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ABSTRACT

Teachers play a major role in the creation of student learning experiences. Conventional wisdom suggests that teachers' knowledge, beliefs and values influence their instructional choices. However, attempts to describe the decision-making process have yielded inconclusive results. Analysis of the beliefs, intentions, and actions of two exemplary science teachers using a project approach to teaching revealed consistent themes that suggest instructional practices are guided by teachers' implicit conceptions. The research project used a naturalistic design to examine teachers' beliefs, and actions in context. Data were gathered about teachers' beliefs using an adaptation of the Conceptions of Teaching Science Protocol (Hewson, Kerby, and Cook, 1995). An interview about instances served as a probe of teachers' beliefs about the ideal goals of project-based science. Teachers' oral and written instructions to students provided information about their intentions to promote a particular science program, and classroom observations and assessment instruments became the source of data about teachers' actions. Statements from each of these sources was classified and grouped, then examined for the presence of common themes. The themes were summarized as a description of the teachers' conceptions and examined by the participants to affirm its authenticity. As a result of this analysis, two teachers with different explicit beliefs about science teaching produced remarkably similar learning experiences for their students. Despite important differences in school culture, demographics and philosophy of teaching, these veteran science teachers created variations on the project-based approach to science that offer students rich experiences consistent with the recommendations of major reform documents. The value of the study comes from its illumination of a process that can elicit meaningful insight into the influences underlying the origin of classroom events. The potential for effective modification of instructional practices is enhanced by a clearer understanding of teachers' role in the creation of curriculum. (Contains 25 references.) (Author/YDS)

Influences on Teachersí Curricular Choices in Project-Based Science Classrooms

by

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Abstract

Teachers play a major role in the creation of student learning experiences. Conventional wisdom suggests that teachersí knowledge, beliefs and values influence their instructional choices. However, attempts to describe the decision-making process have yielded inconclusive results.

Analysis of the beliefs, intentions and actions of two exemplary science teachers using a project approach to teaching revealed consistent themes that suggest instructional practices are guided by teachersí implicit conceptions. The research project used a naturalistic design to examine teachersí beliefs and actions in context. Data were gathered about teachersí beliefs using an adaptation of the Conceptions of Teaching Science Protocol (Hewson, Kerby and Cook 1995). An Interview about Instances served as a probe of teachersí beliefs about the ideal goals of project-based science. Teachersí oral and written instructions to students provided information about their intentions to promote a particular science program, and classroom observations and assessment instruments became the source of data about teachersí actions. Statements from each of these sources was classified and grouped, then examined for the presence of common themes. The themes were summarized as a description of the teachersí conceptions, and examine by the participants to affirm its authenticity.

As a result of this analysis, two teachers with different explicit beliefs about science teaching produce remarkably similar learning experiences for their students. Despite important differences in school culture, demographics and philosophy of teaching, these veteran science teachers create variations on the project-based approach to science that offer students rich experiences consistent with the recommendations of major reform documents. The value of the study comes from its illumination of a process that can elicit meaningful insight into the influences underlying the origin of classroom events. The potential for effective modification of instructional practices is enhanced by a clearer understanding of teachersí role in the creation of curriculum.

Introduction

Traditional notions of the teacherís role in the classroom, that of teacher-as-technician, or teacher-as-deliverer of the curriculum, have proven to be inadequate to the task of understanding how classroom experiences emerge. Considering the teacher as the "creator" of the curriculum recognizes the teacherís critical role in the construction of appropriate and worthwhile experiences for his/her students. Teachersí choices about what to teach and how to teach it are the foundation for the learning opportunities students encounter.

Exemplary teachers are of particular interest in this respect because they are recognized by their peers, their students, and their supervisors for consistently creating worthwhile curriculum experiences. Understanding how exemplary teachers choose among the many factors that impact classroom activities can offer insight into the intricate dynamic of teaching and learning that is so elusive. The research project reported in this paper describes a process in which implicit beliefs and routinized choices are exposed and examined by the participating teachers and researcher. Patterns of influence between teachersí beliefs and their intentions to promote a particular understanding of the scientific enterprise, and between teachersí intentions and their classroom actions provide new understanding of the origin of an effective teacherís curriculum.

The central question guiding this research is: How do two experienced, exemplary science teachers integrate their beliefs and intentions into a coherent sequence of learning activities for their students? Three subset questions for each teacher support the central question: What are the teacherís beliefs about the ideal goals of a project-approach to teaching science? How does each teacher intend to transform his beliefs into specific classroom events?, and What does each teacher require his students to know and be able to do as evidence of the learning experience that he designs?

Background

Definitions of curriculum : Conceptions of teachers as "creators" of the curriculum are not a recent idea. Dissatisfaction with the long-term effectiveness of science curriculum reform efforts of the 1960s and 70s was reported by Harms and Yager in their Project Synthesis research. They concluded, "Teachers make most of the important decisions about course content, text selection and instructional methods, and in so doing they determine the goals pursued by science education." (Harms, 1981, p. 117). This contrasts with the classic understanding of curriculum presented as the Tyler model (1949). Implicit in the Tyler model are two assumptions: (1) students will respond predictably and uniformly to the sequence of curriculum tasks, and (2) teachers will present the learning activities in a predictable and uniform manner. Following the premises of the Tyler model, a number of national organizations invested money, time and energy to develop curricula consisting of sequences of science learning tasks and to train teachers to present these curricula the "right" way. Efforts to create "teacher-proof" curricula (Brophy, 1982) failed to produce the promised learning goals as Harms and Yager reported. Other factors must be influencing the classroom experience of students, and the learning that results. Curriculum researchers renewed their attention to the role teachers play in the execution and interpretation of curriculum goals.

