Influences on teachers' curricular choices in project-based science classrooms

Karen Anne Laba
University of New Hampshire, Durham

Follow this and additional works at: https://scholars.unh.edu/dissertation

Recommended Citation
https://scholars.unh.edu/dissertation/2021

This Dissertation is brought to you for free and open access by the Student Scholarship at University of New Hampshire Scholars' Repository. It has been accepted for inclusion in Doctoral Dissertations by an authorized administrator of University of New Hampshire Scholars' Repository. For more information, please contact nicole.hentz@unh.edu.
Influences on teachers' curricular choices in project-based science classrooms

Abstract
This descriptive research will present two case studies of experienced science teachers using project-based curricula in all or part of their secondary life science/biology courses. The purpose of this study is to reveal the underlying relationships between teachers' conceptions of the nature of science, their understanding of their role as science teachers and their expectations for appropriate and worthwhile student learning, and to describe the influence of these factors on their curricular choices within the project-based framework. Using a modification of Hewson, Kerby and Cook's (1995) Conceptions of Teaching Science protocol as a model, teachers' beliefs and intentions are classified and examined to identify organizing themes. Comparisons between teachers' beliefs and the actions they take in their project-based classroom are used to reveal relationships among the choices that result in students' learning experiences. Finally, the curricula presented by these two exemplary teachers are compared with the teaching standards and content goals defined in the National Science Education Standards (NRC, 1996). Recommendations for the application of the case study perspective of the evolution of learning experiences to reform efforts are offered to practitioners, policy makers, curriculum developers and teacher educators.

Keywords
Education, Curriculum and Instruction, Education, Sciences, Education, Secondary

This dissertation is available at University of New Hampshire Scholars' Repository: https://scholars.unh.edu/dissertation/2021
INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.
NOTE TO USERS

The original manuscript received by UMI contains pages with slanted print. Pages were microfilmed as received.

This reproduction is the best copy available

UMI
INFLUENCES ON TEACHERS' CURRICULAR CHOICES IN PROJECT-BASED SCIENCE CLASSROOMS

BY

KAREN A. LABA
B.A. Biology, LeMoyne College, 1971
M.S. Education, State University of New York at Cortland, 1980

DISSERTATION

Submitted to the University of New Hampshire in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

in

Education

May, 1998

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
This dissertation has been examined and approved.

Dissertation Director,
Dr. Eleanor Abrams
Assistant Professor of Education

Dr. Christopher F. Bauer
Professor of Chemistry

Dr. R. Valentine Dusek
Associate Professor of Philosophy

Dr. Susan D. Franzosa
Professor of Education

Dr. Joseph Onasko
Associate Professor of Education

March 25, 1998
Date

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
DEDICATION

This dissertation is dedicated to Eric Carter and Steve Noble and all the other exemplary teachers who work hard out of love for their profession and for their students. These individuals deserve our thanks and admiration not only for their current knowledge and expertise, but also for their dedication to continued growth. The commitment of exemplary teachers to their vocation results in consistent efforts to enhance their understanding of themselves, their role, their discipline and their students.

My hope is that every student has the good fortune to encounter at least one of these teachers during their school career. My personal challenge is to someday qualify to be counted among their number.
ACKNOWLEDGEMENTS

The intellectual and psychological challenges of completing this dissertation would not have been met without the help of a number of generous people. The participants, Eric Carter and Steve Noble, who granted me access to their thoughts and their classrooms are ‘exemplary’ models of generosity. The resources offered by each member of my committee served as invaluable resources. Dr. Joseph Onosko refused to let me avoid the hard thinking I needed to do, posing meaningful and demanding questions about my claims. Dr. Susan Franzosa insisted I maintain clarity of thought and writing necessary to strengthen my purpose. Dr. Valentine Dusek patiently guided my practical mind through the complex theoretical network of conceptions of the nature of science to improve the precision of my claims. By his example as an outstanding professor as well as a generous supporter of classroom teachers, Dr. Christopher Bauer reminded me that it’s what happens in classrooms that really matters.

My major advisor, Dr. Eleanor Abrams, deserves the most fervent gratitude I can offer for agreeing to work with me when little time was available in her fully committed schedule. Her gentle guidance and wholehearted enthusiasm provided the ideal support I needed to ensure the completion of this dissertation. She offers an exceptional model of collegial excellence.

Meeting the psychological challenge of the dissertation process required the assistance of wonderful friends and family. Classmates responded immediately when confidence lagged, sharing helpful ideas and kind consolation. Special thanks are offered
to Mimi, Val, Fred, and Carol. Sr. Denise and Sr. Georgette contributed their prayers and their praise to sustain my work.

Thanks are an inadequate expression of my gratitude for the support of my family. My husband of 28 years, Paul, patiently and lovingly pushed me to do my best, as he knew I would be satisfied with nothing less. Our younger son, Kevin, responded to crazy schedules and added duties with a remarkable maturity and self-sufficiency that allowed me to pursue my tasks with confidence. The long distance cheerleading of my older son, Keith, kept my priorities ordered and my determination intact. Sadly, my mother isn’t here for the completion of the dissertation, but my father has ably served as her delegate, encouraging me in the ways only parents know how.

This dissertation represents a product of many efforts, written through my hand but reflecting the collective contributions of all those mentioned. Thank you.
LIST OF TABLES

Chapter 3

Table 3-1: Classification Matrix ..................................................... 66
Table 3-2: Steps in Analysis Process ................................................... 67

Chapter 4

Table 4-1: Data Sources and Categories ............................................ 73
Table 4-2: Steps in the Analysis Process .............................................. 74
Table 4-3: Classification Matrix .......................................................... 75
Table 4-4: Eric Carter’s Beliefs About the Nature of Scientific Inquiry .... 85
Table 4-5: Eric Carter’s Beliefs and Intentions Regarding the Nature of Scientific Inquiry ................................................................. 90
Table 4-6: Eric Carter’s Beliefs, Intentions and Actions Regarding the Nature of Scientific Inquiry ............................................................. 96
Table 4-7: Eric Carter’s Beliefs On the Role of Project-Based Curriculum 101
Table 4-8: Eric Carter’s Beliefs and Intentions Regarding Project-Based Curriculum ................................................................. 108
Table 4-9: Eric Carter’s Beliefs, Intentions and Actions Regarding Project-Based Curriculum ............................................................. 114
Table 4-10: Eric Carter’s Beliefs Regarding Appropriate and Worthwhile Student Learning ............................................................... 123
Table 4-11: Eric Carter’s Beliefs and Intentions Regarding Appropriate and Worthwhile Student Learning ................................................... 129
Table 4-12: Eric Carter’s Beliefs, Intentions and Actions Regarding Appropriate and Worthwhile Student Learning ................................................... 134

Chapter 5

Table 5-1: Data Sources and Categories ............................................ 140
Table 5-2: Classification Matrix .......................................................... 141
Table 5-3: Steve Noble’s Beliefs About the Nature of Scientific Inquiry .... 148
Table 5-4: Steve Noble’s Beliefs and Intentions Regarding the Nature of Scientific Inquiry ............................................................. 151
Table 5-5: Steve Noble’s Beliefs, Intentions, and Actions Regarding the Nature of Scientific Inquiry ............................................................. 155
Table 5-6: Steve Noble’s Beliefs Regarding Project-Based Curriculum ................................................................. 160
Table 5-7: Steve Noble’s Beliefs and Intentions Regarding Project-Based Curriculum ................................................................. 165
Table 5-8: Steve Noble’s Beliefs, Intentions and Actions Regarding Project-Based Curriculum ............................................................. 170
Table 5-9: Steve Noble’s Beliefs Regarding Appropriate and Worthwhile Student Learning ............................................................... 176
Table 5-10: Steve Noble’s Beliefs and Intentions Regarding Appropriate and Worthwhile Student Learning ................................................... 179

vi
Table 5-11: Steve Noble's Beliefs, Intentions and Actions Regarding Appropriate and Worthwhile Student Learning ................................................................. 184

Chapter 6

Table 6-1: Comparison Related to the Nature of Scientific Inquiry ................. 202
Table 6-2: Comparison Related to Project-Based Curriculum ....................... 216
Table 6-3: Comparison Related to Appropriate and Worthwhile Student Learning ................................................................. 224
ABSTRACT
INFLUENCES ON TEACHERS' CURRICULAR CHOICES IN PROJECT-BASED SCIENCE CLASSROOMS
by
Karen A. Laba
University of New Hampshire, May, 1998

This descriptive research will present two case studies of experienced science teachers using project-based curricula in all or part of their secondary life science/biology courses. The purpose of this study is to reveal the underlying relationships between teachers’ conceptions of the nature of science, their understanding of their role as science teachers and their expectations for appropriate and worthwhile student learning, and to describe the influence of these factors on their curricular choices within the project-based framework. Using a modification of Hewson, Kerby and Cook's (1995) Conceptions of Teaching Science protocol as a model, teachers’ beliefs and intentions are classified and examined to identify organizing themes. Comparisons between teachers’ beliefs and the actions they take in their project-based classroom are used to reveal relationships among the choices that result in students’ learning experiences. Finally, the curricula presented by these two exemplary teachers are compared with the teaching standards and content goals defined in the National Science Education Standards (NRC, 1996). Recommendations for the application of the case study perspective of the evolution of learning experiences to reform efforts are offered to practitioners, policy makers, curriculum developers and teacher educators.
### TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEDICATION</td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iv-v</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>viii</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II. LITERATURE REVIEW</td>
<td>11</td>
</tr>
<tr>
<td>III. METHODOLOGY</td>
<td>55</td>
</tr>
<tr>
<td>IV. ANALYSIS OF ERIC CARTER'S BELIEFS, INTENTIONS AND ACTIONS</td>
<td>72</td>
</tr>
<tr>
<td>V. ANALYSIS OF STEVE NOBLE'S BELIEFS, INTENTIONS AND ACTIONS</td>
<td>139</td>
</tr>
<tr>
<td>VI. COMPARISON OF TWO EXEMPLARY TEACHERS' CURRICULAR CHOICES WITH THE NATIONAL STANDARDS</td>
<td>189</td>
</tr>
<tr>
<td>VII. CONCLUSIONS, IMPLICATIONS AND APPLICATIONS</td>
<td>227</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>261</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>274</td>
</tr>
</tbody>
</table>

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
CHAPTER 1

INTRODUCTION

"Teachers teach who they are." (Hawthorne, 1992) This simple-sounding aphorism reflects an increasingly influential perspective on the ways teachers make important teaching choices. Traditional notions of the teacher's role in the classroom, that of teacher as technician, or teacher as the deliverer of the curriculum, are inadequate to the task of understanding how classroom experiences emerge. If one accepts the conception Hawthorne suggests, that teachers' knowledge and beliefs and their resulting curricular judgments and decisions determine the learning opportunities which students encounter, then particular choices for the preparation and development of teachers and for the reform of teaching are implied. A perspective that teachers are the curriculum creators recognizes each teacher's responsibility to construct an appropriate and worthwhile experience for his students. A recognition that teachers' beliefs determine student learning opportunities disposes policy makers to allocate resources toward individual personal professional development plans. This dissertation takes Hawthorne's perspective on the role of teachers in the classroom experience, and follows this line of thought: teachers' beliefs influence their intentions; teachers' intentions influence their actions; the collective interactions of the teachers' beliefs, intentions and actions constitute the curriculum.

The purpose of this project is to address two questions: what are the relationships among exemplary teachers' beliefs, intentions, and actions? and how do the resulting classroom experiences for students correspond with the recommendations of the National Science Education Standards (National Research Council, 1996)? A study of the
influence of the beliefs of exemplary teachers on their curricular decisions can contribute to a growing body of knowledge about the influence of preservice and novice teachers' beliefs on the learning experiences presented to students. Two features distinguish this study from previous research: the use of exemplary teachers, and their choice of a project approach to science teaching. By focusing on how our "best" teachers implement an "ideal" form of science curriculum, we can obtain new perspective of the process through which effective classroom teaching emerges.

Two veteran biology teachers who are recognized by their supervisors and their peers as exemplary were recruited to participate in this study. One, a science department coordinator at a suburban high school, has been recognized as Environmental Teacher of the Year by the local chapter of a national environmental organization. During his twenty years of teaching, Eric Carter* has received superior evaluations from the students, his peers and his supervisors. In his current position, he is recognized for his teaching 'success' as well as his contribution to the growth of this progressive high school.

Steve Noble* was named "Teacher of the Year" at Lafayette* High School in 1992. He has spent all of his eighteen years of science teaching at Lafayette, a school known for its traditional excellence and its skill in blending students from the surrounding city neighborhood with their peers from a nearby suburban community. Steve reflects the perspective of his colleagues in setting rigorous standards for his own performance as he does for his students.

Conceiving of teachers as 'curriculum creators' (Connelly & Clandinin, 1988) has implications for various stakeholders with interests in education, including practitioners, curriculum developers, teacher educators and policy makers. With a library of cases from a variety of settings, curriculum developers are better prepared to consider the influence of teacher beliefs on the implementation of their designated plans. Cases like those

* Pseudonym
presented here allow practitioners, teacher educators and teacher preparation programs to offer prospective practitioners vivid examples of exemplary teachers in their varied classroom roles. When the relationship between teachers' beliefs and their delivered classroom lessons can be more clearly shown, then policy makers can target their improvement efforts more efficiently to incorporate teachers' existing conceptions into new programs and policies. Therefore, research projects like the one proposed here have the potential to inform several components of the educational process -- curriculum developers, teacher preparation programs, policy makers, as well as practitioners themselves.

In addition to curiosity about how classroom events emerge, educators and researchers are concerned about the effectiveness of the "learning opportunities" that are offered to students. A central question presents our concern: Are the activities teachers select consistent with those recommended by current reform documents? Recently, the National Research Council of the National Academy of Sciences (NRC, 1996), as well as the American Association for the Advancement of Science (AAAS, 1993) and the National Science Teachers Association (NSTA, 1992), have defined standards for student proficiency in science along with standards for the teaching of science. Because of the newness of the NRC and AAAS recommendations, few systematic comparisons between current practice and the defined ideals have been completed. The case studies of Steve Noble and Eric Carter provide the type of data needed for a useful comparison. Members of the science education community are curious to know if teachers who have been identified as "exemplary" within previous conceptions of professional excellence continue to be models of expertise when measured against the newest standards.

The purposes and direction of this study bring together several strands of research in education. A review of recent research supports three assertions: (1) teachers' beliefs play an important part in determining the learning experiences students encounter; (2) teachers' beliefs develop from the dynamic interaction of many factors; and (3) a
teacher’s choice of a project-based approach to science reflects distinctive beliefs about
science. A brief overview of these strands of inquiry will orient the reader to the
organization of this study.

(1) Teachers’ beliefs play an important part in determining the learning experience
students encounter. A central concern of formal educational systems is to provide
learners with opportunities to develop the knowledge, skills and habits of mind
characteristic of literate people (AAAS, 1989; Shymansky & Kyle, 1992). In classrooms,
the creation of student learning opportunities is significantly influenced by the teacher
research community, recognition of teachers’ critical role in the curriculum development
process is becoming a common focus of attention (Clark & Peterson, 1986; Lederman,
1992; Tobin, 1987; Tobin, Tippins, & Gallard, 1994). Understanding the influences and
context within which teachers make the curricular decisions that structure students’
classroom experiences represents a core professional challenge (Cronin-Jones, 1991;
Duschl & Wright, 1989). The detailed picture of the decisions Eric Carter and Steve
Noble make to carry out their curriculum plans represents a response to the call by the
research community for comprehensive descriptions of interesting cases from diverse
settings.

(2) Teachers’ beliefs develop from the dynamic interaction of many factors. In the
chapter on teacher thought processes in the Third Edition of the Handbook of Research
on Teaching, Clark and Peterson (1986) present a conceptual model summarizing
research on teachers’ thoughts and actions. Teachers’ thoughts are diagrammed as
simultaneously influencing and being influenced by their actions and students’ re-actions.
Some of the categories reflected in teachers’ thoughts about their classroom decisions
include pre-existing theories and beliefs about their discipline and their craft, as well as
preactive (planning), postactive, and interactive (on-the-fly) thoughts and decisions about
appropriate and worthwhile student learning (Clark and Peterson, 1986, p. 257). The
Clark and Peterson model explains that teachers' thoughts and actions are optimized or constrained by a variety of external forces, including community standards, peer influence, and local or national political forces. Clark and Peterson attempt a challenging task, to represent the relationship among the many variables teachers take into account in their classrooms. As they and others have discovered, though, a static model is unable to capture a teacher's ability to adapt to unexpected opportunities or constraints. In the case descriptions in the following chapters, the reader can examine some of the spontaneous choices Eric and Steve make for their students in the context in which they were made.

Complementing the Clark and Peterson model of teachers' decision-making is the work of Kennedy, Ball and McDiarmid (1993) with preservice teachers for the Learning to Teach Project at the National Center for Research on Teacher Education. They constructed a model of influences on teacher's instructional thinking that identified six major categories of influence on classroom decisions: teacher knowledge of the learner, of the nature of learning, of pedagogy, curriculum, and subject matter as well as teachers' conceptions of their role. Both the Clark and Peterson model and the NCRTE framework allow researchers to take a snapshot view of teachers' choices about what to teach and how to teach it. While this is a useful starting point, a more detailed understanding of how teachers select, integrate and balance competing classroom influences would be valuable. The case studies presented in this dissertation allow us to examine some of the variations in influences that contribute to the work of two different teachers using a similar approach to science, both of whom are identified by their respective communities as 'exemplary.'

(3) A teacher's choice of a project-based approach to science reflects distinctive beliefs about science. Science classrooms which are "project-based" typically place a greater emphasis on the practice of science than on the products of scientific research (Project-Based Science, 1997). A project-based science curriculum embraces a constructivist view of student learning (Fosnot, 1996) which recognizes that personal and
individual learning opportunities are the raw materials from which students construct new knowledge. Project-based classrooms encourage students to appreciate the complex, socially constructed nature of science by engaging them in activities that more closely replicate the activities in which practitioners participate (AAAS, 1989, 1993; GLOBE, 1996; NRC, 1996). In most cases, project-based classes involve students in similar skill development tasks as traditional exercises, such as use of measuring tools and microscopes, but project-based curricula differ in that they may allow students to formulate original research questions. Collaboration among classmates and presentation of results for review by others are common characteristics of project-based classrooms. Creating hypotheses and struggling with their modification or rejection are important experiences, which can encourage students to appreciate the tentative, probabilistic, developmental characteristics of the growth of scientific knowledge. Because answers to research questions are not known beforehand, teachers and students in project-based classrooms must struggle with the interpretation and evaluation of research data.

A project-approach to science curriculum offers teachers different challenges in their design of classroom events than they would face if their focus were on "covering" the textbook. By examining the beliefs, intentions and actions of Steve Noble and Eric Carter, we can determine if teachers who choose a project-approach for their students promote conceptions of science consistent with the intentions of the authors of the National Science Education Standards (NSES) (NRC, 1996). In addition to student learning proficiencies, the NSES includes a chapter of recommended Teaching Standards which the authors claim are likely to promote the goals for student learning contained in the Content Standards. Because the case descriptions in Chapters 4 and 5 include abundant detail, the learning experiences Steve and Eric create for their students can be compared with the recommendations of the NSES authors.

In addition to bringing together the three strands of research outlined in the preceding paragraphs, the research reported in this dissertation had to address an important
methodological concern. Since teacher's beliefs extend across a broad spectrum of possible themes, the type of data and the process by which it was collected must allow for diversity within a manageable analytical framework. The naturalistic paradigm as defined by Lincoln & Guba (1985) addresses the goals, intentions and expectations of this research project. Teachers' thought processes are a complex system, with non-linear relationships among an intricate network of forces that influence their beliefs and actions. The principles of the naturalistic paradigm as defined by Lincoln and Guba are suited to systems characterized by intrinsic complexity and non-linear, non-causal relationships.

Research on teachers' beliefs within more conventional traditions, using surveys and paper and pencil instruments, have been unable to reveal the complexity of thinking that characterizes teachers' curricular decisions (Lederman, Gess-Newsome, & Zeidler, 1993). In answering the questions, why am I here? and what am I going to do with these students?, teachers consider a wide range of beliefs often described in earlier research as "teacher knowledge" (Kennedy, 1990; Shavelson & Stern, 1981; Tom & Valli, 1990). It is understood that teachers' choices are bounded by their knowledge of their subject matter, by their repertoire of strategies and methods, by their expectations for student ability and behavior, by their interpretation of district, regional or national goals, and by the conceptions of what teachers ought to be (Hawthorne, 1992; Lederman, Gess-Newsome, & Zeidler, 1993; Tom & Valli, 1990). The naturalistic paradigm explicated by Lincoln and Guba (1985) and described in detail in Chapter 3, is based on an understanding that surveys and predefined written response tools often limit the range of data that can be gathered. An interest in seeing the complexity of the choices Eric Carter and Steve Noble make led to a decision to use naturalistic methods.

Within the naturalistic paradigm, researchers have developed a variety of ways to gather information about topics of interest, an important consideration for the accuracy of the data obtained (Gallagher, 1991). For the study presented here, a variation of the systematic protocol designed by Hewson, Kerby and Cook (1995) was used to analyze
teacher thoughts and actions from a variety of sources. The protocol consists of interviews, observations of classroom activities, review of curriculum materials and assessment tools, along with other relevant artifacts. Teachers’ statements and actions were classified and sorted, and descriptive themes assigned to major categories of thought. A comparison of these themes as they appear across teacher’s beliefs, intentions and actions served as the raw material for inferences about their influence on curricular choices.

Hewson, Kerby and Cook’s (1995) Conceptions of Teaching Science protocol was originally developed to address the need to capture the variety of teachers’ beliefs in a manageable form. They use teachers’ role model definitions as a basis for inferences about teachers’ beliefs, and a classification process that allows a comparison of data of different types. There is abundant evidence that teachers’ conceptions of their role, including descriptions of how they define their purposes as teachers of a discipline, is a common means by which they integrate a variety of beliefs (Briscoe, 1991; Brophy, 1982; Bullough, 1992; Tobin & LaMaster, 1995). There is also research demonstrating the power of role definition to determine curricular decisions (Crawley, 1990; Hawthorne, 1992). Using “conceptions of teaching science” as a framework for data gathering and analysis in this project has yielded a broad understanding of teachers’ conceptions of their discipline, their role, and their students.

An added advantage of the naturalistic paradigm for data collection and analysis is the considerate treatment it requires for participants in the study. The axioms and principles of naturalistic inquiry respect the ethical duties of the researcher who has been graciously allowed to explore the privacy of teachers’ thinking and make representations of teachers’ words and actions for her own purposes (Richardson, 1994). Chapters 4 and 5 present the analysis of the relationships among the beliefs, intentions and actions of Eric Carter and Steve Noble.
Chapter 6 addresses the application of this research to the increasingly influential national standards movement. The patterns revealed by the case descriptions presented in Chapters 4 and 5 are compared with relevant sections of the National Science Education Standards (NRC, 1996). Themes descriptive of teachers' beliefs and intentions are examined in relation to themes evident in the recommendation of the NSES. Similarities and differences between the curriculum enacted by two exemplary teachers and the recommendations of the NSES are significant because of their potential impact on the success of efforts to promote a common vision of ideal science teaching and learning.

