place?*

Leslie: *With our eyes.*

Mr. Ryan: *Good. Good. Any other ideas about how we see things?*

Alana: *Light.*

Mr. Ryan: *Light. How does that happen?*

Alana: *In the dark we can't see things. You need light to see where things are.*

Mr. Ryan: *In the dark we can't see things. You need light to see where things are. Oh, good, good. Any other ideas?*

Diane: *In the dark you need more light to see better.*

Mr. Ryan summarized the points that the students made about how objects are seen, then asked:

Video

Mr. Ryan: *Can anyone tell me why we can't see things in the dark?*

Donnie: *Because there isn't enough light.*

Prior to the lessons, Mr. Ryan and I had informally discussed the research literature on alternative frameworks concerning the nature of light and the difficulty that students appear to have with certain concepts, such as the idea that light travels, that some objects reflect light rather than produce it, and that light must enter the eye to enable

us to see. The teacher's edition of the materials which Mr. Ryan was using suggested presenting this concept initially through discussion, by "eliciting from the student that the current way of explaining light and seeing suggests that light is something which travels from the thing we see to our eyes." Though he tried hard, Mr. Ryan was not able to elicit this statement from the students.

Mr. Ryan: *How many of you think that we see things because my eyes are sending out to, say, the reason that I am seeing Martin is because something is being sent out to Martin that is, my eyes are doing all of the work? (Silence. No hands are raised.) Nobody? Okay. That's good because a lot of people thought initially that that's how we saw things, that it was our eyes that were responsible for everything. It took a long time for people to figure out that light had a part in it and that it was the light that was coming from Martin into my eyes that allowed me to see him. Not something coming from my eyes to him, but light coming from him into my eyes – or whatever it is that you're looking at.*

Donnie and I reviewed the videotape outside of class during our interview sessions. Donnie revealed a confusion she was not able to express in class:

Conversation

Ms. Shapiro: *So, you agreed with the statement that Mr. Ryan made, that the reason I see Martin is because light is coming from him into my eyes.*

Donnie: *No, uh-huh. No. I didn't agree with that. It doesn't make sense.*

Ms. Shapiro: *You say it doesn't make sense.*

Donnie: *It doesn't make sense ... because people don't make light. It's electricity that makes light and it's the sun that makes light.*

Ms. Shapiro: *Any other examples?*

Donnie: *Well, water helps to make electricity, so that, you could say that makes light.*

Ms. Shapiro: *So I understand that you are saying that it's not the light from me that you see. It's the light reflecting off of me.*

Donnie: *Well, the sun shines on you and I can see you because, of the sun, it's not anything else. It's not, you, it's the sun.*

Ms. Shapiro: *It's not me, it's the sun. So, is the sun reflecting off of me?*
 Donnie: *No. No, the sun's not reflecting off of you, it's shining on you, but it's not reflecting off of you (her voice trails off to a whisper).*

Donnie has explained that she disagreed with the idea presented in class that light is reflecting from a person and is then reflected into the eyes of the observer. Her statements conflicted with the explanation she gave to me during our discussion before the lesson. Here Donnie gave the correct scientific explanation for the interaction of vision, light, and objects. She stated that she remembered learning because as she recalled, "*a teacher said that.*" In Mr. Ryan's class presentation she does not apply the idea which the previous teacher gave her, because as she remarked the example given "*does not make sense*" to her. Donnie was able to give the correct response on the survey and in our interview, but she did not appear to believe the idea completely, nor was she able to give the scientifically correct answer on the survey or in our pre-instruction interview. Donnie also was not able to use the idea. The complexity of the dilemma of understanding versus believing was noted in another sequence in class when she switched back to the correct view. Here, as Donnie and I talk about a video sequence, she agreed with an idea presented by another student in the class who provided an explanation as to why we are able to see the moon from the earth at night.