For example, University of Chicago curriculum theorist Joseph Schwab (1978) recommended that teachersí perspectives be incorporated into curriculum development conversations. In describing how curriculum specialists can be more certain that recommended curriculum goals are realized, Schwab expresses the importance of communicating the meaning of curriculum objectives with all participants in the education process:

> these meanings lie in the whole course of deliberations which created them. The meanings lie in what was decided *against* as what was decided *for* . (Those not) privy to all the deliberations, cannot, like bronze molders, take a terminal statement of purposes as a pattern, and from it, realize a curriculum. . . (emphasis added, p. 369)

Schwab recognizes that Tylerís call for curricula consisting of carefully structured sequences of topics, concepts and activities cannot be expected to achieve the learning goals conceived by specialists outside the classroom. Curriculum meaning and learning outcomes depend on decisions made at many points in the sequence, including those decisions made by teachers in the classroom.

For the purposes of this study, ëcurriculumí is used to refer to the entire classroom event that occupies teachers and students. From this perspective, schools are "places offering planned opportunities. . . for quality, productive experiences in living for all who participate in them (Zaret, 1987)." The phenomenological point of view considers classroom events and their meanings as more dynamic, and elusive, than more traditional "snapshot" pictures presented by earlier research (Clark and Peterson, 1986; Shavelson and Stern, 1981).

Teachersí choices and classroom experiences : Conventional wisdom among educators holds that teachersí knowledge and beliefs influence their curricular choices. Clark and Peterson (1986) prepared an important summary of the early research on teachersí role in the implementation of curriculum through their classroom decisions. The research Clark and Peterson reviewed concluded that teachersí planning decisions influence the "opportunity to learn, content coverage, grouping for instruction, and the general focus of classroom processes. Planning (decisions) shape(s) the broad outlines of what is likely to occur" (p. 267). The implication of the Clark and Peterson summary is that the appropriate focus of attention in the study of curriculum ought to be the classroom, and that the classroom decisions made by teachers are the blueprint for describing ñ and perhaps modifying -- student learning opportunities.

Lee Shulman coined the term "pedagogical content knowledge" to capture the intricate network of beliefs, values, and knowledge of subject and practice on which teachers base their curricular choices (1987). A number of recent studies have extracted particular elements from Shulmanís PCK construct and searched for evidence of the influence of teachersí knowledge and beliefs on their classroom actions. Ball and McDiarmid (1990) developed a graphic description of the role of content knowledge on teachersí lessons. Connelly and Clandinin (1988) looked at teachersí role in the evolution of curriculum as it derives from their classroom practice. The authors consider teachersí history as learners as an important component of teachersí pedagogical theories. By examining their own experience, Connelly and Clandinin suggest teachers can better understand the origin of their own curricular choices. Rebecca Hawthorne (1992) described in vivid detail how four English teachers using the same curriculum guidelines and working in the same school district can produce distinctly different learning opportunities for their students. The beliefs, knowledge, values and experiences of each teacher led to the transformation of a common curriculum framework into unique classroom experiences.

Studies attempting to link teachersí knowledge and beliefs to their classroom practice have yielded at times confusing results. Lederman and Zeidler (1987) concluded that teachersí conceptions of the nature of science do not translate directly into observable classroom behaviors. Their classification of teachersí beliefs about scientific knowledge showed little correlation with teachersí actions. Likewise, David Hodson (1993) looked for patterns of influence between elementary teachersí beliefs about the nature of science and their instruction. He reports that there is an unclear connection between teachersí philosophic beliefs and their classroom work.

On the other hand, Cronin-Jones (1991) described the choices made by two novice science teachers that were clearly consistent with their particular beliefs and which resulted in quite different implementations of a new curriculum model. One teacher, "Marcy," believed that factual content knowledge was most important for her students, so she modified the suggested inquiry activities to accommodate more time for direct instruction. A second teacher, "Shelley," expected students to ëcoverí more topics than allowed in the new program, so she shortened inquiry time to allow for the inclusion of more topics. Nancy Brickhouse (1990) reached similar conclusions about the influence of teachersí beliefs on their classroom decisions in her study of veteran science teachers. Teacher "Lawson" considered scientific theories to be practical tools for exploring the natural world, and encouraged her students to think critically and creatively when interpreting their data. Teacher "Cathcart" believed scientific theories to be accurate representations of the physical world, and expected his students to confirm and memorize accepted theories.

The implication of these contradictory results is that there is an intricate, complex, indirect relationship between teachersí knowledge, beliefs and values and their curricular choices. Accepting that conclusion leads us to wonder if we can ever be able to describe and understand how curriculum emerges in each unique classroom. If teachersí curricular choices define student learning opportunities, and if student learning experiences facilitate the growth of knowledge and skills, then every attempt to guide learning toward particular goals demands that we look carefully at the decisions teacherís make to construct the learning events students encounter.

This paper describes an effort to elaborate on the choices made by two exemplary teachers using a project-approach to science curriculum. Interest in looking at teachers using a project approach with their students comes from the trends in current reform efforts. Science classrooms that are "project-based" typically place a greater emphasis on the practice o f science than on the products of scientific research (Project-Based Science, 1997). Project-based approaches encourage students to meet the standards recommended by the American Association for the Advancement of Science: to depend on empirical evidence, to be accurate in obtaining supporting data, to avoid bias, to explore conflicting evidence and to clearly and collaboratively communicate their methods and conclusions (AAAS, 1989). Project-based approaches are considered suitable to many school settings, and appropriate within all the major scientific disciplines. The experience of the participants in this study show that ëproject-based scienceí can indeed take many forms to achieve the desired learning outcomes.

Context of the Study

This study emerges from the current climate of reform in science education that seeks to move teachers and students toward an optimum learning experience. Appreciating the elements that produce the classroom event is a first step in making effective efforts to modify learning experiences.

Two exemplary secondary science teachers were recruited to participate in this examination of the evolution of curriculum. Both are recipients of local and national awards and honors. Their supervisors, their peers and their students cite them as practitioners who exemplify the ideals of science teaching. Both have contributed to the development of state science curriculum frameworks.

Eric Carter* taught in private and public schools for almost 20 years. He has received grants to pursue his own research in migration patterns and has a special interest in teaching environmental science among his general biology assignments in the moderately affluent suburban school where he now works. His interdisciplinary senior seminar class, The Natural World, was visited for this project.

Steve Noble* is a highly respected former "Teacher of the Year" at a large city high school known for its successful integration of urban youngsters with the tuition students who travel from a nearby affluent suburb. Steveís tenth grade College Preparation Biology students participate in a regional water study project each fall as one unit within their traditional biology curriculum.