In Chapter 7, the researcher offers additional commentary on the application of the case study descriptions presented in this dissertation to the preparation and continuing education of science teachers. Admittedly, the intention of developing descriptive case studies of two teachers is a modest goal. In his 1990 Presidential Address to the American Educational Research Association, Philip Jackson (1990) praised research that sets "modest goals" for itself because their investigators were more likely to derive understanding that is worthwhile and trustworthy. This research project does not claim that the relationships uncovered among its participants' beliefs and actions are directly applicable to other science teachers. Rather, the expectation is that the case reports will make a worthwhile contribution to a growing database that is used by curriculum specialists, teacher educators, and policy makers to establish realistic expectations for student and teacher behavior. Without a clear image of the modifications individual teachers impose on a designated program, curriculum developers cannot make reliable predictions about learning outcomes. Policy makers who select assessment tools need a comprehensive library of descriptions of curriculum implementation in varied settings to judge the validity of their interpretations of test results. Anticipating the types of classroom experiences teachers design requires some appreciation for the diversity of teachers' knowledge and beliefs and their influence on curricular choices.
By presenting examples of the use of case reports and the modified CTS protocol (Hewson, Kerby and Cook, 1995) in teacher development projects, teacher preparation programs, curriculum design efforts and school policy decisions, the author hopes to inspire renewed regard for the important role teachers' choices play in the lives of their science students. Just as teachers are advised to expand their repertoire of teaching strategies, education researchers are continually searching for more effective means to see the underlying foundation of experiences in schools. A case study approach offers a useful perspective.
CHAPTER 2

LITERATURE REVIEW

The purpose of this research project is to present two descriptive case studies of the relationships among the beliefs, intentions and actions of exemplary teachers as they structure the curriculum in their project-based science classrooms. Further, the case descriptions will serve as the basis for a comparison between the learning experiences enacted in these classrooms with the recommendations of science education reform standards. This study will provide practitioners, curriculum developers, teacher educators and policy makers with a detailed portrait of the evolution of lesson design in two project-based classrooms against which they can contrast their expectations for curriculum standards implementation.

In this chapter, evidence of the need for study of each of the two research questions is presented. These questions are situated within a large body of research addressing related issues, and summaries of relevant findings from other studies are provided for the reader. Finally, suggestions are made to show where these case studies of the relationship between teachers’ beliefs, intentions and actions in classrooms can enhance our understanding of the origin of classroom events in two project-based science classrooms.
Question 1: How do teachers' beliefs about scientific inquiry, school science curriculum and appropriate and worthwhile student learning influence their curricular choices?

The need to answer research questions about teachers' curricular choices is inspired by an interest in directing student learning in particular ways. Learning happens as a natural process of the human mind. New inferences are being proposed that suggest relationships between the physiology and anatomy of the human brain and psychological theories of learning (Gardner, 1985). We can see numerous examples of learning as infants succeed in controlling motor activities and toddlers construct intricate statements without any apparent structured 'teaching.' We each have abundant personal experience with unintended learning even in a school setting. Some incidental learning is trivial, as when students report how many polka dots are on the math teacher's tie, while some is significant, as when we see students negotiate complex social situations on the playground. Learning is not an activity that requires formal instruction, but occurs as human organisms interact with their surroundings.

Teaching, on the other hand, is an effort to influence the direction of learning toward some particular purpose, often within a formal setting. In general terms, the purpose of teaching is to facilitate understanding of the concepts being taught (White & Gunstone, 1992). 'Understanding' is a developmental process, growing with the increasing complexity of the learner's experiences with examples of the concept and his or her ability to link the concept to related ideas (p. 5). Much research has explored how student understanding is influenced by particular classroom events. If learning can be directed by shaping experiences, then the design and implementation of classroom
activities is an important concern. This study fits within a growing body of inquiry that examines how teachers make the curricular choices that create the classroom events for their students.

An interest in predicting and controlling student learning outcomes by controlling teaching activities is not a new undertaking among educators. In general, these efforts have been broadly defined as the key goal of "curriculum design" (Short, 1986). M. Frances Klein (1986, p. 31) calls curriculum the "substance of schooling -- the primary reason why people attend school." The curriculum represents the "stuff" of school, what students are supposed to learn. In this dissertation, Klein's definition of 'curriculum' is used to include the implicit and explicit attitudes and understandings promoted by teachers in two project-based science classrooms through their selection and implementation of learning activities. By looking at curriculum in a comprehensive way, this study will expand previous conceptions of curriculum, described below, which encompassed a more narrow view of learning experiences in classrooms.

**Theoretical foundations: Conceptions of curriculum**

Traditional models of curriculum design have focused on the classroom activities that students encounter. The Tyler (1949) model of curriculum design is guided by an interest in providing opportunities for students to practice clearly defined behaviors. This model expresses the prevailing notion from the first half of this century that the curriculum can be defined by laying out a set of activities for teachers to present to the students. Two assumptions implicit in the Tyler model are (1) students will respond predictably and uniformly to the set of learning activities, and (2) teachers will present the learning activities in a predictable and uniform manner. Neither assumption has been
shown to stand up when classrooms are observed in action. This model, with its focus on predetermined activities, still exerts significant influence among teachers in general, including science teachers, as a common way of deciding what and how to teach (Tobin, Tippins and Gallard, 1994).

Research involving observations of teacher planning protocols demonstrates that teachers are more likely to consider the selection of an interesting or easily managed activity as the central concern in planning lessons, as opposed to focusing on the needs of the learner (Jones & Beeth, 1995) or considering more comprehensive goals. The question not answered by research into an activity-based observation of classrooms is why teachers appear to make their planning decisions with such a narrow focus, and whether such decisions are consistent across a unit of study in their programs. Regardless of the method of planning that creates the ‘curriculum’ in any particular educational program, the important question is whether the intended learning outcomes have been achieved. This research will explore not only the derivation of the classroom activities which students encounter, but also the intentions of the teacher to promote particular conceptions of the subject matter among their students. By examining the process of creating classroom experiences more comprehensively, this study will provide insight that is lacking from current knowledge.

One fundamental premise of this study is that teachers’ choices control the curriculum that students engage. This conception of the way classrooms function differs from earlier beliefs. Early cautions against the Tyler model of curriculum design highlight its failure to account for teachers’ transformations of curriculum directions to adapt it to their own settings. For example, University of Chicago curriculum theorist

...
Joseph Schwab (1978) recommended that teachers’ perspectives be incorporated into curriculum development conversations (Westbury & Wilkof, 1978). In describing how curriculum specialists can facilitate the development of worthwhile learning experiences, he urged the developer or teacher trainer to remind each curriculum stakeholder -- teachers, learners, experts in the discipline -- of the importance of the viewpoint of the other (Westbury & Wilkof, 1978, p. 368). Schwab wisely expresses the importance of communicating the meaning of curriculum recommendations, not just the teaching patterns or content sequence. He reminds curriculum developers that

\[ \ldots \text{these meanings lie in the whole course of deliberations which created them. The meanings lie as much in what was decided against as what was decided for. (Those not) privy to all the deliberation, cannot, like bronze molders, take a terminal statement of purposes as a pattern and, from it, realize a curriculum.} \ldots \] (p 369).

Schwab reminds the education community that teachers are not programmable robots nor is curriculum analogous to a predictable, uniform software program.

The project described here takes Schwab’s message as a key principle: the decisions about what and how to teach in classrooms are made by the curriculum creators, the teachers. For good or bad, teachers’ choices create the learning experience students encounter. Their decisions have meaning for each bit of substance they explicitly and implicitly contain, and for each bit of substance they choose to omit. Efforts to produce “teacher proof” (Brophy, 1982) curriculum in science classrooms of the 1960’s failed to make long-lasting change in science teaching and learning, in part because the curriculum developers accepted Tylers’ assumptions that curriculum implementation would be uniform and predictable. Instead, as Schwab recommends, an effective curriculum effort must recognize teachers’ central role as the curriculum creators (Hawthorne, 1992). By
pursuing the investigation designed for this dissertation, we can examine closely not only
the classroom activities teachers enact, but the choices they make that result in the
learning experience their students encounter.

Growing recognition of the importance of teachers’ knowledge, beliefs and values
on the enacted curriculum led to several attempts to generalize teachers’ curriculum
decision-making processes. In a summary of research on the relationship between
teachers’ thoughts and behavior, Shavelson and Stern developed a model that considers
teaching decisions to be “well-established routines” (Shavelson & Stern, 1981, p. 483).
They discuss the difficulty constructing their schema because much of the research they
reviewed failed to account for variability of the context in which the subjects worked.
However, most of the studies in the Shavelson and Stern (1981) review are observation of
classroom behaviors, in keeping with the prevailing behaviorist tradition in the 60’s, 70’s
and 80’s.

By looking for common features in teachers’ decision-making strategies, Shavelson
and Stern (1981) presume that the appropriate unit of interest is the endpoint of the
decision process. Certainly, the final activities teachers implement are significant
because they create the explicit aspect of the curriculum students encounter. However,
questions about how teachers choose what they do are left unanswered because, as
Shavelson and Stern (1981) complain, the reports they reviewed omit or only cryptically
present the details of subject matter and setting that influence teachers’ decisions. It
seems that without those critical details, knowing that teachers make certain choices
offers little new information about the implicit and subtle attitudes and beliefs they intend
their students to acquire. The effort Shavelson and Stern present is a step towards
understanding the complexity of classroom life, but their focus on only the final behavior teachers exhibit in implementing curriculum decisions is limited in its ability to enhance an understanding of the curriculum creation process.

In another attempt to summarize diverse research on teachers’ thoughts and actions, Clark and Peterson (1986) prepared a comprehensive summary of research in classroom settings. Their review of research on teacher thinking, including decision making, implicit theories, expectations and attributions, is a summary of journal reports, dissertations, conference papers and technical reports concerned in some way with understanding how teachers’ thoughts play a role in classroom events. Clark and Peterson note that their search indicates this body of literature has a recent beginning, echoing Schwab’s call a decade earlier for more attention on each teacher’s role in defining classroom events.

They begin their summary by praising the work of Philip Jackson and his conceptualization of schooling. Jackson’s *Life in Classrooms* (1968) represents, in Clark and Peterson’s view, a “striking departure” from the experimental research predominant at the time (Clark & Peterson, 1986, p. 255). Jackson’s descriptive study captures more completely the complexity of life in classrooms by focusing attention on the decisions teachers make to carry out the duties of their role. In particular, Clark and Peterson praise Jackson for recognizing that prescriptive statements about how teachers *should* make choices and what proper teacher judgments *should* look like would be inappropriate without a larger knowledge base about teachers and their influences on the experiences students encounter.
Clark and Peterson’s summary offers the beginning outlines of teachers’ decision-making processes, particularly in the areas of content selection and conceptions of teachers’ role. It is clear to Clark and Peterson from the studies included in their review that teachers’ planning decisions do influence the “opportunity to learn, content coverage, grouping for instruction, and the general focus of classroom processes. Planning shapes the broad outlines of what is likely to occur (Ibid., p. 267).” This is the framework within which the case studies of Eric Carter* and Steve Noble* are defined.

Clark and Peterson’s review also revealed reliable descriptions of the relationship between specific beliefs and teachers’ choices. One that is relevant to this study is the effect of teachers’ conceptions of their influence on student learning. Clark and Peterson found that teachers’ attribution of the causes of student success or failure tended to contain a “humility bias” (p. 284) that limited teachers’ acceptance of credit for student success despite the fact that parents and others describe effective teaching as an important factor in the child’s performance. Clark and Peterson note that there is a lack of research into the explicit relationship between attributions of effectiveness and teachers’ interactive thoughts. Do teachers who believe they have a high degree of responsibility for student learning make different choices in classroom planning than those with a lower assessment of their impact?

The research presented in the case studies of Eric Carter and Steve Noble extends the Clark and Peterson summary and examines the relationship between teachers’ beliefs about worthwhile and appropriate learning for students and the intentions they express to promote particular learning expectations. By tracing the degree of consistency between teachers’ intentions and their actions in the classroom, we can see more clearly the

* Pseudonym
influence of teachers' beliefs on the classroom experience students encounter in these two settings.

The Clark and Peterson (1986) review also affirms the value of qualitative methodologies in the study of classroom events. They note that research that includes observation, interviews, stimulated recall and similar ethnographic methodologies are more prevalent in the studies summarized in their report than in the earlier Shavelson and Stern (1981) review. They praise the abundance of data obtained from qualitative studies of even small numbers of teachers and its illumination of complex events. However, they caution that there is still insufficient evidence about effective planning or decision-making to prescribe its use for teacher training or development activities (Clark & Peterson, 1986, p. 281). Generalizations are neither possible nor advisable since there is an insufficient body of research to identify common patterns of relationship between plans, actions, and student achievement. In fact, one of the characterizations that can be made of the research included in Clark and Peterson's review is its illumination of the great diversity of patterns among teachers' choices and curricular decisions.

A number of studies of the influence of teachers' beliefs on curriculum choices have expanded the researchers' methodological repertoire even further. Esther Zaret (1987) and others (Goodson, 1994; Zeichner, 1994) approached their examination of the impact of teacher beliefs on the enacted curriculum by using a phenomenological perspective. From their point of view, schools "are places offering planned opportunities . . . for quality, productive experiences in living for all who participate in them (Zaret, 1987, p. 47)." In such a place, 'curriculum' refers to an event that is "created, acted upon, and recreated when a particular group of people at a particular time in a particular school
setting work and play together in fulfilling their emerging purposes and directions (p. 47).” The phenomenological point of view exposes classroom events and their meaning as much more dynamic than previous “snapshot” views such as those of Shavelson and Stern (1981) or Clark and Peterson (1986). It is assumed that teachers’ beliefs form the basis for their intended actions, but teachers’ beliefs are contextually bound so that adjustments and modifications are not only possible but to be expected. It becomes imperative, then, that observers of the educational enterprise consider the interaction of teachers’ beliefs and the dynamic flow of classroom events to identify patterns and connections that might help describe curriculum evolution in comprehensive and holistic ways. In one sense, this view of the importance of teachers’ beliefs on curriculum definition encourages the empowerment of teachers as the designers of student learning experiences in science classrooms.

Theoretical foundations: Conceptions of learning

The need for this study focuses primarily on the need to understand how teachers make the curricular choices that define student learning opportunities. Conceiving of curriculum as a teacher-created product, influenced by teachers’ knowledge, beliefs, and values, requires that we examine some of the areas of teachers’ beliefs that influence their decisions. A teachers’ beliefs about how students come to know and understand the concepts being taught are a key category of study in this dissertation.

It may seem trivial to assert that students’ learning experiences play an important role in what they come to understand. Yet the philosophical and psychological perspective from which we describe how student learning takes place is an important consideration in deciding whether the research presented in this document contributes to
our knowledge of science teaching and learning. Judging a student's potential for understanding a particular concept is an important part in the curriculum creation process for teachers. Teachers' knowledge of their students along with their knowledge of their discipline combine to inform curricular choices. Learning happens without effort, as mentioned before, but teaching imposes a purpose or direction that has as its goal the understanding of an idea. To understand the reasons behind teachers' curricular choices, it is important to understand what teachers believe about the process of learning and about what counts as worthwhile knowledge.

As asserted above, teachers' knowledge of their students along with their knowledge of the discipline combine to influence curricular choices. Teachers' knowledge of their students exist along a continuum between traditional views of student learning and contemporary perspectives. The notion that learning becomes understanding within the mind of the learner and that understanding can be changed by appropriate interactions within a formal setting are components of constructivist learning theories, one of predominant contemporary theories (Fosnot, 1996; vonGlasersfeld, 1992). Acceptance of a constructivist view of learning implies that the learner is an active participant in the learning process in contrast with traditional views that consider students to be passive recipients of knowledge. The Tyler model of curriculum design implied that students would acquire a common set of understandings by participating in common classroom experiences, a view typical of the traditional behaviorist theory of learning. The constructivist view broadens the expectations for learning that behaviorists propose will result from particular classroom events. A teacher who believes students ought to acquire uniform understanding as a result of their teaching is likely to make different curricular
choices than a teacher who expects diverse learning outcomes from his/her curriculum plans.

The constructivists' hypothesis that learners integrate interpretations of new experiences within existing knowledge frameworks is supported by research on students' alternative conceptions (misconceptions) in science (Fosnot, 1996; Hewson & Hewson, 1988). Student's theories for natural events represent reliable explanations based on their life experiences, but may not hold up under carefully designed new events (Posner, Strike, Hewson, Gertzog, 1987). As is true for many scientific theories, students' explanations are durable within a narrow range of events and may remain durable unless confronted with compelling contradictions that are supported by more conventional explanations. This aspect of constructivism raises questions not only about how student learning in science proceeds, but also about the history of scientific theory building (Duschl, 1990).

Another variation on the constructivist theme assigns an important role in the development of new ideas to the social context in which understanding develops. Ideas and interpretations of experiences are shared and communicated, minimizing their idiosyncrasies and providing a sense of shared reality (Hawthorne, 1992; Vygotsky, 1978). While constructivism is generally considered a theory of learning, it has strong epistemological implications. If knowers (including students) construct their own theories of the natural world, then constructivism as an epistemological position challenges the certainty of truth proposed by traditional views of reality. If knowers share their explanations, then reality is best thought of as a product of consensus, not a preexisting structure outside the knower (Berger and Luckman, 1966).
As a theory of learning, constructivism has some of its origins in the work of psychologists Jean Piaget and Lev Vygotsky in the early and middle twentieth century (Fosnot, 1996; von Glasersfeld, 1992, 1996). In *Genetic Epistemology* (1970), Piaget describes children's learning as a process of accommodation, a merging of new experiences with existing hypothetical or theoretical frameworks developed during previous life experiences. Piaget explained that growth in knowledge proceeds as new experiences are assimilated into a holistic conception of the world or accommodated by modification of existing beliefs.

Lev Vygotsky, a Russian psychologist active in the 1920s whose work only became widely available in the 1960s, offered an explanation of learning that centralized the role of social interaction in its development (Vygotsky, 1978). Vygotsky proposed that the mind is not a network of generalized capabilities like memory and judgment, but rather a set of capabilities tied to the context in which capabilities were developed (Vygotsky, 1978, p. 82). This assertion challenged the certainty of knowledge and its growth by accumulation as proposed by traditional thinkers. It also questioned the assumptions of the behaviorists who believed learning to be characterized as a direct input-output process (Fosnot, 1996). If the human mind learns in a social context, as Vygotsky suggests, there are important considerations for teachers in their design of classroom events.

A look at the principles defined by the AAAS in 1989 can highlight the contrast between constructivist-guided conceptions of the nature of scientific inquiry and the traditional behaviorist view. The AAAS statement, “Scientist try to identify and avoid bias” (AAAS, 1989, p. 28) has quite a different implication than the notion that objectivity can be achieved by means of adherence to proper method. “Science is not
authoritarian," declare the AAAS authors (AAAS, 1989, p. 28), while the search for absolute truth is a central goal of science within the traditional paradigm. One hypothesis of this dissertation research is that teachers’ beliefs along a continuum between traditional and contemporary will influence the science experiences they design for their students. Descriptions of teachers’ beliefs contain fragments of the predominant traditional paradigm, along with elements from the contemporary view known as constructivism influenced by Piaget and Vygotsky. Representing the complexity of teachers’ views as accurately as possible is an important goal of this project.

Constructivism as a philosophical explanation for the growth of knowledge borrows many ideas from its predecessors in psychology and philosophy of science, but applies these ideas more broadly to many forms of knowledge acquisition. Social constructivists clearly show the influence of Vygotsky. Piagetian psychology is evident in the constructivist explanation of the developmental nature of learning. In its discussions of conceptual change teaching, constructivism borrows heavily from Kuhn’s exploration of scientific ‘paradigm shifts.’ While different in significant respects from nineteenth century positivism, constructivism retains positivism’s reliance on the value of an individual’s experiences in the evolution of concepts and the growth of knowledge (Matthews, 1992).

A constructivist description of how learning happens has implications for how teaching is conducted in schools as well as implications for how observers interpret what they see in classrooms. In many classrooms today, the learner is rewarded for individual efforts. In a constructivist classroom, learners would be praised for sharing divergent interpretations with their classmates. The relationship between teachers’ beliefs about
student learning and the classroom activities he/she intends and enacts can only be
determined by probing potentially diverse and contextually specific ideas. Belief in a
constructivist theory of learning defines the direction of this research project and guides
the observations in the classrooms that were visited.

Theoretical foundations: Conceptions of scientific inquiry

In this research project, teachers' conceptions of the nature of scientific inquiry is the
area of science content that were probed for its influence on curricular choices. As stated
earlier, teachers' beliefs about their students combine with their beliefs about their
disciplines to influence their choice of curricular activities. Philosophers of science,
science educators, and scientists have proposed multiple definitions of the nature of
scientific inquiry. Conceptions of the nature of science has only recently become an
explicit topic in science, particularly since the call from the American Association for the
Advancement of Science in 1989 (AAAS, 1989). In the view of the education committee
of this prestigious organization, a conception of the nature of science includes three
aspects: the scientific world view, scientific inquiry, and the scientific enterprise (AAAS,
1989, p. 25). The five principles of 'scientific inquiry' defined by AAAS are of interest
for this study: science demands evidence; science is a blend of logic and imagination;
science explains and predicts; scientists try to identify and avoid bias; and science is not
authoritarian. (AAAS, 1989, p. 28). These principles have been adopted by the AAAS
for its definition of learning standards in the Benchmarks document (AAAS, 1993), as
well as guiding the efforts of the National Research Council in the development of the
National Science Education Standards (NSES) (NRC, 1996). Several of these principles
are strikingly different from traditional views of the nature of scientific inquiry. While
considered the currently “acceptable” view of scientific inquiry among science educators, the AAAS definition does not necessarily reflect the beliefs of practicing science teachers or of philosophers of science. Even exemplary practitioners are likely to hold beliefs about science that reflect traditional principles rather than the contemporary proposal of AAAS.

Philosophers of science propose descriptions of the nature of science that have as many idiosyncrasies as do the descriptions of science educators (Lederman, 1992). In fact, Lederman describes the concept of the nature of science as being as complex, organic, and tentative as scientific knowledge of the universe or ecosystems! (p. 352) What tends to be common among philosophical descriptions of the nature of science is agreement that a description of the nature of science should include explanations of the “generation, replication and validation of scientific knowledge” (Jenkins, 1996, p. 143). Some commentators also add the “values and assumptions inherent to the development of scientific knowledge” (Lederman, 1992, p. 331). Within this broad area of agreement, there is a great diversity of patterns considered to fit within the category of ‘nature of science’ and among it subsidiary categories including the nature of scientific inquiry that is of interest in this research.