Video

Rena: *Darkness must be a place where there isn't any light.*
 Donnie: *Rena said that darkness must be a place where there isn't any light. I thought that was true. I was going to say the same thing.*
 Mr. Ryan: *Yeah. I'd have to agree with that. Darkness is a place without light. Can anyone tell me what light is?*
 Marvin: *The sun is light.*
 Kitty: *Light is something that shines.*
 Melody: *The lights around us are bright.*
 Donnie: *The streetlights are light at night.*
 Carey: *You can get light from a campfire.*
 Mark: *You can get light from stars.*
 Marvin: *Light can come from electricity. Light can come from the moon. It shines at night.*
 Mr. Ryan: *Oh, no. I see Michael shaking his head with that one.*

- Donnie: *Here is what Michael said. I agree with him. He said that the moon is like a mirror.*
- Michael: *Like, the sun reflects its light to the moon – it comes from the sun. The moon is like a mirror.*
- Mr. Ryan: *Oh, good, good. Michael said the moon is like a mirror and it reflects the light that comes from the sun so that we can see it. Good point.*

Conversation

- Ms. Shapiro: *So you are saying that you agree with that.*
- Donnie: *Yeah. I saw that lots of times on, well, (laughs) on Sesame Street. Like it's really for babies, but I like to watch it. (Laughs.) That's probably where Michael saw it, too. The rayses (she uses her hands to demonstrate on the table) from the sun reflect on the moon.*
- Ms. Shapiro: *I see. He said that light travels from the thing to our eyes and that's why we see it?*
- Donnie: *Hmm. (Pauses.) Well, the light reflects on the thing and it bounces off to us so we can see it, like he said.*

Donnie has once again applied the correct idea supported by the Sesame Street lesson. Yet it was quite clear from our continuing discussion that she did not have a firm grasp of the *presented* idea, as she was not able to consistently apply the idea correctly. She wanted to give the correct idea in class, but could not deny what truly did not make sense to her. This became much clearer when Donnie expressed her views on the phenomenon of *refraction* studied later in the unit by the class.

Mark's Revolutionary Idea

The next day, Mr. Ryan told me that he was going to skip the part of the activity that dealt with light passing through liquids of different density. He said that he found in the past that this lesson was not as valuable to the development of ideas in the unit. At the end of the activity, to solve the problem, students would be asked to pull together several of the ideas that had been taught in the unit to date. They were to provide an explanation for the broken appearance of a pencil in a beaker of water. At the end of this activity only one student in the class, Mark, verbally responded with the "correct" answer, and this happened only during the final minutes of class discussion. Donnie was trying particularly hard to

respond to the question in class, and listened carefully to the comments made by the other children.

Worksheet instructions asked students to complete activities, make observations, then provide a statement explaining their observations. The final activity asked students to place a pencil in a beaker of water, and then provide an explanation for the pencil's bent appearance. When Donnie and I reviewed the videotape of the lesson, she watched intently, and then asked, "*Can we go over the discussion part of the lesson? I want to hear it again because I wanted to answer some stuff Mr. Ryan was asking and I wasn't sure about a couple of things.*" We reviewed the videotape and I asked which activity Donnie found the most interesting.

Conversation

Donnie: *The saucer is the one I preferred. It was fun. You got to see something that was really interesting happen. And then you open your eyes and you think it's magic and, but it's not. It's just something that's really tricky and fun to find out. I also like that activity that we did when we were predicting [Activity 2]. That was the most interesting and fun. I don't know, I might have found it interesting because I got them all right (laughs) but I thought that it was a lot of fun to make that decision, like about how the light would go. Here, (watching video) this is where I'm going to start telling what the answer is. I was just going down to try to explain my idea there. (Donnie was called up to the overhead to explain her idea.) What happened was that you took a saucer and you put a coin in it and then you fill it up with water, and you have to be down on your knees so before you put the water in until you can't see anything but the edge of the saucer and then when you fill it up with water then you can see the coin. I tried to answer in the discussion, but my answer wasn't quite right.*

Ms. Shapiro: *You say your answer wasn't quite right here. I'm not sure what you mean.*

Donnie: *No. Sometimes I don't think that, well, that I have some trouble with science. Mostly the last unit that we did. Like I told you what we had to do was take a tiny light bulb and we had wire and we had to figure out ways how to light this bulb and we had different activities to do and actually it was quite fun but in other ways it was*

hard to understand because I didn't know how they could take a little piece of wire and attach it to a battery and then put the light bulb on and the battery and make it light. That, that's hard to understand.