Both Steve and Eric engage their students in active inquiry for the course units reported in this paper. Ericís Natural World course continues a project-based approach throughout the school year. Steveís water quality study occupies eight weeks of the school year in which he will use a mixture of teacher directed instruction, collaborative group work and independent projects. Teachers using a project approach are thought to have some similarity in intentions for their students.

In the context of this study, teachers are understood from the constructivist perspective to be "meaning- making organisms, theory builders who develop hypotheses, notice patterns, and construct theories of action from their life experience" (White and Gunstone, 1992).

Methodology

The choice of a naturalistic research design (Lincoln and Guba, 1985) for this project was guided by the necessity of understanding the context in which teachers make their choices about what to teach and how to teach it. Hodsonís (1993) finding that teachersí beliefs differ depending on the context in which they are applied endorses the choice of the naturalistic paradigm. As detailed by Lincoln and Guba, this approach provides opportunities to learn much about an instance by seeing the event as a socially mediated construction. What teachers know and believe from their unique point of view forms the data set from which they decide what to teach and how to teach it. Since the purpose of this investigation is to look closely at what teachers believe, and to find patterns of influence among their beliefs, intentions and actions, the principles of the naturalistic paradigm are an important part of the design of this study.

Data gathering : At least three types of data are needed to explore teachersí beliefs, intentions and actions. Information about teachersí beliefs were gathered indirectly using a contextual protocol modeled after the Conceptions of Teaching Science Method developed by Hewson, Kerby and Cook (1995). An Interview about Instances invited the participant to explain their beliefs about teaching by responding to briefly described hypothetical (but realistic) situations.

Details of teachersí intentions for their curriculum goals were gathered from transcripts of classroom instructions, teachersí plan books, worksheets and activity guidelines. Information about the actions teachers take to implement their intentions was taken from observations of classes during the project unit and from the assessment tools used to evaluate student learning. As students come to understand quite accurately, items on a teachersí test directly correlate with a teacherís explicit ñ and implicitó learning goals. The categories under study and the data sources for each are shown in Table 1.

Table 1	
Data sources and Categories	
Category	Primary Sources
Teachersí Beliefs	Interview About Instances Informal Interview Teacher commentaries, essays
Teachersí Intentions	Course syllabi Program of studies Curriculum handouts Classroom instructions
Teachersí Actions	Classroom observation Evaluation instruments

Data analysis : Statements related to each teachersí conception of their science curriculum were extracted from the interviews, observations, and artifacts. Using frequent reference to the context of each statement, the individual comments were classified as beliefs, intentions or actions depending on how coherently they completed the sentence stems shown in Table 2.

Table 2			
	Beliefs	**Intentions**	**Actions**
Ideal Goals of Project-Based Curriculum	A project approach to curriculum should . . .	My curriculum will provide opportunities to . . .	The curriculum I design includes classroom activities that . . .

Borrowing further from the Conceptions of Teaching Science Protocol (Hewson, Kerby and Cook, 1995), the collection of statements were examined for the presence of broad themes that could be construed to reflect the essential understanding believed or intended by the teacher. The classification of statements and definition of themes were returned to each participating teacher for review and confirmation. Themes reflecting each teacherís beliefs were compared with those describing their intentions, and both compared with the ideas evident in the analysis of teachersí actions. From this comparison, assertions were made about the coherence and consistency within the curriculum creation process. Evidence of coherence and consistency were considered to be evidence of influence among beliefs, intentions and actions.

Findings of the Study

At the start of this investigation, the working hypothesis proposed that there would be significant differences between the versions of "project-based" science presented by the two participants. The cultures of their schools, the demographics of their communities, and the philosophical orientations of the staff toward teaching and learning are strikingly different.

Instead of the expected differences, however, the analysis revealed remarkable similarities, especially in the features of the learning experiences provided for the students in each classroom. Both teachers showed strong consistency among their beliefs about the appropriate goals of science, their intentions to promote inquiry science, and in the classroom activities they arranged to support their intentions. Both teachers got what they asked for, and were consistent in asking students to demonstrate the knowledge each teacher believed to be most important. Both teachers structured a curriculum that provided students with rich inquiry experiences, in keeping with the recommendations of the National Science Education Standards (NRC, 1995). Both teachers created meaningful and valuable learning opportunities for their students. The difference between the settings in which they teach appear to have less influence on their ability to produce a worthwhile science curriculum. Eric Carter teaches his students to "construct the story" of the resident plants and animals they study. Steve Noble tightly structures his studentís work, emphasizing accuracy in testing water quality encouraging them to collaborate with peers to interpret their results. At the end of the day, though, students are exposed to rich, high quality, authentic learning opportunities in science.

Eric Carterís Project Approach to Science : Eric is a veteran teacher who reflects frequently on the nature of his role in helping students come to understand and appreciate the subject he loves. In one of his professional portfolio essays, he describes his metaphor for teaching:

> "[I ask myself] what ëstoryí can I create that will get the kids excited and involved? ÖOnce kids are engaged in the <u>context</u>, the <u>content</u> becomes meaningful to them and they are ready to learn it by applying it to this context in order to solve the story or question." (Portfolio Essay 2, ëOn Curriculum,í 1995; Emphasis in the original)

Carter accepts the challenge of creating an experience that engages students in the exploration of the natural world that he associates with the construction of a narrative. Scientific inquiry is a process of ëreadingí bits and pieces of natureís story and then using creativity, imagination, reason, logic and existing knowledge to connect the bits and pieces into a compelling story. A prevalent theme in Carterís approach to teaching is his goal to guide his students in the construction of their unique tale.

Eric Carterís reaction to several of the hypothetical instances in the initial interview reveals more about his beliefs on the ideal goals of science curriculum. In Instance 8

(Appendix A), Miss Panacek is conducting a lecture-discussion with her honors biology class on cell types.

Initial Interview, Instance 8

Interviewer: Hereís honors biology. Ms. Pancek is doing lecture discussion here.

EC: Yeah, I love it!