During the first half of this century science textbooks and curriculum guides reflected a belief that knowledge of the “truths” discovered by science should be the basis of a well structured science curriculum (Kyle, 1984). This belief flows from predominant conception of science proposed by Berkeley and Hume (Bentley & Garrison, 1991) and captured under the heading “positivism.” No one definition of the nature of science reflects a perfect representation of ‘positivism,’ though a range of ideas can be defined.
Philosophers of science use several distinctions in their attempt to describe a complete vision of the “nature of science.” The nature of scientific knowledge is described along the range from absolutist to tentative. Ontologically, scientific theories can be seen as an accurate representation of existing natural laws, or they can be classified as a tool for human inquiry (Jenkins, 1996). Historically, it is clear that there are leaps of creativity and intuition that contribute to the growth of scientific knowledge but which cannot be completely explained by adherence to a single ‘scientific method.’

A common claim among the many variations of positivism that have been proposed is that objectivity is possible and that scientific method can be clearly defined. Early in the twentieth century, philosophers of the Vienna Circle proposed a “logical” positivism that recognized that laws cannot be directly induced from empirical evidence (Bentley and Garrison, 1991). This variation on the general positivist theme is complex and less influential within the general culture. For the most part, the positivist and logical positivist conceptions of the nature of science implied a real universe independent of the knower, whose laws were waiting for discovery (Oldroyd, 1986).

While it is true that positivism and logical positivism were philosophical descriptions of the nature of science and not intended as theories of science education, their influence can be seen throughout the culture of the nineteenth and twentieth centuries, with particularly obvious examples in science curricula (Duschl, 1990). The positivist/ logical positivist explanations for the growth of science were intuitively appealing (von Glasersfeld, 1996). Darwin’s inferences complemented with Mendel’s systematic analyses provided the framework for a leap in understanding of living systems. The
physics of the eighteenth century had direct links to the tremendous changes wrought by
the Industrial Revolution. The ‘evidence’ cited for a positivist view was compelling.

Since the emergence of science as a separate discipline in school, science educators
have considered it an important goal to encourage the development of an adequate
conception of the nature of science in their students (Lederman, 1992). In most cases,
science teachers considered the nature of science to be synonymous with implementation
of the ‘scientific method’ (Kyle, 1984). Heavily influenced in their own scientific
training by the positivist paradigm, most science teachers of the past fifty years have
promoted a belief that scientific process can assure proof of a theory, that facts are
objective if obtained with the proper method, and that scientific progress occurs as
knowledge accumulates (Brickhouse, 1990). Despite alternative explanations of the
nature and growth of scientific knowledge that have emerged among philosophers and
historians of science, most practicing teachers present a view of science that is realist
about the existence of a natural world whose laws are waiting for our discovery.

Science textbooks became a compilation of the facts of science, the marvelous
products of scientific inquiry that made possible the incredible technological advances of
the late nineteenth and early twentieth century. Scientific knowledge was thought to be
an accumulative process. As a result, curriculum experiences for students within the
positivist paradigm included attention to the discoveries of scientists who have come
before, in the belief that students could build on their foundation of ‘truths’ to continue
the search for the ultimate answers to questions about the natural world (Benson, 1989).
The belief that facts lead to theories, theories to laws was formulated into curricula that
emphasized strict adherence to proper scientific method in order to assure that the facts being discovered were reliable and free of subjective bias.

In contrast, the perspective implied in the AAAS definition of scientific inquiry has come to be known as "postpositivist" (AAAS, 1989). The American Association for the Advancement of Science recommends treatment of three aspects of the nature of science in American classrooms: the scientific world view, the methods of scientific inquiry, and the implementation of the scientific enterprise (AAAS, 1989). The postpositivist influence is evident in each of the three strands. According to AAAS, a scientific "world view" recognizes that knowledge is subject to change, though it is typically quite durable.

Another important declaration in the document is that science cannot provide answers to all questions of human interest. AAAS asserts that an emphasis on the empirical nature of science is a significant characteristic of its methods (though sufficient historical examples exist of the growth of theories before empirical verification!). Rules of evidence that require openness and replication distinguish the scientific process from other forms of inquiry in human societies, while the recognition that science, like art and other creative endeavors, makes use of imagination as well as logic in the formulation of its ideas (AAAS, 1989, p. 26-27).

In describing the 'scientific enterprise,' AAAS points out that science is a social activity, engaged in by practitioners of all cultures and associated with a variety of institutions. Since it is a social activity, scientists are subject to ethical principles in the conduct of their work which respect the values of the society at large. AAAS also reminds the reader/teacher that scientists are part of their community and participate in public affairs not only as scientists, but as citizens as well, with no greater nor less
expertise in certain areas than other citizens (AAAS, 1989, p. 30). Each of these recommendations differs in varying degrees from a traditional view of science as the means of discovering universal “truth,” which characterizes the presentation of a majority of professors of science.

The National Science Education Standards (NSES) (NRC, 1996) is another major document promoting a particular conception of the nature of science. This document defines what students in particular grade levels should know and be able to do as a result of an ideal school science program. For example, in grades 5-8, students should understand that science is a human activity in which people from diverse backgrounds but with similar sense of interest and curiosity participate. The methods of science include dependence on empirical evidence, which is openly shared with others and which is subject to varying interpretation. Critical review of the work of others is an important part of the search for new understanding, and differences among scientists in similar areas are to be expected and admired (NRC, 1996, p. 171).

According to the NSES, students in grades 9 - 12 should be prepared to discuss the ethical demands on scientific research, and to recognize that scientists are as influenced by cultural norms as are the non-scientists. Students in the higher grades can also be expected to appreciate that scientists exhibit a high degree of skepticism, and demand reliable evidence to support a claim. The uncertainty and incompleteness of scientific knowledge are better understood by older students, whereas younger ones might have difficulty with the concept of uncertainty (NRC, 1996, p. 201).

It shouldn’t be surprising that the AAAS and NRC documents present similar views of the nature of science, since both arise from a common foundation of the postpositivist
philosophies of science, and constructivist views of teaching and learning. These represent the prevailing theoretical paradigms within the field. On the surface at least, this conflicts with the conception of the nature of science that can be seen in the typical science classroom, where the positivist description of science persists in textbooks and among teachers (Gallagher, 1982; Kyle, 1984). Chemistry teachers display gum drop models of atoms promoting the belief that atomic structure is fixed and observable. The pathway of carbon dioxide in photosynthesis is memorized as if some really smart person had cleverly followed a molecule through its pathway. Seldom are the conflicting data retained when students compare results from their experiments. The “right” answer is the goal, and outliers are to be ignored or explained away. This dissertation presents a detailed exploration of the negotiations teachers conduct when making curricular choices concerning the nature of their discipline, in order to satisfy their obligations to students, to standardized tests, to their profession, and to their personal beliefs.

Contribution to existing knowledge

As mentioned in earlier comments, the case studies of two exemplary teachers presented in this dissertation are intended to expand our knowledge of the emergence of curriculum from the point of view of teachers’ beliefs about their discipline, their role in defining learning experiences and their conceptions of appropriate and worthwhile student learning. Previous research has provided interesting snapshots of teachers’ thoughts and actions. Unfortunately, the models they present fail to capture the full context of the setting in which teachers’ thoughts become intentions that are later enacted into classroom activities. This dissertation offers a more comprehensive view, tracking
common ideas between teachers' beliefs and their intentions, and between curriculum intentions and classroom actions.

Clark and Peterson's (1986) pivotal review of research on teacher thinking established that teacher beliefs are important determinants of teachers' choices. The phenomenological perspective used by Zaret (1987) and others (Beeth, 1998; Roth, 1992; Roth, McGinn & Bowen, 1998) provided an expanded means by which we could understand and interpret teachers' influence on the enacted curriculum. A number of research studies have extended Clark and Peterson's conclusions and asked questions about the influence of specific knowledge, beliefs and values about science on the enacted curriculum. These studies have contributed to our growing knowledge about the evolution of student learning opportunities in science classrooms.

Cornett, Yeotis & Terwilliger (1990) used the phenomenological perspective in their study of a beginning science teacher. If teachers' beliefs influence instructional strategy, they asked, then would it be possible to infer teachers' guiding theories from observations of their teaching behavior? In this study, a beginning teacher, a researcher and the teacher's supervisor made inferences about the "personal practical theories" that seemed to guide the teachers' actions over the course of twenty lessons. Surprising congruity between the three independently inferred "theories" were discovered. Cornett et al concluded that teachers' beliefs which have emerged from prior life experiences both inside and outside classrooms, are one of the bases of teachers' actions in classrooms and can be accurately inferred by observers. The analysis of the Cornett investigation suggests that students, as 'participant observers' in the classroom events designed by the teacher, would likely be able to infer particular beliefs embedded within teachers'
actions. It would be difficult to detect this component of the enacted curriculum without examining both teachers' actions along with their supporting beliefs. Cornett and his colleagues suggest that more descriptive case studies of the influence of teachers' beliefs on student learning should be undertaken to see how clearly those beliefs are reflected in classroom actions. The dissertation presented here is a response to that recommendation, with particular focus on veteran teachers who are known to be effective in promoting student learning. This study complements Cornett's work with novice teachers and expands our understanding of how classroom lessons are related to teachers' beliefs.

The Cornett research was a description of evidence for the observable nature of teachers' implicit theories. Other investigators have looked at the influence of science teachers' beliefs in a variety of domains, but three topics are of particular interest: (1) teachers' beliefs about teaching and learning (Cronin-Jones, 1991; Hashweh, 1996; Hewson and Hewson, 1989; Hodson, 1993; Tobin & LaMaster, 1995); (2) teachers' beliefs about the nature of science (Brickhouse, 1990; Gallagher, 1991; Lederman, 1992; Lederman & Zeidler, 1987; Meichtry, 1993; Milne & Taylor, 1995; Pomeroy, 1993; Tobin & Espinet, 1989); and the influence the previous two beliefs on the selection of worthwhile learning activities (Lederman & Gess-Newsome, 1991). These investigations have been primarily descriptive, while a few attempted to modify practices and observe changes in beliefs. In each case, it is clear that teachers' knowledge and beliefs can promote or prevent changes in teaching effectiveness (Shymansky & Kyle, 1992).

A review of the research related to the first topic, teachers' beliefs about teaching and learning science, demonstrates the durability of teachers' beliefs. Linda Cronin-Jones (1991) found supporting evidence to complement the research of Roberts (1982)
and Smith and Anderson (1984) who concluded that teachers have difficulty implementing curricula which emphasize values different from their own. In science reform efforts, Smith and Anderson found that differences between the intended and enacted curriculum could be accounted for specifically by differences between teachers' beliefs and those proposed by curriculum developers about learning and the nature of science. Cronin-Jones (1991) prepared a case study of two middle-school science teachers and described in detail how their beliefs influenced their enactment of a discovery-approach science curriculum.

One participating teacher, “Marcy,” believed that factual content was the most important learning product of science class, so often chose drill and practice activities rather than the open-ended exploration as instructed in the designated curriculum. The second teacher, “Shelley,” did not think that the content of the new program “covered” the necessary material from the district curriculum, so she shortened the intended sequence of lessons to accommodate her sense that students “needed” more time with other topics. Cronin-Jones suggests that “Marcy” and “Shelley” might make curriculum choices more in keeping with program recommendations if their beliefs about student learning and appropriate and worthwhile curriculum were different. The research project presented in this document is a variation on the Cronin-Jones (1991) work. In the cases selected for this study, veteran teachers will have made the decision to pursue a project-based approach with their secondary science students. Will the relationship Cronin-Jones found between beliefs and curricular choices for novice teachers hold true for veteran teachers who are more confident and respected in their classroom efforts?
The recent shift in understanding about learning derived from studies in cognitive science supports the conclusion of Cronin-Jones and others that teachers' beliefs are durable despite change efforts. Most recommendations for reform of science education cite the constructivist description of knowledge acquisition, rather than the behaviorist tradition that has guided teachers and curriculum specialists until recently (AAAS, 1989 & 1994; NRC, 1996). However, most veteran teachers typically have trained and practiced within the behaviorist tradition, a viewpoint that also guides most textbook development efforts. Serious concerns arise when predicting whether the "new" wave of reform, represented by the AAAS and the NSES recommendations, will be successfully implemented. A comparison between the enacted curriculum of the two veteran science teachers reported in this study and the vision of ideal science teaching presented by the reform advocates can be used to enact responsible, realistic implementation goals.

The second category of teacher beliefs of interest in this project is teachers' conceptions of the nature of science. Cronin-Jones' (1991) case studies indicate a strong relationship between teachers' beliefs and their curricular choices. In science classrooms, teachers' beliefs about the nature of scientific inquiry and the values of the scientific enterprise exert a significant influence on the types of learning activities the veteran teachers selects. Nancy Brickhouse (1990) designed a study of veteran science teachers that test Gallagher's claim that students have little opportunity to develop an accurate or appropriate understanding of the nature of the scientific enterprise because of the generally traditional epistemological slant of teachers and of textbooks (Gallagher, 1991).

The Brickhouse study is a particularly vivid example of the power of traditional teacher beliefs about the supremacy of method and the importance of knowledge of the
products of science on curricular decisions. In her case studies of veteran science teachers who had different beliefs about the purpose and power of scientific theories, Brickhouse was able to demonstrate a direct connection between teacher beliefs and student learning experiences. One of Brickhouse's teachers, "Lawson," held an instrumentalist view of scientific theories, believing that theories were tools with which to explore the natural world. She designed learning experiences in which students could explore the implications of scientific theories and examine the supporting evidence for their assertion as well as use them to solve new problems.

"Cathcart," Brickhouse's other participating teacher, believed that theories were universal truths that had been discovered by means of a strict set of procedures to assure their accuracy. This teacher designed learning experiences in which students could 'prove' for themselves examples of the truthfulness of prevailing theories. In "Cathcart's" classes, assessment of learning involved student's presentation of their knowledge of the correct theories and recall of memorized examples. In a dramatic example of the role of teachers' beliefs on classroom experience, "Cathcart" chooses to omit the topic of evolution from his curriculum because he believed this scientific theory contradicted his religious beliefs. For this teacher, scientific "truths" were subordinate to his religious beliefs (Brickhouse, 1990, p. 55). As a consequence, student learning opportunities in this class were significantly restricted.

Deborah Pomeroy (1993) constructed a survey to compare the prevalence of traditional conceptions of science with non-traditional views among three populations: elementary teachers, secondary science teachers, and practicing scientists. Her finding that traditional views of science -- that scientific knowledge is about objective reality and
the purpose of science is to define precise natural laws—are more strongly held by scientists than the other groups at least partly explains the durability of "normal" science, in Kuhn's terms (Kuhn, 1949/1970). The training of practicing scientists within the traditional positivist paradigm of scientific thinking reinforces their acceptance of traditional positivist views. Contemporary descriptions of the nature of science are more prevalent in science education literature and conversation than in the conversations of professional scientists (Bentley & Garrison, 1991).

Pomeroy's (1991) study revealed that elementary teachers expressed more non-traditional conceptions of science than scientists did. They considered intuition and creativity to be an acceptable part of the development of scientific theories. They agreed with statements suggesting that earlier theories might be discarded when new explanations are more useful. Since it is true that, of the three populations Pomeroy surveyed, elementary teachers typically have fewer courses in science, it seems reasonable to conclude that they are less attached to the "normal" science paradigm and more open to the post-positivist perspective presented in the newest reform recommendations. The study described in this dissertation will examine whether Pomeroy's findings are true even for exemplary science teachers using project-based approaches to teaching.

The conclusions of these three research projects -- Pomeroy's findings that teachers' beliefs about the nature of science have their origin in their science training and Brickhouse's and Cronin-Jones's inferences that teachers' beliefs about the nature of science influence in clear and direct ways the types of learning experiences teachers design for students -- will be complemented by the research described in this dissertation.
Extending beyond previous research, these studies of Eric Carter and Steve Noble will look more closely at how teachers balance the choices they make with the demands and constraints presented by their participation in a complex school environment. In all the research examples cited above, teachers were required to make their curricular decisions within a setting that presents significant constraints on their flexibility in making choices. To describe a broad range of interactions, this study examines not only the activities teachers included in their lesson designs, but explores some of the choices that are not included.

While the findings of Pomeroy, Cronin-Jones and Brickhouse are compelling, contradictory evidence has also been reported regarding the influence of teachers’ beliefs on their choices. Both Hodson (1993) and Lederman and Zeidler (1987) caution against asserting a clear and direct relationship between teachers’ beliefs about the nature of science and the actual classroom experiences they design.

In what appears at first glance to be a contradiction to the conclusions of Brickhouse (1990) and Cronin-Jones (1991), Hodson (1993) found that science teachers’ philosophic stance was not a direct determinant of teachers’ classroom behavior. Conflicting events could cause teachers to select learning activities that contradicted their personal beliefs about what science is and how it is best practiced. It appears from Hodson’s (1993) work that the “nature of science” takes on different meanings when teachers think about the context in which it is applied. For instance, the nature of science as an endeavor of professional scientists suggests certain activities and curricular choices. On the other hand, the “nature of science” that is accessible and worthwhile to learners at a particular level suggests very different types of activities and lessons to the teacher. Teachers’
responses to questions on surveys and tests regarding the nature of science will be influenced by the context in which the question is posed. Hodson (1993) cautions against using teachers' responses as an accurate measure of the beliefs that are in effect during their daily work.

Lederman and Zeidler (1987) reached a similar conclusion. They used Rubba and Anderson’s (1978) Nature of Scientific Knowledge Scale to select a sample of teachers they describe as “high” and “low” with respect to their agreement with a conception of science proposed by the NSKS survey. Lederman and Zeidler defined 44 classroom variables based on observations of “high” and “low” teachers and found no correlation between the teacher’s conception of science and the choice of classroom activities. From the lack of relationship between classroom observations and NSKS test scores, Lederman and Zeidler (1987) conclude that teachers’ beliefs are not as certain determinants of classroom behavior as others claim.

Hodson (1993) and Lederman and Zeidler (1987) suggest that the relationship between teachers' beliefs and their actions is not as clear-cut as the conclusions of Brickhouse (1990), Pomeroy (1993) and Cronin-Jones (1991) might imply. One explanation for the discrepancy is that the methods used in the studies of Hodson and Lederman and Zeidler were unable to reveal connections that are subtle or fleeting. For the research conducted in this study, the need for a data gathering process that allows detection of intricate and apparently conflicting ideas was considered essential. As Hodson found, the context in which teachers consider the nature of science influences their assessment of the meaning. In this study, the Conceptions of Teaching Science Protocol (CTS) (Hewson, Kerby and Cook, 1995) presents ideas about science in a
variety of contexts. The CTS method allows a broader range of responses than the limitations of the NSKS that were noted by Lederman and Zeidler (1987). By looking not only at teachers’ stated beliefs about the nature of science in simulated instances, but by also questioning teachers’ understanding of the demands of the designated curriculum and their expectations for student interests, aptitudes and abilities, a more comprehensive depiction of influences on teachers’ choices emerges from the data gathering process. In one sense, this research project will attempt to reconcile the apparent contradictions between the conclusions of Lederman and Zeidler (1987) and Hodson (1993) and Cronin-Jones (1991) and Brickhouse(1990).

One important outcome of the growing body of knowledge about the influences of teachers’ knowledge and beliefs on curricular choices is a recognition of the uniqueness of each case. There is likely to be a great deal of difficulty capturing that variation without resorting to an oversimplification of complex concepts and actions for the sake of ease of data management. Some researchers have reported success by considering metaphors as a means of encapsulating broad belief sets and conceptual structures within manageable forms (Briscoe, 1991; Tobin & LaMaster, 1995). For the purposes of this research, teachers’ conceptions of the nature of science, their ideas about project-based curriculum, and their beliefs about appropriate and worthwhile learning for their students will be defined as their “conception of teaching science” modeled on the work of Peter and Marianne Hewson (1987,1988,1989) and others (Hewson, Kerby & Cook, 1995). A detailed description of the elements of teachers’ conceptions of teaching science and its use in the collection of data for the project is offered in Chapter 3 of this report.
Question 2: How do the learning experiences defined by exemplary teachers using-based curricula compare with the Teaching and Content Standards of the National Science Education Standards (NRC, 1996)?

The recent publication of the National Science Education Standards (NSES) (NRC, 1996) represents the growing influence of the newest wave of reform in science education. Efforts to recognize the variability of available resources, to respect the diversity among student populations, and to enhance the professional work of teachers in the design and delivery of learning experiences have been captured in several documents that define what students should know and be able to do. In addition to the NSES, Benchmarks for Scientific Literacy (AAAS, 1993) and The Content Core (NSTA, 1992) define the content knowledge, the skills and the scientific values that should be central to a quality science program. The availability of comprehensive case studies like those created for this dissertation provided an opportunity to compare the curricula designed by two exemplary teachers with the proposals for “ideal” teaching presented in the reform literature. It is unknown whether the “new” reform recommendations represent significant change from previous practices until there is a comprehensive examination of the work of recognized exemplary teachers.

Concerns among practitioners and other about the implementation of reform recommendations in science arise when previous reform efforts are examined and are shown to have produced disappointing results (Gallagher, 1984). Science curriculum has seen its share of reform ‘waves’ over the years, and evaluation of the effects of the reform ‘wave’ of the 1960s has produced disappointing news. In 1981, Harms and Yager presented the findings of Project Synthesis, which reviewed three major studies of
science classrooms, including Stake and Easley's comprehensive case studies of K-12 science classrooms (Harms & Yager, 1981). After years of intensive effort in science curriculum development and reform following the Sputnik launch in 1958, five generalizations about science classrooms are summarized in Harms' and Yagers' report:

1. Ninety percent of science teachers emphasize preparing students for the next academic level in science, in contrast with broader education improvement goals.

2. Since over 90% of teachers use textbooks most of the time, the text becomes the course outline and the framework for students' experiences and testing.

3. Virtually no evidence was found of students learning by direct experience.

4. Science classes are structured around lectures and question-and-answer techniques.

5. Over 90% of science teachers define their goals for teaching in terms of the content of their discipline. These goals are viewed as fixed and unchanging (p. 114-118.)

The Project Synthesis summary concludes that fifteen years of science curriculum development throughout the 1960's and early 70's, incorporating the best recommendations of practicing scientists about the nature of science, the most current ideas about student learning, and the consensus beliefs about the appropriate goals of science teaching and learning, resulted in science classrooms that were little changed from those of the 1950's. Science was still being taught as a body of proven facts, whose dependability is guaranteed by the use of strict methods and controls. With so little evidence of change as a result of extensive (and expensive!) curriculum reform projects,
the “back to the basics” movement to become a powerful educational policy force during the 1970’s and 1980’s. The Project Synthesis report and the reactionary response of school policy-makers jolted curriculum specialists to consider looking at their field from new perspectives.