Ms. Shapiro: *So you found it hard to do?*

Donnie: *No, it's kind of hard to understand how it all worked!*

Ms. Shapiro: *It seems as though you were finding the unit fun, but a bit difficult to understand.*

Donnie: *I'm finding it really interesting. Some of the activities are hard though. Sometimes I feel like I don't have it all, all of the information to tell what is happening.*

Putting Ideas Together

As we reviewed the tape, Donnie related her frustrated effort to provide an explanation for the broken appearance of the pencil in the beaker. She described how she believed listening to the other students in the class helped her to add to and develop her own ideas, to almost "get all of the information."

Conversation

Donnie: *That's Carey talking now.*

Ms. Shapiro: *She seems to be saying that there is only air in the top part of the glass and that the water in the bottom is what makes the pencil look bigger. Did you agree with that?*

Donnie: *Well, yeah, I took a little bit of that information too. I took some other people's information and put it into mine, but I still didn't quite get all of what I needed. This is where I'm going to answer.*

Video

Mr. Ryan: *Can anyone think of an explanation using the words bending, light, and refraction?*

Donnie: *At that point I wasn't quite sure, how the ... how it happened. Like, I didn't know that there was light in that part.*

Conversation

Ms. Shapiro: *He asked, "Can anyone think of an explanation using the words light."*

Donnie: *Bending and refraction.*

Ms. Shapiro: *That would have given a clue, I guess, about what was the right answer.*

Donnie: *Yeah, but it just didn't make any sense that there was light in there and that that's how it made it bigger. I'm gonna say something here.*

Donnie commented that she felt that she had some of the right idea, but that she believed that the idea that understanding the behavior of *light* was the key to the explanation and was something that she had not put together. She was able to tell me after the lesson that light was the key, to the mystery, but it did not occur to her prior to the lesson.

Video

Mr. Ryan: *What is the water doing to the pencil?*

Conversation

Ms. Shapiro: *Right here it looks as if you were hit with a bolt of lightning. Right there. What happened there?*

Donnie: *I think that I just realized an answer that I wanted to give. Just, let's watch it a second, okay? Leanne is talking about the shadow that the pencil makes in the beaker, but that's not it, the answer.*

Video

Mr. Ryan: *Do you see a shadow? When I took the pencil out, was it the same size as when it went in? Donnie?*

Donnie: *Well, the water and the glass makes it bend...*

Mr. Ryan: *Makes it bend?*

Donnie: *Makes the pencil bend. Makes it look bigger.*

Mr. Ryan: *I'm not sure that I understand what you're saying. If I put the pencil in the water and I look at it, it looks like my pencil's broken. When I take it out it isn't broken any more. Did it bend and fix itself?*

Class: *No!*

Mr. Ryan: *(Emphatically) Okay, what made it look like it was broken?*

Donnie: *The water.*

Mr. Ryan: *Okay. (In a louder voice) But what did the water do to make it look like it was broken?*

Conversation

Ms. Shapiro: *You look very intense here. What was going on for you here?*

Donnie: *Well, I didn't know what the answer was. But I wanted to know. So I was just looking here to see what Mr. Ryan had on the overhead, so all I am doing here is copying down what he had up there. The right answer.*

Video

Natalie: *I think that it is the roundness of the glass.*

Conversation

Ms. Shapiro: *She is saying that it is the roundness of the glass?*

Donnie: *Yeah, later on, Jim says that it acts like a magnifying glass. I also took his information and put it into mine, and it made better what I had, what I was thinking, but I still didn't quite get all of it.*