Interviewer: So this is science teaching?

EC: Yes!

Interviewer: You like this one, right? So what about this dialogue, what tells you that there is science teaching happening here?

EC: Okay. The teacherís asking provocative questions. Sheís trying to engage the kids with the content so its seems like thereís been development of a context or a story line in which the kids are then able to begin to construct some meanings . . . (In contrast to the last one) I feel much better about saying thereís real teaching going on here because the kids are beginning to incorporate the previous dayís class, lab or whatever theyíre doing. You need to organize some way in which they can verbalize it.

Interviewer: Now, you donít have the studentís end of the dialogue here but youíve inferred that in fact dialogue is happening. What tells you that?

EC: Well, itís because Iím feeling engaged to get into that conversation. I think theyíre good questions. Iím assuming the kids are into it too! Heh, heh!

Interviewer: What do you mean by ëprovocativeí?

EC: For the first part, when she asked the question, ëwhatís the difference between eukaryote and prokaryote?í and then she goes into ëwhat do we mean by organization?í Right there itís turning it (the question) back to the kid asking the kids to begin to start to process their thoughts, to get the kids to answer their own questions versus telling a quick answer.

Some of Carterís beliefs about productive science curriculum are implicit in his enthusiastic response to this hypothetical episode. He imagines this lesson will engage the students, as he infers from the way Ms. Panacek redirects her questions. He suspects there must be a context in which students recognize the terms, not just as memorized vocabulary lessons but as terms that suggest more complex meaning about living systems. He imagines that this lesson will provide students the encouragement and support they need to begin to make meaning for themselves, not just regurgitate the teacherís intentions.

Contrasting this response to Carterís reaction to another instance highlights these beliefs even more clearly.

Initial Interview, Instance 7 (Appendix A)

Interviewer: The next one is a Chemistry class doing titrations. Now, is science teaching happening here? We have Mr. Douglas checking titration levels and confirming. . .

EC: Iíd say Mr. Douglas is teaching whether kids can follow steps and safety rules, which are important.

Interviewer: So this is one of the. . .

EC: Yes, but I would think if you are looking at acid-base reactions you couldnít tell that from the scenario.

Interviewer: Okay, so what else would you need to know?

EC: Iíd actually need to talk to the kids to see if they understand why theyíre doing it not just how to get it (an answer).

Interviewer: So the other component you would add would be . . .

EC: The ëwhy.í

Interviewer: You donít have any information here that tells you whether he has had conversations with the kids, whether they get that. But in terms of science teaching skills and safety, itís ok?

EC: And for following directions, yes.

(next instance presented)

EC: Whereas in the last one (Mr. Douglas and titrations) all we can infer from that is theyíre doing a titration, theyíre following some steps.

Carter uses the contrast between Mr. Douglas and Ms. Panacek to voice his belief that learning experiences ought to provide insight into studentís thinking, letting teachers know whether they "get it" or not. Carter canít tell from the hypothetical instance whether Mr. Douglas has had conversations with the students in order to expose whether they understand the underlying concepts in their titration lab, or whether they are merely following steps. For Carter, good science teaching involves the teacher learning about the learner as much as the learner is involved in understanding the content.

Eric Carterís beliefs about ideal science teaching are quite demanding. How does he intend to be able to design learning activities that engage students, provide insight into their understanding, and advance their construction of new meaning? One "rule" he sets for himself is to be able to change and modify his plans in response to student needs.

> "I find that as I go along in a unit, it is important to make changes. The initial story or essential question presupposes that the student has some prior knowledge and understanding of the concepts about to be covered. As the unit/story unfolds, it becomes clearer to me what the kids do know and what misconceptions they may have. Consequently, in planning curriculum, I try to think about the "when and where" I need to add degrees of difficulty (challenges) and or supportive pieces that may include a short topic lecture for some or all, a reading for background, or a quick "hands-on" skill building practice sessions." (Professional Portfolio Essay, "On Curriculum," 1995)

The way Carter meets his own standards for a quality science curriculum is by changing the sequence and types of activities in response to feedback from the students as they move along. The activities students perform require active participation, giving Carter frequent opportunities to gather the feedback he needs to make judgments about the lesson. The direction handout for the Riversí Edge unit describes the requirements for students.

Figure 1

The Riverís Edge: Flora/Fauna

Part I: Plants

A. Examine the following tree species:

White or gray birch

Shagbark hickory

Mature sugar maple

What ëadaptationsí allow this tree to survive the cold?

Hint: Examine the bark and buds.

B. Why do deciduous trees lose their leaves?

Hint: Conifers do not. . .contrast leaf size, and remember surface area to volume ratio lab!

Part II: Animals

A. Choose a New England bird which migrates and answer the following:

Why does it migrate to . . .? BE SPECIFIC AND SUPPORT WITH FACT!

Where does it go?

Why does it come back?

B. Choose a New England bird that does not migrate and answer the following:

Why doesnít it migrate?

How does it survive the cold?

C. Choose an insect and discuss how it ëover-winters.í

D. Track a mammal:

1. Sketch and identify the track.

2. Discuss the natural history of this animal:

What does it eat?

When does it mate? Give birth?

How does it cope with winter?

What is its major predator? How does it avoid predation?

Within the broad essential questions of the Natural World course, the Riverís Edge unit requires students to look specifically at adaptations for cold weather among the plants and animals in the riverside habitat adjacent to the school. Students spend at least one double block period per week outside in their study plots, gathering the observations they need to construct the "story" of the plants and animals they study. Carterís expectations require more than reading about selected animals from resource materials, but gathering and interpreting original observations made by students.

Riverís Edge Class 1/9/97

EC: My goal is not only to have you looking at these adaptations but experiencing them. You need to bring your field journal out, you need to bring a pen. . . Okay letís pack up and head out. Itís a perfect opportunity for you to choose a resident bird species and to begin to form an answer to the question, how does that bird species manage for the winter? You might want to do a little more follow-up work on that particular species.

Students are instructed to "experience" these winter adaptations, and on this frigid day Carter gives students an ideal opportunity to appreciate the challenges their plants and animals face! Before he dismisses them to their separate sites, Carter reminds them what their work involves.