One of the conclusions drawn from the failure of the 1960s efforts is that science education cannot focus solely on the goal of promoting science specialists. The publication of *Project 2061: Science for All Americans* (AAAS, 1989) redefined the goal of science education to be the promotion of scientific literacy for all citizens. The newest wave of science curriculum reform includes the challenge to offer all students opportunities to develop a clear and accurate conception of how scientific knowledge is generated, evaluated and accepted (AAAS, 1989; NRC, 1996; NSTA, 1984). One response to this call for new efforts to promote scientific literacy for all citizens was project-based science or project-based curricula (AAAS, 1989, p. 4; NSTA, 1984; Project-Based Science, 1996). Science educators, research organizations and teachers’ associations encouraged schools to engage students in “authentic” experiences that would simulate the activities of professional scientists (Koballa, 1984) as a means of achieving the literacy ideals. The underlying assumption is that students who gather data, analyze it alone or in collaboration with research scientists, or conduct original research will acquire more comprehensive and accurate understandings of science and the knowledge claims science promotes (Weller & Bird, 1996).

Project-based approaches are assumed to meet the goals promoted by the NSES for quality science teaching. The need for research into question 2 is to confirm those assumptions are justified.
Theoretical foundation: Project-based science

Two factors that contributed to an interest in the project-approach to scientific literacy goals were (a) disappointing results from earlier science education reform efforts and (b) reports of less than desirable scores of American children on standardized tests of scientific knowledge. One explanation for the disappointment with the science teaching that was reported by Harms and Yager (1981) proposes that traditional teaching, which focuses on the acquisition of scientific facts, couldn't respond adequately to the post-war explosion in scientific knowledge (Wise and Okey, 1983). A corollary explanation for previous ‘failures’ suggests that traditional science teaching places too little emphasis on the application of scientific knowledge to the solution of real problems (Wise and Okey, 1983). To change the negative trend, some theorists and science educators suggested that the emphasis of science teaching ought to focus on generation and validation of scientific knowledge rather than solely focusing on the products of scientific inquiry (Showalter, 1975). It was also proposed that the complex nature of scientific inquiry might be understood best if students engaged in suitable simulations of the work of research scientists -- an ideal summarized as “science is best learned as science is best practiced (Sigma XI, 1989).” Engaging students in a project-based approach to learning science captured the ‘student-as-researcher’ image and formed the general outline of the diverse and often diffuse concept known as “project-based curriculum.”

Presently, teachers use various types of projects to engage students in realistic science research as the basis for designing classroom experiences. In parallel with the development of computer technology, specifically more widespread access to the Internet, teachers were invited to have their students gather data to share with scientists.
pursuing research at major universities (Forest Watch, 1992; GLOBE, 1996). In some project-based approaches, teachers receive training in proper data-gathering techniques and return to their home schools to train their students. Student-gathered data is posted and shared on computer data bases maintained by the sponsoring agencies and then used in ongoing research on climate, ecosystems, geology and meteorology. Students may pose questions to their professional research partners electronically, and sometimes gather to share their results with their peers from other schools either “virtually” via the Internet, or physically at regional conferences (AirNet, 1993; Merrimack Watershed Project, 1995).

In other settings, teachers allow students to design and carry out research investigations on their own, holding mini-conferences to present the results of their analyses. Time and schedule constraints often limit the depth of these studies, and expectations for performance on standardized state and national tests of factual knowledge often constrain the amount of curriculum time which may be available for project work (Hodson, 1996).

Common to all variations on the project-based science methodology is the desire to present students with opportunities to develop an understanding of the means by which scientific knowledge is generated and supported. Project-based approaches encourage students to depend on empirical evidence, to be accurate in obtaining supporting data, to avoid bias in drawing inferences from data, to explore conflicting evidence, and to clearly and collaboratively communicate their methods and conclusions (AAAS, 1989). In the seminal AAAS document, the rules by which scientific knowledge is accepted and changed are seen as critical components of an citizen’s scientific literacy. Stated in more
general terms, the goal of a project-based approach to the design and implementation of science curriculum is the promotion of an accurate conception of one aspect of the nature of science, the process of scientific inquiry (Hodson, 1996).

One appeal of the project-based approach is its flexibility. Project-based curricula can be carried out in elementary classrooms or high schools. Rural and urban settings can serve as research sites for weather analysis and satellite surveys. Experienced teachers can allow students to define their own research question; inexperienced teachers can participate in a previously defined research project.

One result of this flexibility is the potential for diverse student learning outcomes. In selecting a project-based approach to their classrooms, teachers are designing experiences for which they have different expectations than traditional teaching models, and for which diverse student outcomes are desirable. The publication of NSES document raises a dilemma for science educators: will the definition of standard learning outcomes promoted by NSES and other reform documents contradict the diversity of learning outcomes that project-based approaches elicit? The comparison presented in this dissertation will examine the similarities and differences between best practices of two exemplary teachers and the recommendations of the national standards. By examining this comparison before efforts to promote the reform ideals have become widespread, we can better judge where change efforts might need their strongest support.

Contribution to existing knowledge

Presently, science education is in the early stages of its newest reform wave. Teachers and school districts are just beginning to align their curriculum with state and national standards recommendations. A number of states are beginning to design and
administer student achievement tests guided by the national reform literature. The comparison presented in this dissertation is an early attempt to examine the similarities and differences between current best practices and the "new" ideals. As more comparisons are completed, specific recommendations for change efforts can be more confidently proposed.

Researcher’s biases

In the conduct and reporting of this research project, there are at least four areas where the researcher’s biases may slant the interpretations presented. The possible biases may appear in descriptions of teachers’ beliefs, perspectives on teaching and learning, definition of curriculum, and concerns for researcher-participant trust.

During interviews and observation visits, and particularly during the classification and characterization of teachers’ statements, efforts have been made to depict the teacher’s perspective as authentically as possible. In my own experience as a science teacher, it is clear to me that I move freely between the positivist and postpositivist views of science that have been described here. I encourage the students to explore alternative explanations for data they have gathered, while expecting them to accurately report back to me the ‘accepted’ interpretation reported in our textbook. We review our own data from a local ecosystem, considering sources for error and making cautious inferences from our small sample, but we also memorize the generalized carbon, nitrogen and phosphorus cycles. When we review media reports of new discoveries, we confidently accept their ‘confirmation’ of prevailing theories, and critically question reports which fall outside conventional beliefs.
My own oscillation between scientific certainty and acceptance of alternative explanations reflects pedagogical decisions which parallel the decisions made by the exemplary teachers highlighted in this study. Students come to my science class from a wide range of backgrounds. I have come to believe that it is extremely difficult for a novice teacher, and virtually impossible for the young student of science, to identify the unstated assumptions and biases within a particular experimental program. As a result, I make choices about the degree to which I emphasize the sources of experimental error when we debrief a classroom activity and the confidence we show toward our own data. My perspective on the nature of scientific inquiry and scientific knowledge blends characteristics of both positivist and postpositivist viewpoints. Labeling my beliefs using either term would be inadequate. Likewise, I resist labeling the beliefs of Eric Carter and Steve Noble using traditional terms. I may be inaccurately transferring my own uncertainty about scientific knowledge to the beliefs of the participants in this study. The reader is invited to consider that bias in considering the descriptions proposed for teachers' beliefs and intentions.

A second area where bias may influence interpretation in this study occurs in the definition of teachers intentions and actions, in descriptions of the nature of teaching and learning. Like most teachers, many of my conceptions of my discipline, particularly the nature of scientific inquiry, are embedded within curriculum choices and are generally implicit and unexamined. The process by which data has been gathered for these case studies has brought out for me some of these unexamined beliefs. The participants also noted that my assertions about their beliefs revealed previously unexplored areas for them, thought they agreed to the accuracy of my inferences about them. In fact, they
both remarked at times that they were pleased to see that an outsider was able to describe
them so clearly even though they themselves would not have been able to do so!
However, it is likely that the terminology I used in identifying key phrases reflect my
familiarity with the postpositivist perspective rather than a direct use of teachers’ own
language. The reader is asked to review the quoted selections to determine if teachers’
meanings are retained within the contemporary terminology.

The earlier discussion of learning theories is intended to guide the reader of this
document to accept the assertion that student learning experiences influence what they
come to understand. The research completed for this project explores teachers’ beliefs
about the nature of learning, as well as teachers’ perceptions of their role in influencing
change in student knowledge. The researcher has described the philosophical foundation
of teachers’ beliefs as a blend of traditional and contemporary views, including
behaviorist views that are implicitly maintained in teacher preparation programs along
with the constructivist strands prevalent in much science education literature today. The
researcher accepts the constructivist explanation for learning as the best explanation that
includes common ideas from philosophy, psychology and cognitive science. Caution has
been exercised to ensure that data gathered from the observation visits and interviews are
characterized and classified in ways that maintain the integrity of the participating
teacher’s own beliefs, whether behaviorist, Piagetian, or constructivist, despite the
author’s own beliefs. The information of greatest interest is how teachers blend their
beliefs with the needs of the students, the demands of the administration, and the
structure of existing curriculum policies.
A third area for potential bias arises in descriptions of teachers' role as curriculum designers. From the researcher's perspective, curriculum design is best thought of as an attempt to meet the needs of a particular set of learners by using the skills, knowledge and ability of a particular teacher, who must act within the boundaries imposed by colleagues, supervisors and students. It is truly an idiosyncratic process, for which no one 'formula' can be recommended. In the conduct of the investigation described in this dissertation, this bias may appear in the form of an overemphasis on the unique elements of each teacher's setting and a failure to see patterns that are similar in the two cases. There is a tendency for the investigator to assign a higher value to the efforts of classroom teachers than to the work of curriculum specialists, which might have influenced the conclusions drawn from the case study analysis. The reader of the final report can judge if such a bias appears to have impaired the usefulness of its conclusions.

Little emphasis on the constraints on teacher choices is included in the preceding discussion, suggesting a bias on the part of the researcher that points to her perception of the actual network of influences on the teachers' curricular decisions. In an effort to promote respect for the influence individual teachers have on the students in their care, a respect that is widely overlooked, the researcher presents teacher choice as more influential on the final classroom 'event' than may be warranted by the data. Care has been taken to consider the influence of external forces, and not just teacher choice, in the evolution of the enacted curriculum. However, the data gathered here is limited in that it omits examination of influences outside the teachers' control.

The fourth potential area of bias reinforces the belief in the power of teachers to control classroom events, and the desire to enhance the role of teacher as professional
that underlies this research. It should be noted clearly that the author's knowledge, beliefs and values are at work in the design of the study presented in this document, just as the claim is made that teachers' knowledge, beliefs and values influence their choices. However, one significant difference between the influence of the author's beliefs on the selection and design of the project and the influence of teachers' beliefs on their design of classroom experiences is the limited opportunity classroom teachers have for reflection. The design of this project has required a thorough review of others' thoughts on the topics of interest, extensive discussion with colleagues and intense reflection on my personal beliefs about science teaching and learning. The result is a moderately coherent argument that supports the values represented by the selection of the content and method of this research. In contrast, most classroom teachers have few opportunities in the course of their normal routine to review current research, discuss serious issues at length with colleagues or spend time reflecting on the implications of their own beliefs and values. Often research on teachers' beliefs suggests that their choices are based on inconsistent values or incomplete knowledge. Many members of the education community, particularly traditional curriculum developers, fail to account for the role of teachers in the design and creation of student learning opportunities. Research on teachers' efficacy statements suggests that teachers themselves do not value their own contribution to student learning. I am unwilling to judge teachers' beliefs as 'inconsistent' or 'unexamined' and this reluctance is evident in portions of the analysis. Instead, I have focused on describing the elements that appear to come into play in teachers' decisions, without engaging in evaluative comparisons. This reluctance may
represent a flaw in the reader’s mind, but it should not be seen as an omission, but rather as an intention of the research process.

A key element in the success of this investigation is the researcher’s ability to invite open discussion from the participants without fear of criticism or negative comparison. The development of a trusting relationship between participants and the researcher was imperative, but cannot be confirmed by any objective measure. The analysis presented in this dissertation is based on the belief that the participants were honest in their responses during the data gathering and in their reading of the final analysis chapters. An overly optimistic view may have biased that belief.

Other biases may be evident to the reader, and should be considered when evaluating the trustworthiness of the findings reported in Chapters 6 and 7. The biases noted above are known and efforts have been made to limit their influence on the conclusions that are proposed. However, the reader is left with final responsibility for determining the applicability of this study to other events and situations in which science teaching and learning play an central role.

Summary

The preceding pages presented the need for a study of two research questions:

1) How do teachers’ beliefs about scientific inquiry, school science curriculum and appropriate and worthwhile student learning influence their curricular choices?

2) How do the learning experiences defined by exemplary teachers using-based curricula compare with the Teaching and Content Standards of the National Science Education Standards (NRC, 1996)?
This chapter also presented the research framework within which these two questions were investigated, and the contribution this analysis will make to the research community's knowledge of teaching and learning in science classrooms.

The three categories within which teachers' beliefs will be examined each have important implications for the conduct of science teaching. While we have some understanding of the ways teachers make sense of their own beliefs in relation to the discipline of science, to their role as teachers, and to their obligations to provide meaningful and worthwhile learning experiences for their students, our knowledge is narrowly defined and limited in its ability to influence change. In combination with an understanding of project-based curriculum and its intention of supporting the development of an understanding of the nature of scientific inquiry among secondary science students, the preceding discussion offers insight into some of the factors that teachers include in their curricular decisions.

Earlier research on teachers' judgments and decisions focused on the individual components of the decision-making process, identifying teachers' beliefs, knowledge of content, and expectations for students as three concerns involved in curricular decisions. Following the traditions of the time, these research projects attempted to expose the role each of these variables played in student learning outcomes. Dissatisfaction with the usefulness of an understanding of factors in isolation grew as program evaluators realized the broad gap between the intended curriculum and the one that is implemented. Investigators began to recognize that the reduction of complex events, such as classroom situations, to sets of isolated factors was not helpful in understanding how learning experiences are selected and presented. The research presented in this dissertation takes a
wide-angle view of classrooms, and of teachers' impacts on the learning that takes place there.

New perspectives on teachers' influences on the enacted curriculum have become more central to descriptions of the process of teaching and learning in science classrooms. New perspectives in our understanding of how students learn have led to changes in the value and concern for the types of learning experiences they encounter. Since student learning experiences arise from a set of decisions teachers make based on their knowledge and beliefs in a variety of domains, interest in understanding how teachers come to make their choices has expanded. This project presents the findings of a research plan designed to identify relationships between the beliefs, intentions and actions of two veteran science teachers as they implement a project-based curriculum in their secondary life science classrooms. It also compares the learning experiences in these two classrooms with the relevant Teaching and Content Standards included in the National Science Education Standards. From this comparison, teachers, teacher educators, reform advocates and policy-makers can direct their change efforts in productive and fruitful ways.
CHAPTER 3

METHODOLOGY

In schools, the opportunities to learn the knowledge, skills, and habits of mind of science are structured for students by their science teachers. Teachers using a project-approach to science are influenced in their choices of classroom activities by a complex array of factors, including their beliefs about the nature of scientific inquiry, the ideal goals of science teaching, and their expectations for student learning. Teachers’ choices are also influenced by their personal science experiences, by the community’s definition of ‘good’ science teaching and learning, and by the recommendations of professional organizations and respected colleagues. The purpose of this case study is to describe in detail how two respected, experienced science teachers integrate these considerations into a coherent sequence of project-based learning experiences for their students.

The following questions will be considered in this project: what are the patterns of influence among exemplary teachers’ beliefs, intentions, and actions? And, how do the resulting classroom experiences for students correspond with the recommendations of the national standards movement? Several subordinate questions support the central queries:

I. What do teachers believe about the nature of science in project-based science classrooms?

What actions and assumptions characterize scientific inquiry?

What are the ideal goals of a project-approach to teaching science?
How best can my students acquire an understanding of the way science seeks understanding?

II. What intentions do teachers express to carry out their beliefs?

What components of the nature of science do teachers select for their curriculum?

How do teachers plan to present those conceptions in their particular classroom context?

What do teachers intend students to understand as a result of their learning experiences?

III. Do the implemented lessons correlate with teachers’ beliefs and intentions?

What expectations do teachers express for student learning outcomes?

Within the unit term, which activities do students actually complete?

What student learning goals does the teacher assess during the unit?

IV. How do the learning experiences devised by these exemplary teachers correspond with the vision of ideal science teaching and learning defined by the current science reform literature?

What are the content proficiencies considered appropriate for secondary life science students?

How does the project unit contribute to students’ achievement of the content proficiencies?
What teaching standards do the national interests propose?

Do the exemplary teachers described in these case studies meet the stated expectations of the national standards proponents?

The activities and design of this research project elicited the data necessary to evaluate answers to these questions.

**Overview:** Since the purpose of this research is to present a rich description of the integration of a number of influences on teachers’ thoughts, intentions and actions, the appropriate methods are those which can elicit abundant data about these areas (Gallagher, 1991). Three types of data are required: (1) information on teachers’ beliefs about the nature of scientific inquiry, appropriate science curriculum and the abilities, interests, and aptitudes of their students; (2) collections of teachers’ descriptions of their intentions and (3) accurate descriptions of teachers’ actions, including assessment tools. Research procedures described here are concentrated on the efficient and ethical collection of this information.

Interviews about instances of science teaching and learning revealed teachers’ beliefs about their discipline, their craft and their students (Hewson, Kerby & Cook, 1995). Examination of curriculum guides, teachers’ plan books, worksheets, and verbal and written instructions served as the source of information about teachers’ perceptions of the goals and purposes of a project-based approach to science learning. Observations of classroom events contributed data related to the teachers’ actions to effect their beliefs and intentions. Statements and actions were classified and summarized, and hypotheses about relationships of influence were proposed. Assertions and their supporting and
conflicting data were presented to the respondents for comment. The cycle of hypothesis – evidence – confirmation was repeated for relevant patterns revealed by analysis of the data. These patterns serve as the central focuses of the final descriptive case report (Lincoln & Guba, 1985).

**Theoretical foundations:** Two theoretical perspectives contributed to the selection of the case study approach and to the choice of the data collection and analysis tools used in this project. The learning theory broadly known as constructivism proposes a powerful means of understanding how learners come to know and understand their world (Fosnot, 1996). Humans are meaning-making organisms, theory-builders who develop hypotheses, notice patterns, and construct theories of action from their life experiences (White & Gunstone, 1992). In the design of this project, teachers are understood from a constructivist point of view to be theory builders, making and testing hypotheses about their role with respect to their discipline and integrating that with their understanding of their students and the curriculum in order to prepare purposeful learning experiences (Prawat, 1992).

As described in the previous chapter, constructivism contrasts with other learning theories that suggest that learners are vessels or slates into which are imprinted meanings taken from outside the knower. For this project, the meaning of an event or curriculum choice is understood to have derived from the teachers’ constructed theories of teaching and learning. An ‘outsider’ such as the researcher (or a reader of the case report), can have access to the meaning of a curriculum decision through the teachers’ words and actions, but its purposes and importance are constructed by the teacher alone (Dagher, 1991).
A second set of beliefs influencing the choice of research design reflects an understanding of the context in which meaning-makers construct their theories about the way their world works. The qualitative research variation described as 'naturalistic' by Lincoln and Guba (1985) proposes that much can be understood if reality is seen as a subjective and socially mediated construct. The curricular choices teachers make are guided by personal theories founded on a lifetime of learning and interacting. 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 project is to look closely at what teachers know and believe and to understand how beliefs influence intentions and actions, the principles of the naturalistic paradigm are an important part of the design of this investigation.

**Definition of terms:** For the purposes of clarity, the following meanings will be assigned to key terms used in this research:

- **Appropriate and worthwhile learning for students:** This phrase is intended to capture teachers' beliefs about their students focused particularly on the events of the classroom. While it is understood that teachers have wide-ranging expectations for their students’ future lives, the aspects of interest here are teachers’ expectations regarding the kind of scientific knowledge that is both accessible to students and worth knowing.

- **Case study:** As used here, case study involves both accurate description of the events, thoughts, and intentions in each of the settings involved and a trustworthy interpretation of the patterns of relationship among the factors influencing teachers’ choices. The final report is written to inform practitioner audiences of the ways teachers implement project curricula in different classrooms, and to instruct curriculum specialists
and policy makers in authentic classroom enactments of designed curricula (Lincoln & Guba, 1985).

Constructivism: In contrast to naive or radical constructivism, the use of constructivism in this project will be more closely allied with social constructivism. That is, each individual formulates a meaningful interpretation of experience within a social setting. The reality on which we act is not necessarily a reality "outside" of us, existing separate from us, but is defined as a result of the integration of new experiences with existing theories of action or belief (von Glasersfeld, 1992). Meanings are constructed in a social setting, involving negotiation with others, reducing some of the serious criticisms of isolation and relativism often associated with more radical forms of constructivism.

Goals of the designed curriculum: Textbooks and curriculum guides typically state learning and teaching goals associated with their products. Curriculum developers’ descriptions of student and teacher actions are not often accepted without modification by teachers implementing a particular set of classroom materials. In this project, teachers’ interpretations of curriculum goals are a central interest and were inferred from a variety of sources.

Project-based curriculum: A strategy of science teaching which expects students to collaborate with professionals in research projects, or to conduct original research in a manner that replicates the activities of the research scientist.

The nature of science: The nature of science to be probed here follows the AAAS definition as presented in Project 2061: Science for All Americans (1989) and described in detail in Chapter 2. It addresses aspects of the scientific world view, as well as the
processes by which scientific knowledge is generated, evaluated and accepted within the community of researchers.

Teacher beliefs: Thoughts expressed orally or in action that guide choices; beliefs are more firmly held than preferences, and appear consistent, at least to the teacher, across many situations.

Participants: The case study report prepared for this project presents a discussion of influences on teachers' choices in two different settings. The respondents were purposefully selected to represent recognized exemplars of the project-based approach to science teaching. It is asserted that teachers experienced with project-based science are less likely to be distracted from their purposes by implementation problems, such as resource availability or time allotment. Teachers recognized as exemplary generally have few if any student management problems, so that the focus of the class is on the learning program rather than social concerns. Informal interviews with administrators and colleagues revealed that these exemplary teachers meet and often exceed professional and community expectations for student success. The introduction of the researcher to the classroom environment presented no evidence that it interfered with student success or teacher intentions.

In addition to their experience with a project approach to science and a record of student success, participants were selected to reflect variations in their school setting, and differences in their choice of specific project focus. There are several reasons to argue for the choice of participants from dissimilar points of view (Hawthorne, 1991). First, there is a tendency when a new curriculum or method becomes popular to assign a label to it that is supposed to capture the essence of the method. Yet, as science educators
know, there are as many forms of project-based curricula as there are teachers. At least ten teachers involved in project-based curricula and available for the project were informally interviewed about their approach to science teaching, and invitations forwarded to those representing different methods to their project design.

From the two different cases, it is hoped that the reader of the final report may be able to recognize some of the context variables that suit their particular interest. Since a written description can never capture all the influential forces at work in a setting as complex as a classroom, presenting two cases that clearly differ will allow the reader to construct a personally meaningful conception of the events related by the final report.