Ms. Shapiro: *So it was Jim's information that you put together with yours?*

Donnie: *Only I had a little bit more than he had. I just took the magnifying glass part.*

Ms. Shapiro: *So you are saying that it acts like a magnifying glass?*

Donnie: *Yes.*

Ms. Shapiro: *So the magnifying glass makes it look bigger.*

Donnie: *Well, (pauses) a magnifying glass is like two glasses together. It makes things look bigger.*

Ms. Shapiro: *How do the glasses do that?*

Donnie: *(Laughs) I don't know!*

This conversation with Donnie took place one day after she had heard Mark's correct explanation and had heard Mr. Ryan reiterate it. In fact, Donnie and the other students in class were required to copy down the correct explanation, as Mr. Ryan had written it on the overhead projector. Although she has stated on several previous occasions in discussion with me that light is reflected from objects, in other conversations, she stated that it is only reflected from some objects. Because she did not appear to have completely grasped the idea that light reflects from *all* objects, she did not use it in combination with the idea that light is bent when it passes through the beaker. The idea, that light is reflected from objects, had been presented repeatedly, and was the main concept in previous occasions in discussion with me. However, in other conversations, she had stated that it is only reflected from some

objects. Because she did not appear to have completely grasped the idea that light reflects from all objects, she did not use it in combination with the idea that light is bent when it passes through the beaker, even though the idea had been presented repeatedly, and was the main concept presented in the previous lesson, "Bend that Beam." In terms of a construct theory explanation, her thinking and explanation reflected the idea that was still making the most sense to her, why would she want to change?

Donnie's earnestness and persistence was evident in the lesson as she *repeatedly* tried to give her explanation in response to the question, "Why does the pencil appear to look larger" even while Mr. Ryan indicated to her that she was not giving the correct response? Donnie persisted in the discussion, and at one point, Mr. Ryan told her that she had "some" of the idea, but not all of the idea. I asked her about this as we watched the videotape.

Conversation

Ms. Shapiro: *When Mr. Ryan told you that you have some of the idea, how did you feel about that, encouraged?*

Donnie: *No. Just as normal as I would feel if I got something wrong. He's saying that and I'm gonna say something after him, cause I'm still talking here, so I'm not quite finished.*

Ms. Shapiro: *He said that you had part of it. But I think you're saying that you somehow count that as being wrong.*

Donnie: *Well, you know, I'm sort of right and sort of wrong, but I wanted to get it! (Laughs) My answers are never right in science.*

Ms. Shapiro: *You're always wrong in science?*

Donnie: *Well, it's usually that I'm halfway right, and in other ways I am sort of right.*

Ms. Shapiro: *So you know that you have some of the basic ideas?*

Donnie: *Yeah, but there are some that aren't there. There are some people who seem to always get it all of the time. Like Katy, Annie, and Carey sometimes, or Mark. Last year I got most of the answers. This year it's just a little bit hard. I don't know why. My explanation for this one, I think it's this one here, Mr. Ryan said that I was on the right track here. He said that I had a really good answer for it, but here Mark had a better understanding of it. He got all of the information. I only got half of it.*