Rivers Edge Class 1/9/97

EC: Okay, what I want you to keep in mind, I put this phrase on the board at one point ñ ëJust because you canít see an animal doesnít mean you canít observe it." What does that mean? Yeah, you can hear it. Okay, scat, chew marks. What else? . . .

Okay, everybody clear? Okay, letís go to it.

Like Ms. Panacek in the hypothetical instance, Carter asks probing questions to decipher studentís understanding of their task. He directs them to begin to answer the key questions of the unit, how does the animal ëmanageí through the winter. His verbal and written unit instructions reveal how he intends to construct meaningful science learning experiences for his students.

The key themes describing Carterís beliefs about science curriculum and his intentions to enact those beliefs are summarized in the table below.

Table 3

Eric Carterís Beliefs and Intentions Regarding Project-Based Science Curriculum		
Carterís Beliefs: Project-based science curriculum should. . .	Carterís Intentions: The Riverís Edge curriculum will . . .	
Promote student participation in scientific inquiry	Direct students to use scientific skills and knowledge in authentic research	
Provide insight into student knowledge	Provide insight into student understanding	
Advance studentsí construction of new knowledge	Lead students to construct new knowledge	
Promote understanding of the nature of scientific inquiry	Promote understanding of the scientific enterprise	
Engage students in conversation about their new understanding	Involve students in small and large group discussion of new ideas	

Was Eric Carter able to implement his intentions during the Riverís Edge unit? The apparent consistency between his beliefs about ideal curriculum and his planned activities is tested when the hazards of daily school routines and the variations in student interests, abilities and motivations interact with well-ordered lesson designs.

On one class day, Eric Carter not only instructs his students to carry out research activities, he participates with them. Carter joined one student team on their plot visit.

Riverís Edge Class 1/9/97

Look at the size of that hole. (What) we do have here is flying squirrels. They use these nest cavities over winter. . .

Look here! Whatís this?. . . Hereís something, a different sort of nut. Look at the chew marks on that.

Thereís a real old shagbark hickory right here, been around a while. You can see whatís going on here. You can see. . . what do you observe on this pattern here?

The ground is scruffed up a bit. You might want to look at that, look for something about squirrel behavior on the ground.

Do you see those tracks?

Oh, ho! We have another sign right here!. . . .

Take a look at that! Okay, thereís something respirating inside. . . Okay, look at the size. How can you describe the size of that hole? . . .

Carter believes science curriculum should engage students in scientific inquiry. This excerpt demonstrates Carterís method for implementing that belief, using his own contagious enthusiasm as a motivator for students.

Carter returns often to his ëstoryí metaphor in his instructions to students. He invited a recognized researcher to share her approach to field journals with his students. He explained why her work would be helpful to them.

Informal Interview 1/16/97

The first few times we went out we focused on the birds. Whatís that bird doing? Whatís the bird eating? Howís the bird surviving? You get that from just observing. But whatís the ëstoryí thatís being told? Claire Walker Leslie came her to do a workshop on field journals. (I told them) Look at this. This is basically what we should be doing. I said, this tells a story. You look at this page (from one of Leslieís journal) and it tells a story.

Carter supports his belief that students should function as apprentice naturalists by his own example in the field as well as by offering invited guests as models of ideal scientific practice. His actions appear to be remarkably consistent with his beliefs and intentions.

The assessment of student learning is one critical test of the agreement between a teacherís beliefs and intentions with his/her actions. Carter describes his beliefs about assessment in one of his professional portfolio essays.

"Therefore, I may assess (and validate) students not just on their product but also on the process by which they undertook (to reach the product). In short, if we vary the way kids can ëget thereí versus the standards we hold tem by, we can validate and report on their work in meaningful ways. . . . not all kids are able to produce ëproductsí yet they are able to show demonstrable manifestations of their academic growth." (Professional Portfolio Essay, "Assessment and Feedback," 1995)

Carter expresses admirable goals for constructing meaningful measures of student knowledge growth. Does he follow through in the Natural World class? The lab practical required students to visit five stations and examine the specimen or artifact at each position.

Figure 2

Name ______________________________ Our Natural World Seminar

Winter Animal Signs Indoor Experience

Part I: Animal ëSignsí: Identify the organism (species) through direct or indirect evidence AND give a reason for your identification. (5 points each; 25 points.

Part II: Short Answer (Please answer the following questions on the back of his sheet). (10 points each, 20 points)

(1) Identify and describe at least 4 physical characteristics of the winter season that animals need to ëcope withí in order to survive.

(2) Compare a warm-blooded organism to cold-blooded organism in how each survives New England Winters.

Carterís grading of the lab practical supported his belief about ëprocessí. He allowed credit for a reasonable argument of alternative interpretations even if the specimens were not labeled correctly. For example, scales in the scat sample could indicate otter or raccoon. The focus of Carterís evaluation was the argument students constructed to support their choice.

The defining features of Eric Carterís project approach to science include active participation in the methods of a naturalist, guiding students to construct new meaning by writing a ëstoryí based on their observations, and appreciating the scientific enterprise by interacting with exemplars. Carterís accomplished his intention to engage students in their science inquiry as much by his contagious enthusiasm as by constructing interesting activities. [He seemed as energized by the lessons as were the students.]

A summary of the major themes describing Eric Carterís beliefs, intentions and actions are presented in Table 5.

Table 4

Beliefs, Intentions and Actions Regarding Project-Based Science Curriculum

Carterís Beliefs: Project-based science curriculum should. . .	Carterís Intentions: The Riverís Edge curriculum will . . .	Carterís Actions: Teacher structures opportunities for students to . . .
Promote student participation in scientific inquiry	Direct students to use scientific skills and knowledge in authentic research	Involves students in the methods and activities of a naturalist
Provide insight into student knowledge	Provide insight into student understanding	Interact with exemplars of scientific inquiry
Advance studentsí construction of new knowledge	Lead students to construct new knowledge	Confront new experiences, develop new knowledge
Promote understanding of the nature of scientific inquiry	Promote understanding of the scientific enterprise	Collaborate with the teacher as a model investigator
Engage students in conversation about their new understanding	Involve students in small and large group discussion of new ideas	Accept alternative interpretations for data
		Experience the rewards of persistence and enthusiasm in pursuit of knowledge

Steve Nobleís Project Approach to Science: The examples reported above show that Eric Carter executes a consistent sequence of decisions resulting in a science learning experience for his students that promote his beliefs and goals. Steve Noble is similarly consistent and coherent in the choices he makes to design a project-based unit. His classroom activities guide students to understand scientific inquiry in ways that are consistent with his beliefs. Despite important differences in some respects between Carter and Noble, the classroom experiences of their students is quite similar.