A second reason for selecting cases with significant differences in approach and setting is to discourage evaluative comparisons between cases (Cronin-Jones, 1991). Teachers using a project-based approach to science but with different underlying beliefs about appropriate and worthwhile learning experiences and working in different settings, are expected to produce classroom experiences for students that appeal to different tastes and are best used for different purposes. It is not the intention of this research project to support any comparative evaluation between the participating teachers (Richardson, 1994). The intended emphasis is on the diversity of student experiences within the types of curricula known as “project-based” rather than to construct a standard on which teachers can be measured.

A final reason for selecting participants in this manner relates to the position of this research within the emerging understanding about the evolution of the enacted curriculum. Recent research in science education has produced a respectable body of knowledge about the common features of project-based classrooms, such as the number
of students participating, or the training and experience of teachers using this method of science teaching (Lederman, Gess-Newsome, Zeidler, 1993; Tobin, Tippins, Gallard, 1994). A lot can be learned from this type of data. However, few reports describe how the enacted curriculum evolves from teachers’ beliefs and intentions limited by other influential forces. Just as refinements in research in molecular biology have allowed biologists to explore the details in the evolution of species, refinements in researchers’ approaches to educational issues allow us to explore the details in the evolution of curriculum. The change in approach toward the case study represents a turn from deductive inquiry to inductive theory building (Lincoln & Guba, 1985). By selecting two cases with dissimilar traits, our range of perspective is widened and our understanding of secondary science classroom contexts is enriched.

**Instruments:** The format of the Interviews about Instances is adapted from Hewson, Kerby and Cook’s Conceptions of Science Teaching (CTS) protocol (1995). The ten instances presented in the initial interview are included in Appendix A. They represent everyday situations in classrooms, laboratories, and non-academic settings. For the interview, respondents were asked to explain whether or not the instance represents an example of science teaching. Follow-up questions explored what components of the event the teacher used as part of his/her conception of ‘science teaching.’ Three primary categories of teachers’ conceptions of science teaching were probed: teachers’ beliefs about the nature of scientific inquiry, their understanding of ideal curriculum goals related to students’ conceptions of science, and teachers’ expectations for appropriate and worthwhile student learning. Statements from the interviews were classified into categories matching these three general areas. Recurring themes and patterns of
similarity and difference were extracted from the statements and formed the basis for initial hypotheses. The constant comparative method (Lincoln & Guba, 1985) of proposing an hypothesis and seeking confirming and disconfirming evidence from the data set was used throughout and submitted to the respondents for validation.

The CTS Protocol was developed for use with preservice teachers as a means of identifying relationships between teachers' role definition and instructional effectiveness. Adaptations of the CTS have been used with practicing teachers to effect change in role definition as part of an attempt to modify teaching style in keeping with instructional reform (Hashweh, 1996; Lyons, Freitag, & Hewson, 1996). As its developers report, the CTS is a means to obtain vibrant descriptions of characteristics teachers value and strive to embody in their execution of their duties, but which may remain hidden in everyday conversation. By offering a familiar context as a trigger for conversation, the Instances are expected to draw out sometimes surprising beliefs about the values teachers hold for their role.

The original form of the CTS has been modified in this protocol to more clearly apply to secondary life science teaching and learning. Students mentioned in the Instances are expressly described as adolescents. Classrooms are life science classrooms. Instances describing research and non-academic settings include traits that are associated with the students’ and teachers’ interactions within the life sciences. The relationship between each Instance and an aspect of teachers’ beliefs is outlined in the correlation table in Appendix B. Questions were added as appropriate to elicit information about the teachers’ beliefs in each major category shown on the chart – teachers’ beliefs about the
nature of science, about the goals of project-based curriculum, and about worthwhile learning for students in life science classrooms.

Data collection: In each case, the Interview about Instances was audiotaped and transcribed. As described above, participants were interviewed about their conception of science teaching as they prepare to introduce a unit of study involving the project-based curriculum. Following the initial interviews, teachers were informally interviewed to identify the progress of their students as the unit proceeds, and to identify any changes in their goals or expectations resulting from unanticipated events. Sample questions for the informal interview are included on Appendix A with the Interview about Instances. Field notes from these informal interviews were transcribed.

Classrooms were visited at least every week during the project unit of approximately six weeks, with the visits recorded as permitted by school policies. Informal discussions before and after each class visit probed teachers’ intentions and choices to capture changes or alterations of plans from earlier description.

The text form of the data includes transcriptions of recordings, field notes, Instances interview, and informal interviews. Curriculum guides relevant to the life science class were collected. Transcriptions of field notes and recordings were returned to the participating teacher for verification of the accuracy and completeness of their content. This body of information provided the data for the case study.

Because each teacher uses project-based learning as one teaching method among several, the time frame for data collection varied at each site. The project-based unit comprised six to eight weeks of classroom activity, with two weeks’ preparation and
closure at either end. Specific dates for data collection activities were negotiated with each participant.

**Data analysis:** Teachers’ beliefs, intentions and actions were classified into nine categories of interest within three major classes: (1) teacher understanding of the nature of science as it relates to the generation, evaluation, and acceptance of scientific knowledge; (2) teacher conception of curriculum goals, particularly the goals reflected in project curriculum literature and teacher guides, as they refer to the nature of science; and (3) teacher beliefs about appropriate and worthwhile science learning for students, specifically those suitable for the student population they serve. Table 3-1 shows the sentence stems which served as classification prompts and which correspond with each element of the matrix:

<table>
<thead>
<tr>
<th>Class:</th>
<th>Beliefs</th>
<th>Intentions</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature of Science/ Scientific Enterprise</td>
<td>Scientific inquiry involves...</td>
<td>Students should know that...</td>
<td>Students learn what scientific inquiry is by...</td>
</tr>
<tr>
<td>Ideal Goals of Project-Based Curriculum</td>
<td>A project approach to curriculum should...</td>
<td>My curriculum will provide opportunities to...</td>
<td>The curriculum I design includes classroom activities that...</td>
</tr>
<tr>
<td>Expectations for appropriate and worthwhile student learning</td>
<td>Students should/ought to have an understanding of...</td>
<td>Teacher expects students to learn...</td>
<td>Students are required to demonstrate...</td>
</tr>
</tbody>
</table>

The sentence stems are drawn from the subquestions detailed in the early part of this chapter.

The analysis of the data gathered into these nine categories followed the method productively used by Hewson, Kerby and Cook (1995) in revealing broad based themes...
within teacher beliefs and actions. Classifications of teacher statements were reviewed for common themes in areas of teachers' beliefs about how students learn or how the high school student best understands science. Theme statements or phrases were defined from the initial sorting, and confirming statements from the data set selected to support the theme. Disconfirming statements were reviewed and evaluated for their significance as a factor in the teachers' belief system. The process of constructing a Theme Analysis Grid is outlined in Table 3-2.

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Transcribe initial interview, class visits, course documents, informal interview</td>
</tr>
<tr>
<td>2.</td>
<td>Selected phrases, sentences sorted into three categories</td>
</tr>
<tr>
<td></td>
<td>Category 1: The nature of science</td>
</tr>
<tr>
<td></td>
<td>Category 2: Ideal goals for project-based curriculum</td>
</tr>
<tr>
<td></td>
<td>Category 3: Appropriate and worthwhile student learning experiences</td>
</tr>
<tr>
<td>3.</td>
<td>Within each category, statements sorted into beliefs, intentions, actions</td>
</tr>
<tr>
<td>4.</td>
<td>Similar statements gathered and characterized by key ideas</td>
</tr>
<tr>
<td>5.</td>
<td>Describe teachers' beliefs, intentions and actions for each of the three primary categories using themes identified in step 4.</td>
</tr>
</tbody>
</table>

A comprehensive summary of themes served as a representation of the teachers' beliefs. The summary was presented to each of the participating teachers for confirmation of its authenticity. Themes revealed by the interview data were compared with themes revealed by teachers' classroom actions, such as instructions to students for data handling or reporting procedures. A side by side comparison of themes present in teachers' beliefs and in actions was searched for indications of patterns of influence between them. The presence (or absence) of influence between teachers' beliefs,
intentions and actions will be the focus of the final case report. Appendix C includes a
time-line for project activities and checkpoints.

The complexity of the analysis of behavior in settings as intricate as classrooms
further argues for basing the methodology of this project on the naturalistic paradigm
(Lincoln & Guba, 1985). While researchers may be able to identify some of the
significant influences ("variables") on teachers' choices, we can never hope to identify all
of them (Briscoe, 1991). Traditional experimental designs involving control of multiple
variables would be impossibly unwieldy in an analysis of a classroom setting. Efforts to
simplify control by collapsing variable categories fails to reflect the natural environment
that we hope to understand.

Classrooms are more than the sum of the teachers and students in them. There is a
synergy that would be impossible to explore without the flexibility of a developmental
methodology as used here. Assignment of teachers' statements and actions into
categories, extraction of general themes, and summation of teachers' beliefs about their
role in the science classroom brings to light only a small piece of the complex puzzle that
fits under the heading "curriculum implementation." But that modest glimpse into
teachers' creative processes is much more than we now have available to us. And after
all, isn't it the wonderful variety and diversity of forms that effective teachers generate
that draws our curiosity to the research in the curriculum field?

Establishing trustworthiness: Unlike experimental research methods, which have a
body of statistical theory to support claims of validity and reliability, the case study
method to be employed in this project cannot rely on claims of accuracy defined by
standardized techniques. Instead, the conclusions of this research project use other
strategies to confirm both the authenticity of its descriptions and the trustworthiness of its interpretations (Lincoln & Guba, 1985; Gallagher & Tobin, 1991). Member checks, whereby transcripts, themes, summaries and tentative hypotheses about patterns of relationship are presented to the participating teacher from whom the data were gathered, served to support or contradict the researchers’ interpretations. These devices help assure the authenticity of the descriptions offered in the final report.

To increase the trustworthiness of the inferences about patterns of influence, a non-participating reader who is familiar with science classrooms was recruited to classify a selected portion of the original transcripts. Agreement and disagreement between the researcher’s and reviewer’s classifications were discussed and agreement negotiated. Unresolved differences of opinion are reported as part of the final case summary.

Limitations: As with all case study research, this project is limited in its potential to provide conclusions that are generalizable to a larger population. Because the goal of the project is to describe two unique instances of project-based curriculum implementation, it precludes any assertion that the cases represent characteristics of other settings. Participants are not selected for their representativeness of a larger category of science teacher, except in their use of project-based classroom designs. Characteristic patterns of influence revealed by the research project are intended merely to describe only these two variations of the many forms of project curricula that exist within the science teaching population.

The results of this study are limited in their usefulness for comparison to other types of teaching situations. Teachers selected for participation are different in significant ways from one another and different also from the larger population of practitioners using...
project-based approach to science teaching. They were geographically available, willing and able to invite a researcher to record their words and analyze their actions, and their school policies allowed their participation. Readers of the case descriptions are cautioned to consider variations in teacher background, school setting, student population, as well as other external factors such as political and social climate of the region, as possibly significant factors that discourage comparisons with other teachers in other settings. The case studies prepared from this research contribute to a library of portraits that may, as the quantity and variety of cases accumulate, offer some usefulness for comparative purposes at a later date.

A third limitation of the present study is the lack of data on student performance/achievement in each of the classrooms being studied. While student achievement is an important consideration, the number of factors which ought to be taken into account to determine the correlation between classroom events and student learning expands the current research project beyond what one researcher is capable of managing. From the theoretical perspective on which this project design is based, it would be necessary to consider each student’s learning history, affective traits, and dimensions of the teacher-student relationship as well as exposure to informal sources of knowledge relevant to the topics of interest here. That is certainly an admirable goal, but not feasible at this time. As mentioned earlier, the participating teachers are veterans who are recognized by their colleagues and superiors as consistently producing positive and worthwhile learning among their students. The two tasks of this investigation are (1) to look closely at the influence of teachers’ beliefs on their intentions and actions in three important categories: the nature of their discipline, their role as curriculum creators, and expectations for
student learning; and (2) to compare the learning opportunities offered to students in these two classrooms with the ideals proposed by national standards advocates.
CHAPTER 4

ANALYSIS OF ERIC CARTER’S BELIEFS, INTENTIONS AND ACTIONS

The relationship between teachers’ beliefs, intentions and actions is rarely direct and explicit. More commonly, teachers’ beliefs and intentions interact in complex ways with other forces in a system to produce a set of actions that create students’ learning experiences. The case studies presented in this dissertation are descriptions of some of the many possible relationships between veteran teachers’ stated beliefs and intentions and their actions in their project-based science classrooms.

The reconstruction presented here is based on input from several sources. Teacher’s beliefs about the nature of science, suitable curriculum goals, and worthwhile student learning experiences are identified from the initial Interview about Instances, (described in detail in Chapter 3), informal interviews during the project unit, and assorted teacher commentaries prepared for professional portfolios and conference presentations. Inferences about teachers’ intentions for the design of a project-based curriculum are derived from course syllabi, program of studies descriptions, and other curriculum documents, but particularly from classroom instructions. Actions teachers take to structure the classroom experience of students are identified from transcripts of weekly visits to the participant’s class during the project-based unit and from tests and other student evaluation tools. Table 4-1, below, shows the association between the data sources and the analysis categories.
Table 4-1

<table>
<thead>
<tr>
<th>Category</th>
<th>Primary Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers' Beliefs</td>
<td>Initial Interview, Informal Interview, Teacher commentaries, essays</td>
</tr>
<tr>
<td>Teachers' Intentions</td>
<td>Course syllabi, Program of studies, Curriculum handouts, Classroom instructions</td>
</tr>
<tr>
<td>Teachers' Actions</td>
<td>Classroom observation, Evaluation instruments</td>
</tr>
</tbody>
</table>

Each teacher's statements within the three categories were organized into sections representing a common intention or train of thought. Terms or phrases taken from the data sources were assigned to each section to capture the meaning of the set of similar statements. These terms became the “themes” which are described in the narrative summary for the teacher’s conception of the nature of science, his belief about ideal curriculum goals and his judgments about appropriate and worthwhile student learning. The procedure for the construction of the narrative summary follows the CTS protocol described by Hewson, Kerby and Cook (1995) for defining conceptions of teaching science. Table 4-2 repeats the outline shown in Chapter 3 (Table 3-2) of the sorting and classification process.
Table 4-2

<table>
<thead>
<tr>
<th></th>
<th>Sorting and Classification Process for Case Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transcribe initial interview, class visits, course documents, informal interview</td>
</tr>
<tr>
<td>2</td>
<td>Selected phrases, sentences sorted into three categories</td>
</tr>
<tr>
<td>Category 1: The nature of science</td>
<td></td>
</tr>
<tr>
<td>Category 2: Ideal goals for project-based curriculum</td>
<td></td>
</tr>
<tr>
<td>Category 3: Appropriate and worthwhile student learning experiences</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Within each category, statements sorted into beliefs, intentions, actions</td>
</tr>
<tr>
<td>4</td>
<td>Similar statements gathered and characterized by key ideas</td>
</tr>
<tr>
<td>5</td>
<td>Describe teacher’s beliefs, intentions and actions for each of the three primary categories using themes identified in step 4.</td>
</tr>
</tbody>
</table>

Inferences presented in this report are supported with examples from the transcripts and represent only some of the many possible connections between beliefs and intentions, or intentions and actions. The interpretation of the data incorporates aspects of the researcher’s own beliefs about science and science teaching as well as her perception of and disposition toward the particular school culture in which the participant functions.

To avoid presenting a case study that is too slanted by the author’s biases, two reviewers with knowledge of teaching and science classrooms were invited to classify teachers’ statements from selections of the written transcripts. Reviewer 1 sorted teachers’ statements into the same category as the author for 65% of the phrases in the selection. Reviewer 2, however, correctly matched the author’s classification on only 30% of the selections. Discussion with Reviewer 2 identified a misunderstanding of the distinction between “curriculum” and “expectations for student learning.” Reviewer 2 agreed to code a second selection from Eric Carter’s transcripts, and similarity between the reviewer and the author was more evident, with almost 70% agreement. In some cases,

*Pseudonym*
differences between the author's and the reviewer's coding occurred when the author assigned different meanings to distinct phrases within a single sentence. For the most part, reviewers assigned single sentences to only one classification based on the overall meaning inferred from the context of the statement. Differences were discussed and consensus was reached between the author and the two reviewers on the appropriate classification of Carter's statements.

Assigning statements to particular categories involved reading the transcripts in context and selecting those that best reflect the participants' responses to sentence stems defined by the researcher. For example, to identify teachers' beliefs about the nature of scientific inquiry, the transcript statements were selected that complete the stem:

Scientific inquiry involves... Table 4-3, shown previously in Chapter 3, is repeated below to show the matrix of categories and the corresponding stems used to classify participants' thoughts.

<table>
<thead>
<tr>
<th>Table 4-3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stems for Classification of Teacher Statements</strong></td>
</tr>
<tr>
<td>Nature of Science/Scientific Enterprise: Scientific inquiry involves...</td>
</tr>
<tr>
<td>Students should know that...</td>
</tr>
<tr>
<td>Students learn what scientific inquiry is by...</td>
</tr>
<tr>
<td>Ideal Goals of Project-Based Curriculum: A project approach to curriculum</td>
</tr>
<tr>
<td>My curriculum will provide opportunities to...</td>
</tr>
<tr>
<td>The curriculum I design includes classroom activities that...</td>
</tr>
<tr>
<td>Expectations for appropriate and worthwhile student learning:</td>
</tr>
<tr>
<td>Students should/ought to have an understanding of...</td>
</tr>
<tr>
<td>Teacher expects students to learn...</td>
</tr>
<tr>
<td>Students are required to demonstrate...</td>
</tr>
</tbody>
</table>

As a second procedure to confirm the accuracy of the inferences about teachers' beliefs and intentions, participants reviewed the narrative summaries for comment and critical review. Taped interviews with the participants following their reading of the
summaries were transcribed and participants' confirmations and criticisms are incorporated into the final report.

This chapter includes the narrative summaries for Eric Carter, describing his beliefs, intentions and actions within the three primary categories. Patterns of relationship between Eric Carter's beliefs and intentions, and intentions and actions are proposed and supporting evidence is presented. Carter's reaction to the description of his work is included at the end of the chapter.

Chapter 6 compares Eric Carter's curriculum efforts with the relevant content and teaching standards proposed by the National Research Council in its document The National Science Standards (NRC, 1995). A comparison of the product of veteran science teachers' choices with the vision of exemplary teaching presented by science curriculum reformers provides evidence of the relationship between the real and the ideal classroom environments.

Eric Carter, Storyteller

[I ask myself] what 'story' can I create that will get the kids excited and involved? . . . Once kids are engaged in the context, the content 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, "On Curriculum," 1995)

In this excerpt from an essay prepared for his professional portfolio, Eric Carter describes the job of science teacher as narrator of the fascinating stories from the natural world. Science teacher and students are participants in the creation of a plot line within the epic novel of humankind in its environment. Students are not just passive listeners to the story, but actual characters influencing and being influenced by events within their
own group and beyond. This metaphor flows throughout Eric Carter’s project approach to science teaching and learning.

In almost 20 years of teaching, Eric Carter has shared his efforts at constructing nature’s narratives with diverse groups of students, from privileged private school scholars to college undergraduates and graduate students to the current collection of suburban public school pupils he sees daily at Parkside* High School. Carter’s efforts are well suited to the Parkside culture. The affluent, highly educated professionals who constitute the majority of voting taxpayers in the communities feeding Parkside support a progressive educational philosophy consistent with the beliefs of well known proponents of school reform. The student-centered focus at Parkside sets the standard for all curriculums, requiring students to be active participants in the design and implementation of authentic learning opportunities. Effective communication, oral presentation, critical analysis skills and proficiency in common technological tools are expected of all students, not just the college-bound. Heterogeneous grouping, limited only by self-selection in some interest areas, complements the ideals of high standards for all students.

Efforts by some community members to change the focus at Parkside to a more traditional format including a stronger emphasis on memorization of standard knowledge have been rejected by voters on a number of occasions in the most recent elections. Concerns about a growing student population have recently reinvigorated calls for larger class sizes and fewer small group courses within the normal school curriculum to reduce the costs of building additional classrooms. So far, the coherent message of support for the existing approach among teachers and administrators as well as the clear success of the first few graduating classes when measured using standardized scores on national
examinations has muted the more extreme objections. Awards received by Carter and other Parkside teachers from local, regional and national organizations enhance the school's superior reputation among educators and community members.

The twenty-four seniors in Eric Carter's class, Our Natural World, are familiar with the school's general performance standards as well as Carter's particular reputation as a demanding but reasonable teacher. First names are the common form of address for both students and teacher, promoting a relaxed and collegial atmosphere. The yearlong Natural World course is one of several interdisciplinary offerings listed in Parkside's "Program of Studies," counting for one credit in English and one credit in Science at completion. Carter and colleague Lisa Diamond* of the English department share responsibility for the overall context in which the students work to reveal the "story" of the natural world, and explore other writers' descriptions of their own personal discovery of nature. Selections from the writing of Annie Diller, Steven J. Gould, and Barbara Kingsolver accompany the field guides and lab journals as primary reading sources for students.

Each trimester of the Natural World course focuses on a different aspect of the overall theme of habitat diversity. During the fall trimester, students explore the conservation area adjacent to the school to uncover patterns in the relationships among the plants, the animals and the physical environment. Succession, symbiosis, energy transfer and form and function are some of the key content topics within the curriculum. During the winter term, evolution and adaptation are the foci. Discussion of the geology of the area and its influence on plant diversity flows into a study of the evolutionary

* Pseudonym
adaptations of plants and animals to the winter environment. Students are asked to write the “life history” of a local resident and migratory animal based on observations during the course, with particular emphasis on the organism’s challenge to survive in the winter months.

Students are given an opportunity to develop a global perspective by sharing data on their local ecosystem with students in other regions via an electronic database developed by Eric Carter and his colleagues at Parkside. A student-run symposium in which the student researchers share their findings with invited environmental scholars, and with other students is the culminating event for this segment of the course.

Along with other classes populated by senior Parkside students, the spring trimester of the Natural World course is challenged to include preparation for a Senior Project which all must complete. Eric Carter changes the direction of his efforts during this final term from an outward, global viewpoint to an emphasis on personal responsibility towards the human community and the environment. Students complete their school-year-long study of their plots by identifying the returning migrant birds and the emerging plants and insect species that serve as the fundamental food supply for the ecosystem. Students consider a variety of indices as standards on which to evaluate the adequacy of the aquatic and terrestrial systems. The construction of a “personal environmental ethic” described in the course syllabus is the final student product of this term.

The data from which the following summary is constructed was gathered from weekly visits to Eric Carter’s Natural World class during the winter term, when students were engaged in their exploration of animal and plant adaptations. Visits during the fall term served as an introduction of the visitor to the students in the class, and as
background for the researcher, but were not included in a formal way in the analysis presented here. The class meeting schedule was a modified block schedule, assigning five time slots per week, but on only four days. A copy of the block schedule is included in Appendix E. Visits were made on the double block days, since those were typically the best times for students to carry out their ecosystem site observations.