- Ms. Shapiro: *What was it that Mark got that you didn't?*
Donnie: *Okay. I'm not good at explaining things, but (laughs) well, what happened is that I thought that the water and the glass did it.*
- Ms. Shapiro: *The water and the glass is what you said before.*
Donnie: *Yeah! Because I didn't think of the light. I don't know why I didn't think of the light like Mark did (laughs). I don't know why I didn't!*
- Ms. Shapiro: *Hmm. Well, the glass is something that you can see through...*
Donnie: *Yeah, you can see through it. Now I said that it acted like a magnifying glass. It was almost [inaudible] like this. I said that it acted like a magnifying glass, and it acted like a magnifying glass because the water I said was a liquid, and I said that the glass is like a magnifying glass, and the beaker well, the glass and the liquid together would probably make it look bigger, but I said it, the pencil, looked bent like this or something, made it bend, like, but I didn't mean that it was bent, just that it looked bent.*
- Ms. Shapiro: *I see. You know, it sounded to me like you meant that it did bend it, too.*
Donnie: *You know, that threw me right off. I had no idea, well, what was going on, what to say there.*
- Ms. Shapiro: *What threw you right off?*
Donnie: *That it wasn't just the water. At this point I didn't have any idea that it had, that light was in it, was in the answer.*
- Ms. Shapiro: *Hmm. (pause)*
Donnie: *Because well, I didn't know what was happening here because of the light. Because you can see light. I just didn't have any idea that light had something to do with it. I was really surprised. I don't know how I could've come up with that idea. But I know what happens now. The light, it goes through the water and it hits the pencil, and the water and the light makes it look broken and how it does that is that the light shines into the water, you know and you can see it, the water, and then it goes right in and then it hits the pencil and then you see on the water line, and the ... you can make it go down, and it's supposed to be like that, (shows me a straight finger and points to the beaker), but it goes like that (crooks her*

finger and points to the beaker and the pencil). *I didn't explain that very well.*

Ms. Shapiro: *No, that was fine. How did you get the idea that light is the key?*

Donnie: *From what Mark said in class ... in the discussion.*

Ms. Shapiro: *So that gave you a clue to the idea. I see, so it makes sense to you now, that it's the light.*

Donnie: *No, not really. But Dean said that, and Mr. Ryan said that it was right.*

Donnie was able to tell me the key to understanding human vision. But despite the fact that she provided the scientific explanation for refraction, but she realized that she was not fully *understanding* the idea. She would be able to answer such a question correctly on a quiz, examination, or survey of ideas about light phenomena, but she herself stated that she did not have a real understanding of the refraction concept.

This attempt to provide a richly detailed example of an aspect of one student's learning experience highlights one of the major contributions of the research. It shows the child's efforts to learn as connected to personal and social factors, in addition to connection making within prior ideas structures. Figure 3 is presented to show important new views about the nature of the learner. At the heart of the diagram is the learning person. It is the learner, not the curriculum that is the centre of focus here. The ideas that the learner develops are based, *not only* on the ideas learners hold about the nature of phenomena, such as light, but are influenced by an entire constellation of features, not the least of which is the learner's views of self as science learner.

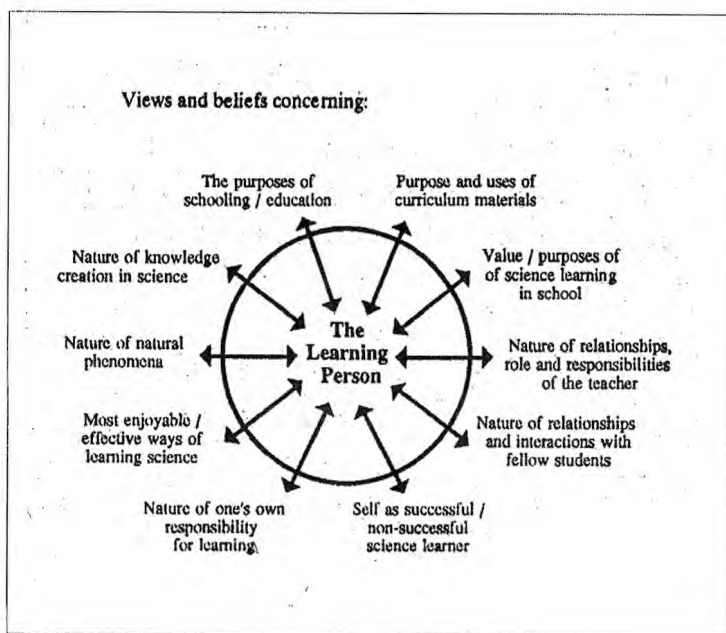


Figure 3. Developing the features of a Personal Orientation to Science Learning (Shapiro, 1994, p. 162)

Semiotics – Adding Understanding of the Messages of the Science Learning Environment

Another significant application of this research program is its effort to help educators become more aware of the messages and meanings of science that are embedded in the learning environments we create. *Semiotics* provides a useful framework to help analyze the messages of science learning environments, and has been a major focus of this work.