A central theme in Steve Nobleís beliefs about the teachersí role in defining student learning experiences appears in his response in the initial interview about hypothetical instances.

"To me, thatís what a teacherís got to do. Iíve said a couple of times here, ëmy hands in the pot.í Iíve got to have my hooks in there."

For Steve Noble, the teacher is a sculptor, molding the studentís understanding of the world by designating specific learning activities. He believes students should practice the tasks of investigation that are central to scientific inquiry, and his choice of a project-approach is the vehicle through which they can engage in authentic research. His belief in the importance of the teacherís role becomes clearer in his response to Instance 1 in the Initial Interview, which describes ëJeffí and ëSabrinaí working in the library gathering data on nutrition values.

Initial Interview, Instance 1 (Appendix A)

SN: In this scenario the teacher is very removed and the assignment may have come from the teacher. Thereís learning going on as a result of the teacherís assignments, but the teacher himself or herself at this point, at least according to this scenario, doesnít seem to have his fingers in the teaching. Itís more the studentsí teaching themselves.

Interviewer: And what would the next level be?

SN: The next level would be Jeff and Sabrina back in class with their columns, with their percentages, with their values, and the teacherís saying ëOkay, what did you get Jeff and Sabrina and Larry and Sue and George? Letís see what weíve learned here.í And the teacherís bringing it back and saying, ëYouíve taught yourself, youíve played with this idea. Have you learned what I want you to learn out of this?'í It's a valid way of going at things and Iíve used this avenue, but the teaching isnít going on here [in the library], but happens later.

Steve Noble recognizes that learning happens even when the teacher is not there, but for there to be a ëcurriculumí or direction to the learning, the teacher must be involved. More specific characteristics of a curriculum that Noble wants to provide for his students are revealed by his reaction to Instance 8, Ms. Panacekís Honors Biology class discussion of cell types.

Initial Interview, Instance 8

SN: I always hated it, and I still do ñif Iím in a class and the teacherís giving fill-in-the-blank questions. He knows the answer and thereís only one answer and therefs only one word that will fit! Thatfs not teaching, or if it is, itfs awfully poor question asking. This (Instance 8, Ms. Panacekfs class) is good because shefs asking questions, getting a response. Now, maybe itfs not a book response. So what? "Letfs see what you mean."

Interviewer: So it becomes an interactive activity as opposed to a directive. . .

SN: Yes, yes. Itfs interactive all the way! And shefs got her fingers in the pot because shefd the one directing this around, because theyfre not kicking around ëprokaryoteí and ëeukaryoteí and mispronouncing it and not spelling it correctly, and maybe switching the two in their notebook definition. But shefs directing it and shefs interacting and pulling it back. Shefs guiding it because shefd going apparently where she want to go. Hopefully, shefll get there, and it looks like she will.

Interviewer: Youfve been in a class like this, havenft you?

SN: Yes, I like those classes. Theyfre interesting because it allows [student] questions to come up naturally.

Even though Noble believes teachers direct the events in a classroom, his feelings about Ms. Panacekfs class suggest that student interaction with the ideas and the content are vital to the success of the learning experience. Where Eric Carter described ëconversationí as critical, Noble uses the idea of ëinteraction.í

A third key theme revealed in Noblefs Initial Interview responses relates to his affective goals for his students.

Initial Interview, Instance 8 (Ms. Panacekfs Honors Biology discussion)

SN: Therefs a difference in perception of whatfs interesting. Science can become interesting in this way (Ms. Panacekfs interactive discussion). I would like to think that because itfs more interesting, that some of the academics would last longer. . . But at 15, Ifm not teaching them to be doctors. At 15, Ifm trying to catch them and interest them in science. . . My goal in this kind of discussion would be that the students would become more interested.

By engaging students in an interactive discussion and in inviting activities, Steve Noble hopes to ëcatchí the students, to interest them and thereby help them retain the knowledge he guides them toward. In the midst of a traditional school culture, how does Steve Noble intend to implement his beliefs with the wide range of students in his Biology class?

Noble explains his intentions to the class when he introduces them to the watershed unit.

Watershed Class 9/30

"My plan today is to set the scope and parameters of our work over the next 3 to 4 weeks. We are going to be looking at what happens in a watershed, particularly the human influence. Our particular interest is in Springfield*, though there are many sites north and south of us (participating in the study).

The focus is on students getting out of the classroom and doing a real study program that has benefits for the community. You will collect data on the current conditions of the river near our school. The river has played a significant role in the development of the city of Springfield, as well as in cities south of here. We will put into perspective this valuable resource.

As citizens of the city, you should be proud of this resource. Some of you may have parents or grandparents who remember how ëyuckyí it was. . . .

Wefll begin by looking at the history of the river, of its influence on the people who came to live here. Then wefll do the testing part, connecting the biology and chemistry wefre studying to the river."

The content of the watershed unit will include study of the cultural and historical impact of the river, as well as knowledge of the biology and chemistry of a primary waterway. Noble suggests to students that they may have a personal connection to the topic though their parents and grandparents, another method he uses to ëcatchí their interest in the subject. Steve structured the watershed unit to allow two class days to prepare group presentations on aspects of the historical, cultural, and geographical aspects of the watershed. Students spent one double period lab class learning how to use the water test kits, one lab class at the river test site practicing their testing skills in the field, and another lab class day for the "official" quality testing day. Class time between double lab periods were occupied with reinforcing content, discussing the standards and limits of the water quality tests, and identification of fresh water flora and fauna. The structure of the schoolfs daily class schedule restricted Stevefs flexibility, but nevertheless, he managed to orchestrate a smooth sequence of events.