A. Eric Carter's Beliefs, Intentions and Actions Related to the Nature of Scientific Inquiry

1. Teacher's Beliefs: Scientific inquiry involves...

What do the available sources of data reveal about Eric Carter's conception of the nature of scientific inquiry? The “Interview about Instances,” administered at the beginning of the data collection process, elicits the participant's ideas about teaching science, a composite concept that includes beliefs about teaching and beliefs about science. As mentioned in Chapter 2, this case study uses a conception of teachers' beliefs that reflect their practical use during the teachers' daily work as opposed to a hypothetical, theoretical conception. This deliberate decision at times creates confusion between what teachers believe about scientific inquiry and what they believe students should know. Since the interest in this study is to see how beliefs influence classroom behaviors, teachers' beliefs about scientific inquiry are necessarily intertwined with beliefs about what students should know. The data gathered here is not suited to determine the degree of correspondence between teachers' beliefs about inquiry and an idealized conception of the nature of scientific inquiry presented by curriculum specialists or philosophers of science.
To tease out the distinction between what Eric Carter considers the typical traits of scientific inquiry and what he thinks students should know, two of the hypothetical situations presented during the initial interview described non-classroom settings. His reactions to these two instances give clues to Carter's general ideas about scientific inquiry as distinct from his beliefs about science teaching.

In Instance 4 (Appendix A), a pair of boys meet up to make muffins following a recipe they used in Home Economics class that day.

[Initial Interview, Instance 4]
Interviewer: Is there science teaching happening here?
EC: (pause) I don't think so.
Interviewer: Because. . . ?
EC: One is, I'm having a hard time seeing . . . Seems what they saw was a demonstration and they're trying to duplicate the demonstration. Uhm, I don't know how old these kids are, what their experience is. If this is more of an investigation instead of an application, okay, then perhaps okay, but if it's a replication, then I wouldn't necessarily say that there is science happening here.
Interviewer: Okay, so you would distinguish between replication and an investigation. Would you say that this could be a science experience of sorts if one of the conditions were different?
EC: Perhaps. Let's say in writing this up suppose they were missing an ingredient. What would they do? Could they use something else or would they ignore it? So that would make it more of a science investigation.

Carter's contrast between investigation requiring thoughtful action on the part of the children and replication or duplication is an important distinction. Instead of concern over the product of the event, whether the muffins were good or not, Carter selects criteria that reflect on the process of achieving a result. For Eric Carter, science is a process of solving problems, figuring out how to explain, describe, and understand how the world works.
A second non-classroom example, Instance 5 (Appendix A), describes children floating twig and paper rafts along a stream of water after a rainstorm.

[Initial Interview, Instance 5]
Interviewer: Okay, here we have a similar situation to the muffins event, where kids are just sort of hanging around and playing a bit. Is science teaching happening here?
EC: Yes.
Interviewer: Okay, and what characteristics tell you that?
EC: Okay, one there's some observation, some experimentation, presumably they're starting to synthesize a little about cause and effect in a very playful way. Okay, I think what might be missing, that we don't know, that there's some conversation happening which gets them to draw upon what they're observing, what they're experiencing, and maybe some other questions come up.

Eric Carter sees the children in this instance engaged in science because they're not only observing, but experimenting in trying new boats, and likely developing some hypotheses about what types of features make successful floating objects. In addition, Carter hopes that there is some synthesis of their observations into new ideas and new questions, which can trigger further experimentation. The key to encouraging the kind of synthesis Carter imagines is the conversations that may or may not be happening between the children in this particular hypothetical case.

Experiences in the natural world, careful observation in the natural setting, and experimentation leading to synthesis of new ideas are several distinct themes that are repeated in Carter's responses to questions about the other hypothetical instances. In contrast to the popular view of science as a static body of facts, Carter uses action verbs to describe his understanding of science. In the examples presented in the initial interview, Carter mentions observing, looking for patterns, making interpretations from experiences as activities that he considers 'science.' Particularly striking is Carter's
reaction to Instance 10 describing a class where students are reviewing the results of a gel electrophoresis, a scene that most would say is characteristically “science.”

[Initial Interview, Instance 10]
Interviewer: So this last one is about lab groups analyzing a gel electrophoresis.
EC: Um hmm.
Interviewer: Is there science teaching happening in this event?
EC: I don’t know.
Interviewer: You have lab groups huddled in different places, reviewing their gel results.
EC: Yep. Yeah. Who’s asking the question?
Interviewer: Would it matter? Suppose it was the student lab groups to each other.
EC: Well, I think it does matter. Because if . . did the kids observe this themselves? Are they thinking about their own techniques? Or was this pointed out to them? Um, okay, so the source.
Interviewer: The source, the origin of the question is a critical piece of information to you?
EC: Yes. If this is developed by the group themselves, then this is a wonderful demonstration by that group of a piece of learning concerning technique.
Interviewer: Suppose this is part of a worksheet that each group has to fill out.
EC: Then I would have more doubt (that it represents science learning).

Eric Carter’s confusion about this example hints at his beliefs not only about science, but also about student engagement with the scientific questions they are asked to consider. If, as Carter seems to indicate in other portions of the interview, he believes that scientific inquiry ought to focus on an effort to solve problems and answer questions, it seems reasonable that he would have difficulty determining whether science is happening in this hypothetical scene until he could determine the origin and motivation for the gel analysis. Carter expresses no concern about whether students get the right answer for their worksheet, but rather is concerned that there is a legitimate interest among the students themselves to answer a question that has meaning to them.
Carter frequently mentions the need for thoughtful conversations about alternative hypotheses and perspectives as central to the effective practice of scientific inquiry. In his response to Instance 6 (Appendix A) in which environmental science students are collecting trash from the school grounds, Carter says,

I think there is a place for this kind of (values) teaching. In a situation like this, you may have some kids who are opposed to this and I think it's a great opportunity to begin to explore why and to know that there isn't necessarily one answer there are several different opinions. . . . This would fall under what I would begin to define as 'scientific literacy'. I think it's important for them to become literate and I think it's important to get them involved in the discussion. [Initial Interview, Instance 6]

For Carter, it is just as important for student scientists to share interpretations and opinions among their colleagues, to critically assess interpretations in light of new data and to invite the challenge “to keep on searching for new meaning and understanding” (Portfolio Essay 3, “Assessment”).

Carter's conception of science as an open-ended venture has met with some resistance, though, as he cites in an essay he prepared for his professional portfolio required for all faculty at Parkside. He cites an instance where an exchange student in his class complains about the frustration caused by scientific uncertainty declaring, “This is NOT science! In my country, science is dogmatic!” (Portfolio Essay 2, “On curriculum”) Carter acknowledged her conception of science and had a thoughtful conversation with her about his more open-ended view.

In responding to the hypothetical situations presented in the initial interview, Carter distinguishes between science and other disciplines in declaring that science involves looking for clues, for direct and indirect evidence, and putting those items together to “begin to write the story” about the natural world. What makes a good science
experience is “asking provocative questions,” “making some criteria about what makes
good data,” and “starting to synthesize” observed patterns into some new knowledge, at
least new to the knower (Initial Interview).

A summary of the predominant themes expressing Carter’s beliefs about the nature
of scientific inquiry is presented in Table 4-4 below:

<table>
<thead>
<tr>
<th>Teachers’ Beliefs: Scientific inquiry involves...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observing &amp; looking for patterns</td>
</tr>
<tr>
<td>Experimenting</td>
</tr>
<tr>
<td>Making interpretations</td>
</tr>
<tr>
<td>Carrying on conversations &amp; sharing interpretations</td>
</tr>
<tr>
<td>Critically assessing alternative explanations</td>
</tr>
<tr>
<td>Being open to new meaning</td>
</tr>
<tr>
<td>Telling a story</td>
</tr>
<tr>
<td>Asking questions</td>
</tr>
</tbody>
</table>

2. Teacher’s intentions to promote a view of the scientific enterprise: Students should
know that science is about . . .

The next step in constructing a trustworthy representation of the influence on Eric
Carter’s curricular choices is to determine his intentions to promote a particular view of
scientific inquiry to his students. As summarized in the previous section, Carter
expresses beliefs about inquiry that include observing, looking for patterns, and asking
questions. He also suggests that scientific inquiry accepts new interpretations and
critically assesses alternative explanations. Our task in this section is to uncover what
conception of scientific inquiry Carter intends to bring to his students through his choice
of classroom experiences.

In the syllabus Carter distributed at the beginning of the school year, he defines the
course objectives in broad terms.
Carter's syllabus can be used as one statement of his intentions for the tasks that students will perform to emulate the work of professional naturalists – "explaining basic principles," "using field techniques," "connecting the effects . . .". Carter defines what students should know and understand in terms of the processes of scientific inquiry, clearly differentiating his goals from more traditional expectations about learning in science which emphasize the facts or data obtained by others. "Using field techniques" is a different type of task than "listing the components," or "writing the equation that define ecological dynamics," objectives that might appear on a traditional secondary ecology course.

Of course, the syllabus undergoes significant modification as the school year proceeds in reaction to personality and institutional factors. It is important for this analysis to look at both the syllabus as an idealized description of Carter's curriculum intentions as well at his classroom instructions to his students as the implemented or enacted version of his original plans takes shape. In the first double-block class of the unit, Carter offers these directions.
[River's Edge Class 01/09/97]
(students will be visiting their study plots on this bitterly cold morning to begin their observation of organisms' adaptations to the winter environment)

Okay, let's review today. My goal is not only to have you looking at these adaptations but experiencing them . . . (procedural instructions on proper dress, leaving and returning to the building, materials and study supplies).

What I want you to keep in mind, though, is - this is real important - I put this phrase up on the board at one point and I want to go back to it. And I want you to focus on it for our fieldwork today: "Just because you don't see an animal doesn't mean you can't observe it." What does that mean? Yeah, you can hear it. Okay you can see markings including tracks, chew marks and scat.

It's a perfect opportunity 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?

The topic of today's journal entry is going to be observing an animal, making some interpretations of some animal signs.

Carter instructs his students on their first trip to their study plots to make careful observations of the clues they find so that they can begin to construct the story of each organism in its habitat. He emphasizes their personal experience with the evidence that the site can offer them, if they look carefully enough. He continues this line of instruction at the next double-block class.

[River's Edge Class 01/16/97]
(students were scheduled to walk a moderate distance to a bog, but freezing rain has delayed the arrival of a number of teachers as well as school buses.)

Okay. I really wanted you guys to have a chance to get out to the bog, but I really don't think today would be the appropriate day to get out there. . . Let me give you several different things.

Our piece with the migratory and non-migratory birds - just to back up a bit - I want you to zero in on something. (Teacher opens cabinet and brings out several reference books). This book lists every bird found in North America. The unique thing about this kind of guide is there are no pictures. This will give you a short synopsis of the biology of every bird, . . . everything you need to know about its habitat, where it winters, food sources, reproductive behavior. It'll give you lots of resources for your information. Plus you've got the articles again.
(teacher reviews expectations for this unit, alternative schedules for the bog trip.)

Who’s going out? I’ll go with the coyote trackers. Those who want to stay warm, . . . I’ll be back.

Here Carter modifies his plan for all students to engage in direct observation of the study site to accommodate adverse weather and travel situations. He allows students to choose to continue their outdoor fieldwork or to remain warm and dry while continuing their research using other methods. In the face of obstacles, the temptation for the teacher is to abandon the outdoor research component in favor of more controlled lesson plan that relies on secondary sources, like the resource books Carter offers his class. Carter resists the temptation to absolve student from conducting their own work completely, and instead of giving them “answers,” he simply offers general advice on resources students might find helpful in their work. His decision to accompany the group going out in this miserable weather sends a subtle but clear message that the central effort of habitat analysis requires active participation. By his example, Carter reinforces his message to students that writing the required “life histories” of the resident and migratory animals requires visits to the habitat even in disagreeable conditions.

The most vivid examples of the conception of scientific inquiry Carter intends to promote appear when Carter is working with students in their study plots.

[Rivers’ Edge Class, 1/9/97]

Look at the size of that hole.

(Bangs tree with a stick.) We do have flying squirrels here. They use these nest cavities over winter. If we do a couple of these guaranteed we’ll see some come out.

Look here, what’s this?

You can see... What do you observe in this pattern here? Do you notice anything here? That might be something you want to check out (in our reference books) as regards the behavior of squirrels. Look for something about squirrel behavior on the ground.

Do you see the tracks?
It's a mammal, about this big (spreads hands about 2 feet apart). It's primarily aquatic. Eats fish. Usually you'll find scales of the fish in the scat. But remember here, we're taking down some observations. So what would be appropriate information to gather about this?

The clips above from one 30 minute segment of Carter’s conversation with a group of students show Carter offering a model of the type of inquiry he intends them to carry out. Implicit in Carter’s behavior and tone of voice are affective attributes like curiosity and enthusiasm that contribute to the experience of authentic research and make it appealing to certain students.

Carter’s instructions to the class on the next session, following his absence to attend a conference related to his summer research internship, represent a summary of his course intentions. Within those instructions are references to Carter’s expectations for the conception of science that students will attain by the time the project unit concludes. He explains what he intends to include in the following week’s assessment experience.

[River’s Edge Class 01/30/97]
I’ll have different tracks set up in the classroom, as well as scat and chew marks. Okay. Then there’ll be a couple of questions. And what I’m going to ask you to do is use your natural history skills and make some determinations about those.

It won’t be as simple as ‘Identify what that track is...’. Instead, I’m going to ask you to make some observations about what you observe with that track or with that scat and based on that determine what this tells you about what animal does this belong to.

Then the final, using this (instruction sheet given out at the beginning of the unit) as a checklist. This will be due in final form in your field notebooks on Tuesday.

This description of the final unit assessment captures Carter’s beliefs that scientific inquiry is about observing clues, detecting patterns, and making interpretations. Carter is explicit in his description of the unit test. He expects students to recognize that scientific inquiry in the field of habitat analysis is about engaging in these types of physical as well
as intellectual tasks. Carter intends students to acquire a realistic, authentic conception of the nature of scientific inquiry by conducting analyses themselves.

The similarity between the major themes describing Carter’s beliefs and intentions regarding a particular conception of the scientific enterprise is shown in Table 4-5.

<table>
<thead>
<tr>
<th>Teachers’ Beliefs: Scientific inquiry involves...</th>
<th>Teachers’ Intentions: Students should understand that science is about...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observing &amp; looking for patterns</td>
<td>Observing &amp; searching for patterns</td>
</tr>
<tr>
<td>Experimenting</td>
<td></td>
</tr>
<tr>
<td>Making interpretations</td>
<td>Making interpretations, posing hypotheses</td>
</tr>
<tr>
<td>Carrying on conversations &amp; sharing interpretations</td>
<td>Being open to changing interpretations</td>
</tr>
<tr>
<td>Critically assessing alternative explanations</td>
<td>Critically evaluating data</td>
</tr>
<tr>
<td>Being open to new meaning</td>
<td>(no direct examples in this data set)</td>
</tr>
<tr>
<td>Telling a story</td>
<td>Telling a story</td>
</tr>
<tr>
<td>Asking questions</td>
<td>Answering questions</td>
</tr>
</tbody>
</table>

3. Actions that promote a particular conception of the nature of scientific inquiry: Students learn what scientific inquiry is by . . .

A key question in this dissertation is whether and in what ways Eric Carter’s beliefs about scientific inquiry and his intentions to promote a particular view of science among his students influence his design of curriculum experiences. How are this teacher’s beliefs and intentions translated into actions? From the visits to his classes, we can see at least three avenues through which Carter translates his beliefs and intentions into curriculum goals: direct instruction, indirect modeling, and test construction and grading. In the previous section we can see that there is a significant similarity between what Carter believes are the identifying characteristics of scientific inquiry and what he intends students to understand when the project unit is completed. The task in this section is to
determine whether Carter maintains this consistency when students begin to carry out his instructions.

Increasingly, there is evidence that the unspoken messages teachers bring to their students have a great deal of influence on what they come to know and understand (Hofwalt, 1984). Teacher’s enthusiasm for a subject is identified as one factor that contributes to student achievement in some cases (Brigham, 1992). Carter’s enthusiastic modeling of the type of research approach he instructs the students to take in their study plots is one of the most striking attributes of his teaching.

[River’s Edge Class, 01/09/97]
(Class departs for team sites after in-class memoranda. Teacher and observer choose to accompany one group.)

Look here. What’s this? ... Here’s something, a different sort of nut. Look at the chew marks on that. ... What do you observe on this pattern here? ... So that might be something you want to check out (in classroom reference books). ... Do you see the tracks? ... Oh, ho! We have another sign right here!

Take a look at that! (Fine ice crystals outline a hole along the river bank) Okay. There’s something respirating in there! What would be appropriate information to gather about this?

Rather than sitting at his desk, Carter joins a group on their visit and participates in the observation of the site and the search for clues about the behavior of the organisms that live there. He poses questions out loud that reflect the naturalist’s curiosity and observation skills. By following his example, students more clearly comprehend what they are expected to accomplish. His questions focus their attention to the patterns they see and push them to assert interpretations that they can share with him and with each other. In another instance of modeling as an effective teaching technique, Carter and his students were out in the icy rain completing their search for the clues they might use to write their life histories. Students on the trail ahead of them quiet Carter and his group.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
[Rivers’ Edge Class 1/13/97]
Can everybody see that? Despite the fact that both sets of tracks are quite old, you can make some inferences about that.
(Student mentions coyote tracks. Their classmates blocking the trail ahead shush them.)
Now see, that’s a hawk. Probably a female red-tailed hawk. The males migrate, but females tend to stay in their own territory.
(Two student groups and Carter watch the hawk perched on a fence post devour a red squirrel she just captured.)
That’s a red squirrel. That’s pretty big prey. Field mice that it’s feeding on (typically) could probably eat three or four a day. That red squirrel probably will be it for today.
It’s pretty remarkable to be able to view his. She’s pretty worried. See how she cocks her head to watch us? Maybe she thinks we’re another red squirrel.
Okay, Sue, watch out! (Students laugh quietly at Carter’s tease of the petite redhead.)

Carter models the patience naturalists need to gather the data necessary to construct reliable “stories” of the natural world. By sharing information about hawk migration and nesting habits, he demonstrates the need to be familiar with the work of others who have studied similar settings. He shows that scientific inquiry requires active participation, patience, endurance and persistence. Often, as in the case of the hawk sitting, those attributes are rewarded with very special experiences.

The collaborative nature of the scientific enterprise was taught more explicitly when Carter shared an impromptu description of his participation in a scientific conference.

Upon discovering that conflicting school events would drain away half his class population, Carter shared with the remaining students his experience presenting his findings from a recent research internship in Mexico.

[River’s Edge Class, 2/13/97]
There were 30 of us on the University of California campus based in a cluster of rooms with lights out and shades drawn and we had to do like senior project, like you’ll do.

The thirty of us . . . share the work we’re doing. About 10 of the 30 are working on algae and cyanobacteria. The area that I’ve been mostly
concentrating on is bats. One exciting thing happening was that, confirmed during that conference, was a find I had captured last July when I was down there. (It) was the first one of a type of insectivorous bat that was ever reported down there. Not a new species but still exciting.

What we were able to do by the end of the conference is compile a species list and it was quite impressive. One entomologist in 10 days at the site collected 72 species of butterfly! This one small portion of the planet can yield so much variety! So the diversity is phenomenal!

Last year when I had some Parkside students down there, I set up mist nets two mornings to capture birds. 70% of those birds were migratory birds from the northeast--Maine, New Hampshire, Vermont. That's why we're studying the patterns of organisms in our own plots and in Mexico. They're very connected to each other.

Carter presents to students an image of the scientific process as one that involves communicating clearly to ones' peers for the purpose of sharing interpretations and findings freely and openly. While these objectives are not part of the stated curriculum outcomes on the course syllabus, Carter's description brings the students an opportunity to understand some of the habits of mind and values implicit in the scientific enterprise.

The "plan B" nature of this particular class session became an opportunity to present another aspect of science that was not explicitly contained in the curriculum plan.

For students, the clearest source of evidence of what counts as valuable knowledge is the teacher's assessment tools. Students understand that what a teacher says he/she intends to have them learn is often not what appears on a test. Eric Carter's lab practicum includes implicit messages about what knowledge about the nature of scientific inquiry he considers valuable. Figure 4-2 is a reproduction of Carter's test for the River's Edge unit.
Figure 4-2

Lab Practicum

Reminder... Field Journals ARE Due Friday!

"Just Because You Can't See an Animal Doesn't Mean You Can't Observe It."

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

(1) Organism: __________________________________________
Reason: ________________________________

(2) Organism: __________________________________________
Reason: ________________________________

(3) Organism: __________________________________________
Reason: ________________________________

(4) Organism: __________________________________________
Reason: ________________________________

(5) Organism: __________________________________________
Reason: ________________________________

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

(1) Identify and Describe at least 4 physical characteristics of the winter season that animals need to "cope with" in order to survive.

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

At each of the five stations for Part I of the exam, Carter has set out specimens from the field which offer the types of clues the students have been gathering and analyzing during the course project. Some of the specimens offer direct evidence, such as a cast of a footprint. Others offer indirect evidence, like a chewed twig or a scat sample containing fish scales. As he explained to the students before the exam, Carter expected students to identify the relevant features on the specimen, and to use that evidence to support their hypothesis about the animal that is responsible for the mark, print, or scat.

Carter's lab practical exam was true to his description of it during the previous class meeting. In scoring the test, he allotted only 1 of the 5 points per question to the correct identification. The remaining 4 points were an assessment of the student's presentation.
of the clues they observed on each of the five samples and the reasoning they used to
develop their hypothesis. Students were expected to consider whether the fish scales
present in the scat were more characteristic of the river otter or the raccoon. Their critical
assessment of the evidence was the key to their score.

In a similar fashion, Carter evaluated student field journals on a scale of 1 to 4, with
most students receiving a score of 2-3, using the criteria of completeness, accuracy, and
care with which they completed the required observations. Scores were reduced if
students omitted a journal article or evidence of research using classroom or outside
sources. Scores were higher for those journals that included abundant detail, drawings or
measurements, of the study sites, along with written commentary showing student
consideration of alternative explanations for the observations.

The examples cited above are representative of Carter’s beliefs about his discipline
and his passion for sharing his joy with his students. They also reveal Carter’s spoken as
well as his unspoken, perhaps even unaware, intentions and actions to promote a
particular understanding of the nature of the scientific enterprise. When Eric Carter gives
instructions to his students for the unit’s activities, he defines expectations that closely
mirror his beliefs about the active nature of the scientific enterprise. He repeats the
phrase: “just because you don’t see an animal doesn’t mean you can’t observe it” as a
motivator to push students to persist in their efforts as ecologists. He directs them to “get
out to the bog,” to “zero in on something” in the field, to “make some interpretations,”
“come up with some hypotheses,” and “determine what this (observation) tells you
about” the animal members of the ecosystem. Each student’s task is to take the
observations they make and the interpretations of the data they have derived from
collaborative conversations with their classmates to "write the life histories of your selected animals". Carter's intended activities for his students parallel his beliefs that the scientific enterprise is an active endeavor, requiring gathering data by observation, recognizing patterns in the data, and interpreting the patterns in order to construct a viable story of the habitat under study. In addition to the processes through which scientific endeavors proceed, Carter models and describes his own experiences with the values inherent in the scientific mindset he expects students to exhibit. He reminds them that "there isn't a right or wrong answer" when interpreting data, that each of them needs to "assess what you know from what you've observed" using criteria that correlate with those of experts as well as those of classmates.