Semiotics is the study of signs and sign using behaviour through the use of words, patterns of speech, tone of voice, tempo, drawl, body motions, and gestures. Semiotics considers not only how social groups create meaning-making practices that are uniquely their own, it is concerned with the ways individuals make sense of practices within settings created by the larger group culture. Through its focus on signs

and symbols, semiotics is a form of inquiry that attempts to explore the set of meanings that constitute any act of communication. To begin a semiotic consideration of events, we must, as in the study of constructivism, awaken to the idea that reality is not disclosed directly, but is experienced through symbols and activities mediated by language and culture. The central questions of semiotics are questions of meaning, knowledge and knowing through the use of signs and sign systems. To semioticians, all cultural phenomena are essentially processes of producing and interpreting signs. In studies of the classroom, the semiotic perspective not only asks, "In what ways are teachers and students working together in the acquisition of knowledge?" but also, "How are the ways that teachers and students working together in learning communities representative of the values and activities of the larger culture?"

Here is an example of the way that I introduce semiotics to student teachers. On the first day of classes, I arrange the furniture in the classroom in a very traditional way. Our moveable worktables and chairs are placed in rows, separate from one another. Students sit individually or in pairs at the sides of the classroom. On the second day of class, students come into the room to find that the tables have been rearranged into hexagons or circles. I ask them to look at the arrangements with the question in mind, "How does the furniture 'speak' about science and science learning to students?" The placement of furniture in the science classroom constitutes an act of communication. But what does it communicate?

Student teachers typically respond, often echoing teacher phrases; "The arrangement in rows says that we are to do our own work. We are not to talk to one another and our eyes should not wander. The grouped arrangement suggests that we will be working together in science. It says that we may collaborate, perhaps share resources, and that it is all right to talk." In this way I am asking for a consideration of the features of the classroom environment as part of a larger set of cultural meanings that presents a message that children learn to read in school settings.

As part of the physical environment of the school, a segment of the architecture of the school, the furniture arrangement is a part of an elaborate *system of signification*, read by all who enter the classroom setting. The placement of the chairs is a way of communicating with learners, acting as a sign to students about how the lessons in this classroom will proceed. Whether a conscious decision of the teacher or not, it stands as a powerful sign to the learner, representing science and

science learning. We have begun a semiotic reading of the science classroom and of science learning.

Learners are not only consumers of sign and symbol systems, they are also symbol users. Understanding the complex ways that we use sign and symbol systems provides powerful insight into the ways that we communicate with learners in the school setting. The school setting is an expression of forms of action, ideas about how action will proceed, and the ideas and values created by our culture. It is also the setting created to reproduce these ideas and values. Within the semiotic view, the sign is regarded as the smallest unit of meaning, something that stands for something else. This meaning of sign is far more extensive than the everyday meaning of the term. The sign is a cultural unit representing an attempt to organize and communicate something about the world. As a sign, the color green in certain settings is a sign that it is all right to go forward. In another setting, it may indicate an attempt to be ecologically aware or environmentally conscious. Waving one's hand in certain contexts means goodbye, in others, it is the indication of a desire to speak. A key insight of semiotics is that sign systems involve the constant correlation of content and expression. When we take a semiotic perspective, we focus on communication rather than isolated linguistic forms. We therefore look closely at sets of signification systems, an approach that is particularly useful in research on school and classroom interaction. For example, at what kind of disadvantage are learners who do not share the same cultural code and how can we usefully see science as a special code to be learned along with cultural codes of behaviour and interaction in school. This leads us to an important critique of the messages of culture that we use, as we see that these codes are cultural territories as well as ideological entities.