A comparison of Steve Noblefs beliefs and intentions to create meaningful and worthwhile learning experiences for his students is shown in Table 5.

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Table 5	
Steve Nobleís Beliefs and Intentions Regarding Science Curriculum	
Nobleís Beliefs: A project approach to curriculum should . . .	Nobleís Intentions: My project-based science unit will . . .
Provide opportunities for student learningpresent important skills and conceptspresent a view of science as ëinterestingí	Provide opportunities for students to engage in ërealí science investigations Learn and practice data gathering skills Know the historical and cultural context Make scientific inquiry interesting to students
Engage students in exploring new ideasinvite a personal connection	Provide a personal connection with the content
Create an interactive learning experience	Share group results and discuss alternative conclusions
Allow teachers to guide learning in particular directions	Follow teacherís directed plan for learning the content

Steve Nobleís ability to balance the demands of a district-wide curriculum, the expectations of colleagues, and the interests, abilities and motivations of his students determines whether his beliefs and intentions can be enacted into a productive learning experience. The allocation of time for various learning activities serve as one measure of his effort to achieve the learning goals he promotes. A second measure is the nature of his assessment of students.

Steve grades five items to assess this unit. In addition to summaries of water quality newspaper articles and a formal group lab report on the water quality analysis, students take two tests, one a lab practical and the other an essay/ short answer written exam. The lab practical follows the format of the water analysis whereby each group tests a prepared sample for three specific substances. Students record the groupís results on a master table on the board, and construct a narrative conclusion about the quality of the sample based on standards used for the river study. An excerpt from the test direction sheet is shown as Figure 3.

Figure 3

Central River Watershed Project, Group Test [excerpt]

Part IV, Section J: Water Chemistry

1. Each group must do their three chemical/physical tests on the water sample provided. Please write all results on the front board (show all calculations on your answer sheet).

2. Each group should review the class data, then use their best judgment and correct calculations to determine a single measurement for each parameter from the data provided. For any questionable results provide brief explanations for your analysis decisions.

3. Each group should use the Q-value charts to determine the proper values for each water test measurement.

4. Each group should use the Water Quality Index Chart to determine the resulting WQI number from the class data. Fill in all data and submit with your answer sheet.

5. Each group should use the actual data and the WQI results to write a summary which discusses the test results as clearly as possible. Identify acceptable and unacceptable results, the effect of any present pollutants on local water conditions, possible polluting sources, and suggested solutions to any polluting problems which seem to be present.

As a group exercise, this test meets Nobleís goal of providing students with interactive experiences. Discussion within each group forms the basis for the summary conclusions required as the final component of the examination. Requiring students to apply the analytical skills learned and practiced during the project meets Steveís intended goal of providing students real science experiences.

Steve scoring procedures mirror his belief in the open-ended nature of scientific study, a characteristic noted to students in a class about the "subjective" nature of safety standards for each of the parameters measured in this study. Groups were required to make judgments about the validity of the test results completed by their classmates.

Post-Unit Interview, 11/4

SN: A couple of groups said, "weíre going to throw out the ë5í because itís really different from the others." Others said, "Weíre going to leave it in because it was there.

Interviewer: How did you evaluate their choice?

SN: I only wanted to know why they made their choice, not judge one choice as better than the other. They had to use the chemical charts. . . .Fifty points was dealing just with that. . . and the last ten points was looking at the numbers and giving me an analysis of whether they were acceptable or unacceptable. [They had to] look at the effects of those particular pollutants, [give] possible sources and [offer] suggested solutions.

On the whole, grades on the performance test for this unit were consistent with grades from earlier instructional units. Steve laments the severe institutional constraints that prevent him from using the project approach for other units. The test was a rich source of feedback and he expressed a wish that he could spend more time working with the students to refine their data collection and analysis skills throughout the year.

The consistence among major themes describing Steve Nobleís beliefs, intentions and actions can be seen in Table 6 below.

Table 6

Steve Nobleís Beliefs, Intentions and Actions to Promote a Project-Based Science Curriculum

Nobleís Beliefs: A project approach to curriculum should . . .	Nobleís Intentions: My project-based science unit will . . .	Nobleís Actions: My curriculum activities involve students in . . .
Provide opportunities for student learningpresent important skills and conceptspresent a view of science as ëinterestingí	Provide opportunities for students to engage in ërealí science investigations Learn and practice data gathering skills Know the historical and cultural context Make scientific inquiry interesting to students	Gathering data for use in real scientific analysis Evaluating data for validity Using valid data and historical and cultural ideas to make judgments
Engage students in exploring new ideasinvite a personal connection	Provide a personal connection with the content	
Create an interactive learning experience	Share group results and discuss alternative conclusions	Work collaboratively with peers
Allow teachers to guide learning in particular directions	Follow teacherís directed plan for learning the content	Complete tasks according to teacherís schedule

Discussion and Implications

The selections presented above demonstrate that both Eric Carter and Steve Noble make curricular choices that support their underlying beliefs and intentions. Despite considerable weather constraints, Eric Carter provides abundant opportunities for his students to gather the evidence they need to ëconstruct a storyí of plant and animal winter adaptations. Working within the rigid structure of a 7 period school day under a required common content sequence, Steve Noble is quite successful in ëmoldingí his studentís project activities to promote the interactive learning he values. Both teachers offer students a rich experience that correlates closely with the proficiencies promoted by the National Science Education Standards (NRC, 1995).

The clarity and coherence of their instructional decisions allows us to look at the process of curriculum creation in ways other types of research did not allow. Efforts to examine particular elements of a teacherís Pedagogical Content Knowledge (Shulman, 1987) out of context led to inconclusive findings regarding the influence of teachersí knowledge, beliefs and values on their instructional practices. Lederman and Zeidler (1987) were unable to correlate nature of science beliefs with teaching strategies. Hodson (1993) found few patterns of relationship between elementary teachersí philosophic beliefs and their science teaching. Cronin-Jones (1991) described cases in which explicit beliefs clearly influence novice teachersí implementation of a new teaching model. Brickhouse (1990) found similar relationships among veteran teachers. The case analysis presented in this paper provides more detail to affirm our conventional wisdom that indeed there are strong patterns of influence between teachersí beliefs and actions.