A summary of the key themes describing Carter's beliefs, intentions and actions regarding an appropriate conception of the nature of scientific inquiry is shown in Table 4-6.

| Beliefs, Intentions and Actions Related to the Nature of Scientific Inquiry |
|---|---|---|
| Teachers' Beliefs: Scientific inquiry involves . . . | Teachers' Intentions: Students should know that science is . . . | Teacher's Actions: Acting as naturalists: observing, looking for patterns |
| Observing & looking for patterns | Observing & searching for patterns | Making interpretations, posing hypotheses |
| Experimenting | (no direct examples) | (no direct examples) |
| Making interpretations | Making interpretations, posing hypotheses | Making interpretations |
| Carrying on conversations & sharing interpretations | Being open to changing interpretations | Considering alternative interpretations |
| Critically assessing alternative explanations | Critically evaluating data | Critically evaluating interpretations |
| Being open to new meaning | (no direct examples) | Being open to new ideas |
| Telling a story | Telling a story | Writing the life histories |
| Asking questions | Answering questions | (no direct examples) |
The classes visited for this analysis contained no examples that could be inferred to present students with an understanding of the role of experimentation as one component of scientific inquiry. The naturalist’s fieldwork does not typically include traditional controlled experiments for obvious reasons. The field biologist depends quite heavily on the process of observation, data gathering, pattern detection, and hypothesis generation. Carter recognizes the limitations of time and scale in habitat analysis experimentation, and focuses his student’s work on these skills and tasks because they are more manageable.

B. Eric Carter’s Beliefs, Intentions and Actions Related to Project-Based Science Curriculum

In this section of the analysis we will look at the relationship between what Eric Carter believes ideal project-based science curriculum should be and the types of lessons he plans and enacts for his students at Parkside. What does Carter think an ideal curriculum should do? How do his beliefs about project-based curriculum relate to his design of activities in his own class? And finally, how do the classroom events Carter's students experience correlate with what he says he believes and intends his curriculum to do?

1. Beliefs: A project-approach to curriculum should . . .

Statements in the transcripts of interviews and class visits that are assigned to this curriculum category are those that describe what Eric Carter believes classroom experiences should do for students and teachers. (As defined in an earlier chapter, ‘curriculum’ refers not only to the content matter students encounter in their courses, but also includes the activities by which the students become involved with the content.)
Carter’s reaction to several of the hypothetical instances in the initial interview reveals some of his thoughts. In Instance 8 (Appendix A), Miss Panacek is conducting a lecture-discussion with her honors biology class on cell types.

[Intial Interview, Instance 8:]
Interviewer: Here’s honors biology. Ms. Panacek is doing lecture discussion here.
EC: Yeah, I love it.
Interviewer: So is this science teaching?
EC: Yes!
Interviewer: You like this one, right? So what about this dialogue, what tells you there is science teaching happening here?
EC: Okay. The teacher’s asking provocative questions. She’s trying to engage the kids with the content so it seems like there’s been development of a context or a story line in which the kids then are able to begin to construct some meanings. . . . (In contrast to the last one) I feel much better about saying there’s real teaching going on here because the kids are beginning to incorporate the previous day’s class, lab or whatever they’re doing. You need to organize some way in which they can verbalize it.
Interviewer: Now, you don’t have the student’s end of the dialogue here but you’ve inferred that in fact dialogue is happening. What tells you that?
EC: Well it’s because I’m feeling engaged to get into that conversation. I think they’re good questions. I’m assuming the kids are into it too! Heh, heh.
Interviewer: What do you mean by ‘provocative’?
EC: For the first part, when she asked the question, ‘what’s the difference between eukaryote and prokaryote?’ And then she goes into ‘what do we mean by organization?’ Right there it’s turning it (the question) back to the kid asking the kid to begin to start to process their thoughts, to get the kids to answer their own questions versus telling a quick answer.

Carter’s enthusiastic response to this hypothetical scene suggests that he agrees with the some of the curriculum elements that are evident in this example. Carter appreciates the teacher’s ability to engage the students with the content. He reveals here that he believes curriculum should allow students to construct meaning from the activities or lessons in which they participate. This lesson, in Carter’s view, is one in which
learning is very likely to happen. The involvement of students in the dialogue about the subject matter is what is key to good curriculum. He expresses similar beliefs about the role of curriculum in responding to Instance 5 where students are making dams in the rain gutter. “Bottom line is I think the best teaching comes from the student constructing themselves. Okay, a good teacher would set up a situation like this allowing kids to explore to feel it to see it and begin to pull that together.” (Initial Interview, Instance 5)

In Carter’s judgment, the curriculum teachers construct for their students ought to provide opportunities for students to construct knowledge themselves.

The quote used at the opening of “Eric Carter, Storyteller” reiterates Carter’s conception of suitable curriculum as one which encourages student participation in their own learning. In an essay he wrote for his professional portfolio, Carter describes his beliefs quite clearly.

(Initial Interview, Instance 7:]
Interviewer: The next one is a chemistry class doing titrations (Instance 7, Appendix A). Now, is science teaching happening here? We have Mr. Douglas checking titration levels and confirming . . .
EC: I’d 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 couldn’t tell that from the scenario.
Interviewer: Okay, so what else would you need to know?
EC: I’d actually need to talk to the kids to see if they understand why they’re doing it not just how to get it (an answer).
Interviewer: So the other component you would add would be...
EC: The why.
Interviewer: You don’t 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, it’s OK?
EC: And following directions, yes.
(next instance presented)
EC: Whereas in the last one (Mr. Douglas & titrations) all we can infer from that is they’re doing a titration, they’re following some steps.

Without dialogue with students, without an opportunity for the teacher to see how (or whether) the students are grasping the meaning behind an activity or merely following prepared instructions, Eric Carter does not feel that the curriculum is adequate to the task of teaching and learning science. Another instance in which students are asked to classify a set of acorns according to common features elicited similar misgivings on Carter’s part.

[Initial Interview, Instance 9:]
Interviewer: Here’s another activity in which students are working on a worksheet, they have to do a collection (Instance 9, Appendix A).
EC: I worry about this one.
Interviewer: Okay, why do you worry?
EC: Uhm, the reason why is because of what I don’t see here, which could be part of this but I don’t see it here. I don’t know what sort of work has been done with the kids to get them to construct criteria, to discuss what is criteria for grouping right. In the worst case scenario, I could see the kids being very frustrated by this.
Interviewer: Because they don’t have that background?
EC: Because they don’t have that background, they don’t understand what is even meant by this, and then, once again, the worst case scenario -- which I have seen happen -- is then there’s no follow-up by the teacher and then blame, “Okay, you guys aren’t working hard
enough!” So that’s why this one causes a bit of concern, and that’s from years and years and years of being in different classes and seeing sometimes where this can backfire.

For Carter, a teacher’s design of class activities must take into account the background of the students, and must support the needs of the students however weak or strong their background knowledge is. If students are frustrated, the classroom experience is unlikely to lead to new understanding. When Carter is asked what he would add to the lesson to make it more effective, he explains,

[Initial Interview, Instance 9]
I think they need some kind of conversation about what makes a good classification system. What kinds of features make good comparisons? How do you compare? Kind of a brainstorm activity with the kids getting them ready to really look critically at it... They have to have it in kids lingo, too. It’s an important step even though it’s time consuming., I think it’s to get them to establish their own lingo with what you’re hoping they’re going to go to.

The ‘conversation’ that was so important in Carter’s conception of scientific inquiry appears to be an important component of his beliefs about ideal curriculum too.

A summary of the key themes describing Eric Carter’s beliefs about the proper role of project-based science curriculum is outlined in Table 4-7.

| Table 4-7 |
| Beliefs Regarding Project-Based Science Curriculum |
| Teachers’ Beliefs: A project approach to curriculum should... |
| Promote student participation in scientific inquiry |
| Provide insight into student knowledge |
| Advance student’s construction of new knowledge |
| Promote understanding of the processes of scientific inquiry |
| Engage students in conversations/ dialogue about their experiences and their new understanding |
2. Intentions: My curriculum will be designed to provide . . .

How does Eric Carter expect to be able to design classroom experiences for his students that encourage learners to construct their own knowledge? His ideal requirements for curriculum set some formidable goals, daunting for even the most experienced teacher.

In Carter's professional portfolio essay on curriculum, in his syllabus and project handbook, and in his classroom directions to students, Carter indicates that the ideal curriculum should not only define student learning opportunities, but should allow teachers to diagnose individual student needs and guide the design of helpful experiences as the unit proceeds. Carter's solution is to view his curriculum as a continually unfolding set of events whose direction is as determined by the students as it is by the teacher. In comments for his professional portfolio essay, "On Curriculum," Eric Carter explains how he accommodates the inherent complexity and variability of teaching and learning.

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 session. (Professional Portfolio Essay, "On Curriculum")

Eric Carter intends to design his curriculum to be interactive enough to give him opportunities to discover student conceptions (and misconceptions), and flexible enough to allow him to add, subtract or modify the daily or unit lesson plan to account for new input. Content continuity is maintained by the teacher in the definition of the initial
“context” or “essential question” to be addressed in a particular unit. Within the broad boundaries of essential questions, Carter has enough freedom to make choices that suit the needs of a particular student group on any particular day.

In the written syllabus for Our Natural World, Carter defines two essential questions to be addressed during the year: “What are the interrelationships that connect life in nature?” and, “How do we human beings fit into nature?” (Natural World Syllabus, 1996-97). His syllabus explains that in this course he intends to “reacquaint kids with nature and help them see the connections and choices they can make as one species in and among the living parts” (Natural World Syllabus 1996-97). Students are expected to develop proficiency in investigative and communication skills as part of this senior seminar course, in part to prepare them for their senior project presentation due in May.

Additionally, in the senior seminar that I teach, I have consciously tried to plan my first three units to model aspects of the senior project. The first two units focus on communication skills for presentation technique and active research. (Informal Interview 1/16/97)

Carter explains that the River’s Edge project unit observed for this analysis “is designed around the learning log and requires students to problem solve, (and to) interpret data, while taking annotated notes on references that they are reading” (Professional Portfolio Essay, “On Curriculum”). In the handout distributed to the students at the beginning of the unit, Carter lists the specific research activities required for the unit.
Figure 4-3

The River's Edge: Flora/ Fauna

Part I: Plants
A. Examine the following tree species:
   White or gray birch
   Shagbark hickory
   Mature sugar maple
   What 'adaptations' 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 doesn't it migrate?
   How does it survive the cold?

C. Choose an insect and discuss how it “over-winters”

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 it's major predator? How does it avoid predation? (T94SEC)

In the context of the broad essential questions of exploring the natural environment, Carter has narrowed the topic of this unit to focus on the specific interactions of sample plants and animals with the natural environment using a study site outside the classroom door. The tasks students are asked to complete are the specific tasks naturalists perform to explore a particular study plot. The analysis questions posed in the instructions require students to apply previous knowledge about ecosystems to the specific conditions.
observed and recorded during fieldwork informed by classroom reference material and other outside resources.

Carter’s statements in his portfolio essays and on the course syllabus indicate his intention to design a curriculum that reveals student knowledge and allows flexibility. These documents also reveal that Carter intends his project unit to require students to practice the skills of the field biologist to gather and interpret relevant indicators of the behavior of living things. On the first day of the field visits for this new unit, Carter reiterates his intentions for this project directly to the students.

[River’s 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 let’s pack up and head out. It’s 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.
You can also continue the bird observations from last class . . . Okay the project sheet you have . . . (has) a number of questions that need to be addressed as we’re working.

Concurrent with his procedural instructions, Carter pushes students to consider the meaning of their work, to think deeply about the central questions they are trying to answer. His focus is not only on the specific details about pencils and field journals, but about the larger questions which form the core of the unit.

[River’s 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 -- ‘Just because you can’t see an animal doesn’t mean you can’t observe it.’ What does that mean? Yeah, you can hear it. Okay, scat, chew marks. What else?. . .
How many of you know what I’m talking about? The one I put on the overhead. . . . Okay. . . that part of it will refer back to last week. Okay? Everybody clear? Okay, let’s go to it.
Carter’s flexibility toward curriculum plans came into play at the next week’s class, when freezing rain forced the cancellation of a walking trip to the nearby bog and also delayed his arrival at school as well as the arrival of several school buses. His ability to maintain a focus on the central question of the unit and modify the specific day’s lesson without a major detour from the project unit goals distinguish Carter’s ability from less experienced teachers.

[River’s Edge Class, 1/16/97]
EC: I really want you guys to have a chance to get out to the bog, but I really don’t think today would be the appropriate day to get out there... All right, so let’s do this. How many of you need to go outdoors to our plots?... Good! Okay, let me give you several different things. Those of you that would like to stay nice and warm, what I would suggest are the following resources. . . . It’s a compendium of all the sorts of birds we see in North America. The animal tracks book and the other guides will help you with our resident species. Okay? Plus you’ve got the articles again.
Questions?

In current terminology, Carter ‘stays on message’ even when events outside his control contravene his best laid plans for this project unit. In only one case during the period of this research project did Carter express frustration with the effects of “real life” on his curriculum plans. Upon returning from a three day absence to attend a research symposium for his own study site, Carter discovers that almost half the students will be missing a class period because of a special scholarship exam, a ski team meet, and a student senate meeting. He had planned to use this class to summarize the completed unit and to brainstorm ideas for the habitat symposium the class would conduct to present the results of their research. Quickly surveying the remaining students, Carter detoured around the intended plans to share his symposium experience with the ten or twelve students who were left.
[River’s Edge Class, 2/13/97]
EC: This is what I’d like to propose. That I’ll do something with you today, a Plan B. This article by Barbara Kingsolver is really rich. What I’m going to do is I’m going to give you the article copies again today and ask you to take notes. We will have this discussion on Tuesday, and . . . No it will have to be Monday. Take some notes and we’ll have a fruitful discussion of this on Monday. Tuesday, we’ll lead into the brainstorming as far as looking at what we need to do to pull of the symposium. Then Thursday when we have the double block period we’ll actually kick it off.
What we’ll do today, I’ll mention this to you about the conference I just got back from. (Describes the conference events and activities. Students listen with interest.)
Let’s see. I wasn’t planning on using this today, but I want you to take a look at this for a moment and think about what this quote means. . . Okay what’s Bodkin saying?

Carter continues this “detour” class with a discussion of issues presented at his conference and relates it to the central focus of the River’s Edge unit, the relationships among living systems and the physical world. Even though there was audible frustration in his voice when adjusting plans for the day, Carter’s belief that curriculum emerges from the experiences of students and teachers helps him move beyond the annoyance to structure the available time into a worthwhile learning experience for his students.

There is wide-ranging consistency between the Eric Carter’s beliefs about a project approach to science curriculum and his intentions to promote active research in his science classes. His belief that curriculum should provide insight into student understanding is repeated in his stated intention to maintain a flexible approach to lesson planning that allows him to take into consideration the evolving knowledge of the students in his class. His repeated suggestion in response to the initial interview situations that curriculum should ultimately be aimed at promoting student’s understanding of the scientific enterprise is reiterated in his classroom instructions and course syllabi in which he declares his purposes directly and explicitly. A summary of
the key themes inferred from the data describing Carter’s beliefs and intentions to promote ideal project-based science curriculum are shown in Table 4-8.

<table>
<thead>
<tr>
<th>Beliefs and Intentions Regarding Project-Based Science Curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Teacher’s Beliefs:</strong> Science curriculum should . . .</td>
</tr>
<tr>
<td><strong>Teacher’s Intentions:</strong> the River’s Edge curriculum will . .</td>
</tr>
<tr>
<td>Promote student participation in scientific inquiry</td>
</tr>
<tr>
<td>Direct students to use scientific skills and knowledge in authentic research</td>
</tr>
<tr>
<td>Provide insight into student knowledge</td>
</tr>
<tr>
<td>Provide insight into student understanding</td>
</tr>
<tr>
<td>Advance students’ construction of new knowledge</td>
</tr>
<tr>
<td>Lead students to construct new knowledge</td>
</tr>
<tr>
<td>Promote understanding of the nature of scientific inquiry</td>
</tr>
<tr>
<td>Promote understanding of the scientific enterprise</td>
</tr>
<tr>
<td>Engage students in conversation about their new understanding</td>
</tr>
<tr>
<td>Involve students in small and large group discussion of new ideas</td>
</tr>
</tbody>
</table>

3. Actions: Teacher structures opportunities for students to . . .

One major assertion of this inquiry is that the students’ learning experiences in science classrooms are the result of the teacher’s negotiation among his/her curricular beliefs and intentions and the external forces that impact a teacher’s execution of his curricular plan. As summarized above in Table 4-8, Eric Carter believes that project-based science curriculum should provide insight into student understanding and allow students to construct new knowledge by participating in activities that represent authentic scientific inquiry. In this section of the analysis, we look at whether the experiences Carter’s students encounter in his class are faithful to his beliefs and to his intentions.

One caution must be offered regarding the analysis of this topic. Two of the six classroom visitation days during the River’s Edge project unit were clearly atypical. (A unit lesson plan outline is shown in Appendix D.) Disruption to the normal routine due to weather, conflicting school events, and teacher absences forced Eric Carter to “punt,”
to make last-minute changes in curriculum plans to accommodate these unforeseen challenges. In a way, while difficult for Carter, this offers the researcher an opportunity to contrast the four “normal” days with the disrupted ones to reveal more detail about Carter’s curriculum decision-making.

On the ‘normal’ class days, Eric Carter not only instructs his students to carry out the research activities he defines, he participates with them in their plot studies. On the first class visit to the study area, Carter joins one student team and directs their attention to observations of subtle clues at their plot.

[River’s 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! What’s this? ... Here’s something, a different sort of nut. Look at the chew marks on that...
There’s a real old shagbark hickory right here, been around a while. You can see what’s 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... If you want you can take a couple of these inside and sketch them more closely.
Do you see those tracks? Oh, ho! We have another sign right here! I’m gonna let you guys... there is a lot of activity in the next 10 meters. There’s a chickadee.
Take a look at that! Okay, there’s something respirating inside... Okay, look at the size. How can you describe the size of that hole? ... Okay the size is appropriate for an otter. That could be. But remember here we’re taking down some observations. So what would be appropriate information to gather about this?

Carter’s earlier statements indicate he believes students should learn science by participating in scientific study. He structures class time to provide ample opportunities for students to complete their own investigation of a sample habitat plot. He joins them in their explorations, gently guiding them and directing their attention to relevant
observation in the field. In so doing, Carter puts into action his beliefs and intentions for his project approach to science curriculum.

Another way Carter brings students to understand how to carry out the inquiry he has defined for them is to offer exemplars of the type of work he expects them to produce. During the project unit preceding River's Edge, Carter invited Claire Walker Leslie to present a seminar at Parkside on her approach to field journals. In one informal interview reflecting on his approach to the unit this year, Carter explains how he hopes Walker Leslie's work will enhance his efforts to have the students develop authentic research skills.

The last couple of times we've gone out, I've had to be a little more directive with this group... .The first few times we went out we focused on the birds. 'What's that bird doing? What's the bird eating? How's that bird surviving?' You get that just from observing. But what's the 'story' that's being told? Claire Walker Leslie came here 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 Leslie's journals) and it tells a story. (Informal Interview, 1/16/97)

Carter supports his desire to have students function as apprentice naturalists by his own example in the field and by inviting guest to explain the purposes and methods of field journals that students can refer to as exemplars. By his behavior as a facilitator in the field visits, Carter models for students the practice of careful observation. By arranging a visit from an exemplary model of field journal reporting, he helps students visualize his expectations for communicating their observations in a meaningful way.

What about the disrupted class meeting days? Do Carter's actions promote his ideal of student practice of scientific inquiry skills or does he abandon his curricular beliefs and intentions for a more easily managed curriculum plan that requires less active
participation by students? The clearest answer to this question comes from Eric Carter's modification of his daily plans on second double-block day of the project. Freezing rain delayed school buses and made it inadvisable to walk the half-mile to the bog for observations that day. Carter himself was delayed by a traffic accident caused by the icy roads.

[River's Edge Class, 1/16/97]
Guys, let me give you several different things. (Offers indoors research options for students who wish to stay warm and dry. He retains the plan to visit the study sites adjacent to the school, and teases the “die hards” who still want to get more data for their journals.)
Okay. Let’s get to it. The group that’s going out? Okay, we’ve got the coyote trackers. I’ll go with you guys. (To the rest of the class) I’ll be back! (Two groups, teacher, and observer walk gingerly along the icy path to the study area.)
Okay, what do we have here? So what do you think about this? What else can you see in this fresh track? Yeah. Can everybody see that?... Zero in on this spot. See if you can find the trees that it’s gnawing on. (Students are shushed by a smaller group standing ahead on the trail. The whole party stands in the freezing rain watching a hawk perched on a post eating her just-captured prey.)
Now see. That’s a hawk. Probably a female red-tailed hawk... (Excitedly, but hushed so as not to disturb the hawk.) This is pretty remarkable to be able to view this! She’s pretty worried. See how she cocks her head to watch us. Maybe she thinks we’re another red squirrel. Okay, Sue, watch out! (Teacher and other students laugh quietly at the tease of the petite red-head.)

Rather than sit with a warm cup of coffee, Carter joins the groups of “die hards” in his class who want to continue their outdoor observations. He directs their attention to relevant clues with the same enthusiasm that he had on the gentler weather days. Carter and the “die hards” are rewarded for their diligence with the ‘remarkable’ opportunity to watch the hawk capture and consume its the prey. No textbook could provide students with remotely similar experiences of the scientific enterprise.
The second class disrupted by outside events was planned as a preliminary discussion of a symposium for students to share their ‘stories’ of the plants and animals in their study plots. When a significant number of class members were to be missing for a variety of activities, Carter had to decide whether to give the remaining students a “study hall” for the time period, to continue the symposium planning without the full group, or to detour along another curriculum path. Recognizing that students would need to feel involved in the initial planning in order to make the symposium successful, Carter modified his original lesson plan to provide an enrichment discussion with the remaining students of the general topic of biodiversity.