This critique is particularly useful in teacher education programs in which we help teachers develop and expand their understanding of the many different forms that text can take in the learner's reading of the classroom. I find that when I introduce these ideas to student teachers it becomes very exciting to them as they begin to consider how the messages they have created become such a significant part in the meaning that is being conveyed to students. We want teachers and students to become adept not only at the reading of the signs, symbols, and meaning of science, but in the creation of signs and symbols to contribute to the meaning that is being consumed by learners.

Viewing classrooms semiotically helps us to see that entire systems of signification within school settings serve as resources for both

teachers and learners and are a means through which knowledge is accessed. When teachers master the signs and symbols of our culture and become aware of those of others, they know when to break unspoken cultural rules to become inventive in using new messages and symbols in interaction. A semiotic understanding allows us to become wide awake to and critical of the use of sign and symbol systems when they hurt or exclude individuals who are not members of the dominant culture or when they become overly rigid forms of communication.

Reviews of research on science teaching practice show that cultural insights about what happens in science learning are not widely addressed in the literature. For example, as Aikenhead (1996) and Krugly-Smolksa (1995) noted, when science teaching practices are studied, cultural differences among students are rarely explicitly acknowledged or addressed nor are individual differences. Pomeroy (1994) outlined the research agendas of several published studies that deal with the concerns of cultural diversity and the messages of science in school settings. The research agendas of the majority of the studies attend to the direct messages of the curriculum and the teacher rather than the messages conveyed by the school science-learning environment.

Work undertaken on this topic (Shapiro, 1998, 2004, 2006, 2010; Shapiro & Kirby, 1998) has attempted to develop a classification of the types of messages in science learning for use in both research and in teaching to raise awareness of the messages that go beyond the direct transmission of ideas about science. The purpose of this work has been to include features that are often overlooked but which have a powerful impact on the development of an understanding of science. The creation of a classification system (Figure 4) was developed through a systematic review of research materials collected on science learning settings to help educators consider the nature of the messages that are provided through the school science learning environment often speak a very different message than intended. A semiotic review of the various features of the environment we create for students provides us with new ways of rethinking the messages and meanings in science that we create for students.

Figure 4. Types of messages in the school science learning environment (from Shapiro & Kirby, 1998, pp. 230-231)

ARCHITECTURAL MESSAGES	SCHOOL POLICY MESSAGES
• Reading the School Building - The schoolyard environment - Entry to the school - Structure of the building/organization of rooms within - Special places for science within the the structure? • Classroom Messages - Messages of science on walls, bulletin boards, and other spaces • Furniture arrangement - seating • Arrangements for science learning - Science corner? - Tables, work-spaces, specialized facilities (sinks)	• School administration - Time-tabling - Nature of science leadership within the school - Library - Emphasis on acquisition of science resources - Library displays - Extra to classroom experiences - Science clubs, science fairs, field studies, tree planting days, school-wide environmental or science programs, special speakers - Financial resources allotted - Generalist or specialist teaching - Collaboration among teachers • Physical use of school facilities - Special science storage room - Special science classroom • District - Support for science consultant role - District resource centre Encouragement of professional development of teachers

	• Nation/Province/State - View of the important of science teaching - Amount of time allotted to science teaching - Program of studies - Testing practices • Community involvement - Parent groups/support - Corporate sponsorship - Criticism
SOCIAL/BEHAVIOURAL MESSAGES	TEXT AND CURRICULUM MESSAGES
• Rituals of social interaction - Rules of conduct - Rituals of interaction and behaviour - Teacher placement viz-a-viz student places - Invitation of parents and other speakers into the classroom • Teaching approaches - Teaching strategies - Teacher enthusiasm for topic - Science fairs, Home projects - Relative priority of science viz-a-viz other curriculum topics - Testing practices	• Resources used for teaching and learning science - Images of science/Images scientific procedures/Images of scientists - Portrayals of participants in science - Science-technology connection