The example provided by these two respected science teachers remind us that "project-based science" approaches do not describe a single form of curriculum. Working in different contexts, each teacher offers students an opportunity to replicate the activities of research scientists, the key characteristic of project-based programs. These examples should encourage reform proponents that dissimilar teachers working in unique settings can construct a coherent curriculum that incorporates many recommendations found in the reform literature. This research should discourage the popular perception that a goal of education should be to find the "one" effective curriculum to produce desired learning outcomes. From the two situations described in this study, it is clear that there can be more than one form of productive project-based experiences.

The educational importance of this research does not come from its confirmation of our conventional wisdom that teachersí beliefs influence their practice. Its value comes from its effectiveness at promoting teacher reflection and consideration of curriculum choices. From her review of research on teachersí beliefs and their impact on instruction, Julie Gess-Newsome concludes that "the most effective source of teacher change [continues to be] reflectionÖ" (1998, p. 71). The Interview about Instances proved to be an efficient way to make teacherís beliefs explicit and available for reflection. The process of identifying and examining implicit beliefs, comparing them with teachersí intentions and classroom actions, can allow teachers to search for underlying consistency and inconsistency. Complementing teachersí personal examinations with concurrent review of student learning outcomes can provide a rich data source for understanding the factors that create the science curriculum that appears in classrooms.

Efforts to improve learning in science classrooms must consider the role of teachersí beliefs on the implementation of reform recommendations. In his forward to George Hillocksí new book, *Ways of Thinking, Ways of Teaching* , Lee Shulman reminds us of this truth: "Educational change must always be mediated through the minds and motives of teachers" (1999, p. vii). This project respects Shulmanís view and attempt to look closely at teachersí "important decisions (Harms, 1981)." Through the process used in this research project, choices often hidden from examination are revealed and can be used for study by educators in a variety of settings.

Two examples serve to show application of the Interview about Instances with inservice and preservice teachers. Eric Carter used selected hypothetical instances at his department meetings to stimulate discussion of the values and beliefs held by members of the science staff about "good" teaching. In a teacher training institutions, preservice science methods students and intern teachers used the instances to examine their philosophy of science teaching. In the practicum setting, use of the Instances to compare a host teacherís beliefs with an internís beliefs resulted in fruitful discussion of curriculum standards and realistic expectations for student learning.

One caution must be urged when applying this research protocol in attempts to modify teachersí practices. If, as Shulman and others claim, all change is mediated through the minds of teachers, the implication is that reform agents must change teacherís minds in order to effect durable change in their practices. Any outsiderís attempts to change teachersí beliefs demands serious consideration of the ethics of such practices. Sandra Abell and Larry Flick, in a JRST editorial, "Who do we think we are anyway?" (1997), capture this concern. They caution against researchers making judgments about practitionerís efforts based on limited data. Concern for each teacherís agency demands that researchers provide the vehicle for examining existing beliefs and facilitate discussion of the effectiveness of particular values, but the ëoutsiderí must allow the practitioner to retain responsibility for deciding what, if any, change is desirable.

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Appendix A: Conceptions of Teaching Science Instances

1. Jeff and Sabrina have several books open around their library table. The columns in their individual "food diaries" are gradually filling up with values for calories from fat, proteins and carbohydrates. Soon theyíll get started calculating the percentages of minimum daily requirement.

2. Paulaís father, Dr. Matthew Connors, volunteered to visit her class during Parentís Week. He brought with him a number of slides and transparencies of the finch and turtle species Darwin studied on the Galapagos Islands. Dr. Connors talked to the students about Darwinís understanding of natural selection and its influence on the types of living species we see on our earth.

3. Mrs. Steinmetz draws the Punnett square on the board as she explains the process to her ninth graders.

"By convention, we put the motherís pair of genes along the top of the box, then the fatherís two genes along the side. When we take one gene symbol from the top and one from the side to fill in each of the four central boxes, weíve determined the gene pair possible for each child."

4. Alex and Kev have home ec this year. They brought home a recipe for blueberry muffins their teacher demonstrated in class that day. They found all the ingredients in Kevís pantry so they went to work trying it out as soon as they got off the bus.

5. The thunderstorm had passed by quickly, but it left a steady stream rushing along the gutter. Julian and Margaret used sticks and litter to build dams while waiting for the school bus.

6. Mr. Carterís Environmental Science class scurried around the ballfields and along the driveways like insects. Each team had a black bag trailing behind, some heavier than others with man-made debris. They had all looked forward to Environment Day because they could go outside and enjoy the fine spring weather and do their part by collecting the winterís accumulation of trash around the school.

7. "Remember: be sure to record the contents of the titration tube after each change."

Mr. Douglas moved around each lab group and carefully noted whether students were following the written directions and the safety rules he had drilled with them earlier in the week. Several groups were moving through the list of steps quite efficiently. As usual, a couple of teams needed closer supervision.

8. Honors biology class came late in the day on Miss Panacekís schedule.

"Whatís the difference between eukaryotes and prokaryotes? Jason?"

"Thatís close. The prokaryotes donít have the same organization as eukaryotes. What does that mean, Sarah? What do we mean by ëorganizationí?"

"Ok. If thatís true, that bacteria donít have nuclei, then how are their functions controlled? I mean, we called the nucleus the ëcontrol centerí. Do bacteria have no ëcontrol centerí?"

9. Worksheet 6A required the students to sort their collection by whatever criterion they chose, then to draw a diagram of their classification system. Sean and Paula brought in a handful of acorns, and began separating them by cap shape. Paula was the better artist, so she started drawing their tree diagram onto the work space.

10. One lab group was huddled along the corridor, another had grouped their stools together at the lunch table. Deciphering the faint marks on the gel was going to be hard. Was this lane a double because of poor technique, or does it represent a specimen with a homozygous genotype?

Laba, 1

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