School settings convey elaborate systems of signs to learners indicating what it means to be a competent learner in the science classroom. We reward students according to the degree to which they have modeled those signs for us. Children coming from a particular social class or who speak a certain language are at an advantage in such a system. Lesson

organization, language use, and activity patterns are largely structured for students by teachers using unexamined cultural values sometimes giving advantage to learners with only the right kinds of beliefs, values, and language skills. Textbooks and bulletin boards carry images of science often being conducted sometimes only by representatives of one gender or race, presenting a significant message of exclusion to learners. Language and dialogue structures may become ritualized in school settings. We need to take notice of the ways that communication structures permit students to use scientific language and thinking for themselves and how these structures influence their intellectual development and opportunities to discover and challenge new ideas.

Cunningham (1984, 1987) commented on the value of helping teachers become more aware of the process of semiosis (sign making and interpreting capacities) operating within the students they are teaching. He considers the job of nurturing the understanding of sign making processes along lines compatible with the subject being taught. If students are constantly being taught disjointed and unintegrated items of "stuff," they cannot build the structures we seek. If we emphasize semiotic structures and the skills for building the education becomes a more meaningful experience for both students and teachers. Cunningham (1984) suggested, "In short, a semiotic perspective encourages teachers to attend to the skills of learning subject matters rather than learning the stuff of subject matter only (pp. 9-10). He does not propose that prospective teachers become semiotic scholars, but rather, that they be introduced to the notion of signs and the process of semiosis and become sensitized to the structures and codes of experience which both they and their students are building as they operate in the world. This view of knowledge directs the attention of teachers away from teaching specific bits of knowledge to the cultivation of higher intellectual skills. Semiotics is not the only field that leads educators to this kind of awareness, but unlike others, it provides us with some conceptual forms for analyzing the knowledge building skills and provides insights into ways in which they may be nurtured. It recognizes the learning person as a socio-cultural being suspended historically in semiotic systems that themselves can be disempowering. In the semiotic system of the classroom, teacher and students are co-participants in a dynamic and mainly implicit process of constructing and reconstructing an intricate social reality of interlocking actions, beliefs, and values. As Habermas noted, language is the vehicle for attaining this goal and yet a problem with language is that it has an ideological dimension and can

serve as a medium of power and oppression, especially in its role as reservoir of societal traditions.

In our own Faculty of Education we are attempting to move from a system of teacher education that fuels the competitiveness and individualism that orients itself towards achieving success by dominating others, to one that values personal growth, cooperation, and the development of rich relationships. We find students and instructors who are more comfortable at first with traditional knowledge delivery modes. Periods of transition are exciting as students begin to see even a physical environment built that presents learning as opportunities for discussion, project based work, and collaboration.

My research develops from an attempt to link significant epistemic and socio-cultural aspects of learning in ways that move research forward, but also in ways that are useful to the classroom teacher. The project of constructivism is not to impose reform, but, as we learn from feminist research, of primary concern are the moral bases of human relations in learning and this leads us to an ethic of care. In considering the social nature of constructivist approaches to teaching, Taylor (1998) links constructivist theory to the critical theory of Jergen Habermas. He argues for the importance of building a foundation for pedagogy that sees the individual not only as an epistemic being but also as a socio-cultural being. From this perspective we see the importance of developing and embracing a moral ethic that upholds respect for human dignity in interactions and allows equal freedom to learning. Taylor proposes that we consider value development of an ethical basis for the communicative relationships that are inspired by emancipation and caring in social interactions. Changing patterns of interactions in school settings requires time and trust. There is a need for increased awareness of how this new dialogue on the personal, cultural, and constructive nature of communication settings challenges practice, but most importantly, improves learning. I am hoping that our continuing work with teachers and students will contribute to the ongoing transformation of science classrooms into sites of vibrant intellectual and communicative activity.

NOTE

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