[River’s Edge Class, 2/13/97]
Let’s see. I wasn’t planning on using this today, but I want you to take a look at this for a moment and think about what this quote means. (Puts quote on overhead referring to need to consider habitat as well as individual.)
Okay, what’s Bodkin saying?
So in terms of biodiversity, how would you define biodiversity... All living organisms, Okay. Okay, their habitat. Let’s make a list here. You all have your field journals, get them out. Chris, your definition of biodiversity? Lindsay, what would you add? What else? Yeah that’s a real important point. When we look at what biodiversity’s all about, when I put it like this – a function. Each organism ... I have to add a home for each organism.
(continues calling for ideas from students)
Okay, so we’re looking for some interspecies relationships too. Think about our symbiosis unit (from the last trimester of the Natural World course, completed immediately before the River’s Edge unit). There might be a variety of symbioses, more than just the predator prey relationship. Cory, what did you have for your study? Right, so in addition to a certain population of gallflies, what else do they need to survive? Right, a population of goldenrod ...

Despite being unable to proceed with the symposium planning class as he had hoped, Carter pursues his curriculum goals by working with the remaining students to relate their research to larger issues in ecosystem studies. He highlights connections

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
between the student’s observations and current debates in the scientific community about
habitat definitions and biodiversity concerns. He challenges students to consider
alternative hypotheses about the influence of disturbance on organisms and to “weigh in”
in support of one position or the other based on their own knowledge.

[River’s Edge Class 2/13/97]
We need to take into consideration not only what the number of species
might be, but we need to consider what the populations of those
individual species are.
So let me put something on here. (Places a graph on the overhead.) If we
look at ten different individuals, ten different species and look at their
populations we would tend to see...we may see what’s up here,
something like this...Can you see what I’m getting at? When we
look at it from our perspective in this class, when we look at wildlife
management plans, what are some of the implications of this?...
There are two variables that you need to keep in mind, and I want you to
write this down. It’s a really tough questions and nobody has the
answer. And I want you to think about this. I want you to come up
with a hypothesis regarding this statement: Higher diversity means
greater stability. Right now biologists are debating this and this is a
true debate.

Carter’s conception of curriculum as an evolving event, continually being
reformulated to accommodate competing interests and needs, supports his ability to make
last-minute changes that are consistent with his other curriculum goals. Teachers who
hold beliefs about curriculum that are more restrictive might insist on accomplishing
“coverage” of required content or skills regardless of interference from bad weather,
ilness, or other interruptions. In contrast, Carter’s more broadly framed belief that
curriculum should allow students a variety of opportunities enables him to modify his
lesson plans without feeling as if his fundamental curriculum goals are being sacrificed.
Interruptions (or disruptions) become learning opportunities that were not anticipated, yet
can offer worthwhile experiences for the learner.
In general, in both ‘normal’ class days and abnormal ones, Eric Carter enacts a curriculum that complements his beliefs about what a project-based science curriculum should involve: students actively engaged in a scientific inquiry. Table 4-9 shows a comparison of Eric Carter’s beliefs, intentions and actions regarding the project approach to science teaching and learning.

<table>
<thead>
<tr>
<th>Beliefs, Intentions and Actions Regarding Project-Based Science Curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher’s Beliefs: Project-based science curriculum should...</td>
</tr>
<tr>
<td>Teacher’s Intentions: The River’s Edge curriculum will...</td>
</tr>
<tr>
<td>Teacher’s Actions: Teacher structures opportunities for students to...</td>
</tr>
<tr>
<td>Promote student participation in scientific inquiry</td>
</tr>
<tr>
<td>Direct students to use scientific skills and knowledge in authentic research</td>
</tr>
<tr>
<td>Involves students in the methods and activities of a naturalist</td>
</tr>
<tr>
<td>Provide insight into student knowledge</td>
</tr>
<tr>
<td>Provide insight into student understanding</td>
</tr>
<tr>
<td>Interact with exemplars of scientific inquiry</td>
</tr>
<tr>
<td>Advance students’ construction of new knowledge</td>
</tr>
<tr>
<td>Lead students to construct new knowledge</td>
</tr>
<tr>
<td>Confront new experiences, develop new knowledge</td>
</tr>
<tr>
<td>Promote understanding of the nature of scientific inquiry</td>
</tr>
<tr>
<td>Promote understanding of the scientific enterprise</td>
</tr>
<tr>
<td>Collaborate with the teacher as a model investigator</td>
</tr>
<tr>
<td>Engage students in conversation about their new understanding</td>
</tr>
<tr>
<td>Involve students in small and large group discussion of new ideas</td>
</tr>
<tr>
<td>(no direct observation)</td>
</tr>
<tr>
<td>Experience the rewards of persistence and enthusiasm in pursuit of knowledge</td>
</tr>
</tbody>
</table>

No evidence was obtained during the weekly visits to the River’s Edge class that Carter enacted his goal of involving students in conversation with their peers about their research findings. As mentioned earlier, the researcher visited on the double block days, when students were exploring their study sites. As shown in the daily lesson outline Appendix D, the single block class days were used to discuss articles, to compare data.
and to continue research on the animals selected for detailed investigation. Even though the researcher did not observe students comparing findings, and discussing key issues, Carter’s daily plans included abundant opportunity for those activities.

Evidence of Carter’s desire to implement a curriculum that would encourage students to enjoy their visits to their study site was not as obvious in the survey of his initial interview responses or his classroom conversations. His actions in the field spoke louder than his words, though, to suggest that he finds study of the natural world an enjoyable and wondrous experience. It is not hard to imagine that one reason Carter chooses a project-approach to science teaching is that he personally derives a great deal of pleasure in his outdoor research experiences. The genuine enthusiasm that can be seen and heard in his work with students appear to be an important influence on his curricular choices.

C. Teacher’s Expectations for Student Learning

And what I’m going to ask you to do is use your natural history skills and make some determinations about those (animal signs). . . . But note, I’m assessing what you know from what you’ve observed outside, from some of the lectures we did during this unit, and from the articles. (River’s Edge Class, 1/30/97)

The third category of interest in this analysis of the influences on curricular choices addresses teachers’ expectations for student learning. As with the previous two categories, Eric Carter’s conceptions of appropriate and worthwhile student learning is a composite idea. It incorporates his beliefs about what students ought to know, as advised by professional organizations, local curriculum guidelines and state and national tests, with his own personal beliefs about appropriate science knowledge. This category also includes Carter’s understanding of what students are capable of knowing, based in part on
knowledge he has acquired during his twenty years of classroom experience and his professional preparation program.

Teachers' expectations for student learning is selected as an influence on classroom decisions for obvious reasons. Teachers' perceptions of the potential for students to achieve intended curriculum goals place limits on the types of activities that will be pursued, regardless of the accuracy of the perception. Common statements such as these can be heard in any gathering of classroom teachers: “Well, our district has no money for field trips/ GPS meters/ spectrometers, so we can’t do that project.” “Our students aren’t that capable. We should stick with the basic stuff and not get into any projects.” “My students are too young/too old/ too mature/ too immature to handle that kind of class structure.” Similar statements are heard regarding all disciplines and in all school structures, some referring to physical or administrative constraints, others related to the personalities of staff and students. The analysis to be conducted here aims to identify Eric Carter’s beliefs about what his students ought to know and what scientific knowledge they are capable of learning. It seeks to describe how Carter’s beliefs are reflected in his stated intentions for the assessment of student learning, and how they influence his criteria for student achievement.

1. Beliefs: Students should/ought to have an understanding of . . .

Eric Carter’s beliefs about what his students ought to know and understand are inferred from his responses to the hypothetical instances in the initial interview and from his statements in essays prepared for his professional portfolio. Selections from Carter’s responses during the interview reflect a clear set of beliefs about the development of scientific understanding.
[Initial Interview, Instance 5]
Interviewer: Okay, here's a similar situation where you have students just
hanging around and playing around a bit. (Instance 5: Julian and Margaret
using sticks and twigs in the gutter while waiting for the school bus.) Is
science teaching happening here?
EC: Yes.
Interviewer: Okay, what characteristics tell you that?
EC: Okay, one there's some observation, some experimentation, presumably
they're starting to synthesize a little about cause and effect in a very playful
way. Okay, I think what might be missing that we don't know that there's
some conversation happening which gets them to draw upon what they're
observing, what they're experiencing and maybe some other questions come
up.
Interviewer: So you're saying the two children or individuals involved in this, the
teaching is happening between them?
EC: Between them and also individually as well because they're observing and
putting things together and seeing what's happening.
Interviewer: So you don't distinguish in physical terms a difference between
science teaching coming from outside versus coming from inside. You think
that's . . . those can be . . .”
EC: No, right. I think that's a very important one in terms of looking at it.
Bottom line is I think the best teaching comes from the students constructing
themselves. Okay, (a) good teacher would set up a situation like this allowing
kids to explore -- to feel it, to see it -- and begin to pull that together.

This excerpt, used as an example in previous sections of this chapter, is repeated
here to reiterate Carter's expectation that student learning happens when students are
active participants in the learning process. Students making dams in the rain gutters are
learning science in an informal way because they are involved in observing,
experimenting, and synthesizing understanding. From this example combined with
others throughout the interview, we can propose that Carter believes students can learn
science in a wide range of settings, not just formal classroom situations. Central to any
learning event for Carter is a conversation with students about their experience.

Carter's essay "On Developing Curriculum" in his professional portfolio contains
another description of the influence of his beliefs about how knowledge arises and how
students develop increasing understanding of science on some of the curricular decisions he makes.

(1) Getting started: what “story” can I create that will get the kids excited and involved?

This really involves being playful with the content to get the right context. I feel it is most important to get the kids going and messing about with a good story or questions before delving into any content. The story or question needs to create cognitive dissonance for the kids...it has to be something they can relate to but causes them to question their own understanding of it (and often may be counter-intuitive). Once kids are engaged in the context, the content 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. I truly believe that the role of the teacher needs to be one that causes kids to be confused rather than one of knower of all knowledge! (Emphasis in the original) (Professional Portfolio Essay 2, “On Curriculum”)

In making his curricular choices, Carter’s first consideration appears to be identifying the kind of experiences that are likely to lead to student learning. His experience and reflection have taught him that students must be engaged in the search for meaning before they can be expected to learn new concepts or facts. Learning for Carter is a synthetic process, carried out by the learner. New concepts are constructed from experiences with the natural world. As detailed in the curriculum section of this chapter, Carter designates the teacher’s role as that of designer of experiences that will inspire/motivate the students to engage in the construction of meaning.

Carter is clear in identifying teaching situations presented in the hypothetical instances that he considers unlikely to trigger the type of student engagement necessary for learning to happen.

[Initial Interview, Instance 1]
(Instance 1: Jeff and Sabrina are doing library work for a nutrition worksheet.) Interviewer: All right, so is science teaching happening in that situation? EC: Science teaching? Uhm. Yes.
Interviewer: All right, what makes you decide that? You hesitated on that.
EC: Yes I did hesitate. For one I had some questions about who Jeff and Sabrina were. I'm assuming that they're students. Second, they're talking to one another which I would hope they are, so I'm assuming they're talking to one another. In that context I would say teaching is happening. . . . probably they were given an assignment, which is really pretty classic research, and they're filling in some blanks. Now, what they're learning, I'd really like to talk to the teacher to find out what the point of the assignment is because what I see being taught is how to go to the library, finding a resource that might help in answering this question. I'm not sure that they're learning about fats, proteins, carbohydrates.

Carter thinks Jeff and Sabrina might be expected to learn something about the nature of the food groups listed in their resource materials, but he isn't certain this method will bring about that kind of understanding. All he can claim is that they are likely to learn about library use, and important and "classic" tool, but not the worthwhile learning that students ought to be engaged in.

In the instance describing Mr. Douglas' titration lab in Chemistry class, Carter again turns the interviewer's question about whether science teaching is happening into a discussion of whether students are likely to learn.

[Initial Interview, Instance 7]
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: I'd 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 (whether kids understand) acid-base reactions, you couldn't tell that from this scenario.
Interviewer: Okay so what else would you need to know?
EC: I'd need to actually talk to the kids to see if they understand why they're doing it not just how to get it. (Emphasis added)

As we saw in his response to the food groups research, Carter hesitates in deciding whether teaching is happening when he cannot be sure that learning is going on. It is interesting to note how Carter interprets my question about science teaching as a question
about student learning. In a secondary science methods class for preservice undergraduates, I asked students to construct an essay answering the question, What makes a good science teacher? I directed discussion of the student’s list of characteristics to uncover the traits in their list that directly addressed the purposes of teaching, namely to promote learning. Carter considers science teaching and science learning as two sides of the same coin.

In these examples and in several other sections of the Initial Interview, Carter identifies the types of experiences he believes students need in order to acquire the type of scientific literacy required of them. Carter’s responses indicate he believes students learn how scientific knowledge is obtained by participating in the processes of science themselves, by “set(ting)up something in terms of interpreting data”; “try(ing) to make sense of what’s dominant and recessive”; “(engaging) in some observation, some experimentation”; and “observ(ing) and putting things together and seeing what’s happening” (Initial Interview). In several negative examples of science teaching included in the hypothetical instances, Carter distinguishes the active type of learning that he believes necessary for science students from the more common passive classroom experience: “kids have to have some experience with it”; “not just replication but experimentation” (Initial Interview).

Eric Carter speaks confidently and consistently of his belief that students ought to obtain knowledge of science by getting involved in a scientific investigation of problems that are meaningful to them in the context of their lives. In Instance 9, he points out that “kids” are best able to understand if concepts are presented at a level that reflects their ability.
Interviewer: What do you . . ., what kinds of experiences would the kids need to know in order to proceed productively in a group like this kind of activity?

EC: I think they need some kind of conversation about what makes a good (classification system). Let’s say you’re looking at comparisons — what kinds of things, how do you compare, what kinds of things do you look at? So kind of a brainstorm activity with the kids, getting them to really critically look at it. Because one of the things I find is that kids say it better than adults. Saying it to kids, they have it in kid’s lingo. Okay, so I think that’s an important step even though it’s time consuming. I think it’s to get them to establish their own lingo, to go along with what you’re hoping that they’re going to go to.

Carter expects students to be able to analyze classification systems if he were conducting the class described in Instance 9. Student ought to be able to decide what criteria make a good classification system and to be able to describe their choices in language that makes sense to them and to their peers.

Carter also expects students to be capable of performing the tasks of scientific inquiry at increasing levels of complexity depending on their background and experiences. Carter considers it the teacher’s obligation to structure student learning experiences so that “kids” can make sense of their activity.

Interviewer: So that’s an important distinction in your mind between telling and teaching.

Here’s another activity in which students are working on a worksheet. They have to do a collection.

EC: I worry about this one.

Interviewer: Okay, why do you worry?

EC: Um, the reason why is because of what I don’t see here, which could be part of this but I don’t see it here. So, I do think my worry . . . If the blanks were filled in, I wouldn’t worry as much. Here’s the blanks I see. I don’t know what sort of work has been done with the kids to get them to construct criteria, to discuss what is criteria for grouping right. In the worst case scenario, I could see the kids being very frustrated by this.
Even complex ideas like defining criteria for adequate classification systems, can be learned if the “work has been done” to prepare the students for the activity. The key method to get the “work” of preparing students to learn is the conversation that teachers must conduct to identify student’s existing knowledge and diagnose their need for new ideas.

[Intial Interview, Instance 9 (cont’d.)]
Interviewer: (They’re frustrated) Because they don’t have that background?
EC: Because they don’t have that background, they don’t understand what is even meant by this. And then, once again, the worst case scenario (which I have seen happen) is then there’s no follow-up by the teacher, and then blame. “Okay, you guys aren’t working hard enough.” So that’s why this one causes a bit of concern.

On the other hand, if the kids have had some exposure already to critical skills and they understand how to begin to construct some criteria—this didn’t happen on the first day of school, the first week, but maybe a month into it. Okay. And the kids have had some experience with it, then I think the kids can do a fine job with it.

Learning complex concepts can happen, but along a continuum that proceeds at a different rate for each student. The teacher’s responsibility in guiding learning in productive directions includes the need to diagnose current understanding and prescribe future directions. Carter suggests that the hypothetical instances used in this research project might be suitable for revealing student understanding of science.

[Intial Interview, Instance 3]
EC: Can I go back to something here? I think you could use this (Instance 3, students making muffins) as a science teaching situation, in terms of asking the kids in the class to read this and ask them. Is science teaching happening here? What makes science tick? Okay, so I’d use that scenario to pose to kids. Interviewer: So you’re asking them what their conception of science is by asking them, are these kids involved in science?
EC: That’s right.
Knowing student's conceptions can guide teacher's choices for the activities and expectations that are appropriate for the particular group that arrives each school year. A summary of the key themes describing Eric Carter's beliefs about appropriate and worthwhile student learning in science are presented in Table 4-10.

<table>
<thead>
<tr>
<th>Table 4-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beliefs about Appropriate and Worthwhile Student Learning</td>
</tr>
<tr>
<td>Construct new knowledge</td>
</tr>
<tr>
<td>Practice of scientific inquiry:</td>
</tr>
<tr>
<td>Observe, interpret, question, critically evaluate, consider alternative hypotheses</td>
</tr>
<tr>
<td>Share interpretations, have conversations about meaning</td>
</tr>
<tr>
<td>Communicating scientific understanding</td>
</tr>
</tbody>
</table>

2. Teacher's intentions: Teacher expects students to learn . . .

Eric Carter's designated classroom activities along with the syllabus and course description for the Natural World seminar are the most direct source of information about his intentions to promote student learning in particular ways. However, a fine line separates what Carter assigns as student activities and what understanding he intends them to derive from their experiences. For the most part, Carter's statements referring to tasks students must accomplish are assigned to the "curriculum" category of this analysis, presented in the previous section of this chapter. Statements referring to what students must demonstrate as evidence of learning are considered to reflect what Carter intends students to know and understand. While the distinction may seem trivial, there is a potentially important link between how teachers believe student learning happens and what they require students to demonstrate as evidence that learning has occurred. For example, widespread criticisms of "cook-book" labs focus on the inadequacy of fill-in-the-blank worksheets as evidence of growth in student understanding of the underlying
concepts presented in the laboratory exercise. This inquiry examines the activities in the project unit that Carter designs for his students, and the learning outcomes he anticipates will ensue. Are the activities Carter designates likely to invite appropriate and worthwhile knowledge?

On the syllabus for "Our Natural World", Eric Carter defines the evaluation plan for the course.

Evaluation:
In answering the above questions (essential questions), you must exhibit knowledge and the following skills: problem solving, literacy and communication. The format for demonstrating your knowledge and skills will include fieldwork, seminars, lab work and a variety of written exercises. Keep in mind a global bio-geo-chemical cycle and how your analysis of it shows a 'local-global' connection. (Our Natural World Syllabus, 1996-97)

As one segment within a full year course, the Rivers' Edge unit observed for this research was specifically designed to give students an opportunity to develop their problem-solving skills in the context of field studies of their individual plots. Carter expects the field experiences to prepare students to be able to demonstrate their expertise in discriminating among their observations for clues to support their hypothesis about the "life histories" of the animals they have studied. The documentation for EcoNet, the data base to which student report their observations, included additional learning objectives for the project. In the excerpt shown in figure 4-4, Carter describes the explicit as well as some implicit expectations for student performance.
Figure 4-4

EcoNet Biodiversity Project Handbook

The goal of this project is to enable high school students (1) to establish permanent biodiversity monitoring projects and (2) to establish a global telecommunications link (using email) with other high school classes interested in developing biodiversity monitoring plots.

To support the general goal of “establishing (a) permanent biodiversity monitoring project,” students will be expected to get involved in “surveying and mapping 20 meter by 20 meter permanent quadrants . . .”, “note(ing) tree species density, frequency and dominance figures”, and “including species located . . . at four seasonal midpoints (with priority given to indicator species of insects, birds, reptiles, amphibians, mammals, and plants” (EcoNet Project Protocols). As described in the curriculum section of this dissertation, the activities Carter has planned for his students in the River’s Edge unit are intended to map directly into this database. He intends students to perform the EcoNet procedures and to acquire increased understanding of habitat characteristics along the way.

While the syllabus and curriculum guidelines offer some information regarding the teacher’s expectations for student learning, classroom instructions are even more informative because they are direct statements to the students regarding what will be expected of them. On the double-block class four weeks into the River’s Edge unit, Carter discusses student progress toward completing assigned tasks. Carter had been absent from class during the previous week while his student teacher was completing her practicum requirements and he had missed a couple of class sessions to attend a biodiversity conference related to his summer internship work. This class session was an opportunity to reconnect with the students and to remind them of his expectations.
I want to take a couple of minutes talking about where we are with our river’s edge project.

A week from today, next Thursday, I’m going to set up a winter animal signs indoors experience for you. Okay. And what it will be is something like a test. I have different tracks set up in the classroom, as well as scat and chew marks. Okay, then there’ll be a couple of questions. And what I’m going to ask you to do is use your natural history skills and make some determinations about those. I’m going to ask you to make some observations about what you observe with that track or with that scat and based on that determine what this tells you about what animal does this belong to.

And then the final, okay, using this as the checklist? Things that I want you to observe. That will be due in final form in you field notebooks on Tuesday, Feb. 11. After that, then we’ll get going with our biodiversity symposium.

Okay, now what I strongly recommend...you might want to take a look at that (Project Wild newspaper) and at some of the other articles. Last thing I want to point out to you are these voucher sheets. The animal signs that you’ve been seeing, okay, I’m going to collect that along with your field journals. You’re going to be giving me that Tuesday.

Since we first started we haven’t had snow to work with. So I strongly advise those of you that do need to do tracking that you use today to do it. The snow has been very unpredictable this winter. Okay?

And that about concludes my notes. Questions that any of you might have?

(Student asks about grading criteria for the field journals.)

Okay, most of what I’m going to be zeroing in on are the wildlife signs that you’ve observed and how you interpret that. Keep in mind that next Thursday we’ll have the assessment but we should have some fun with it. But note I’m assessing what you know from what you’ve observed outside, from some of the lectures we did during this unit, and from the articles. How organisms are adapted.

In this end-of-unit summary, Carter repeats the task requirements that he will be using to evaluate student’s completion of the unit. He explains his intentions for what he euphemistically calls the “winter animal signs indoor experience,” which he later refers to as a ‘test.’ He reassures students that this experience should be “fun” apparently to alleviate student’s concerns about test situations. Carter seems to be dealing with a conflict in this presentation. On the one hand, he attempts to set demanding standards for
students to become competent in the skills and knowledge of the naturalist. On the other hand, he offers numerous supports so that they have no reason not to succeed.

Carter's relationship with his students both individually and collectively comes through as an important consideration when determining what expectations to set for them. When asked in an informal interview to describe the nature of this particular group of students, Carter explains that, early in the semester, teachers who work with these seniors noted that they are notoriously unreliable at meeting deadlines, but extremely remorseful when scolded for their slackness. In one class in the fall, Carter expressed disappointment in them when only seven of twenty-five students had read an assigned article to be discussed during class.

So I asked, how many people read the article? Hands up. Seven out of twenty-five! So I said, we really can't discuss this. You can't make it up on the spot. And it was like... the kids were like crushed! It was unbelievable! They pleaded with me to just read it now. They were apologizing to me. I've never had a group like this, with these group class confessions or apologies. (Informal Interview, 1/16/97)

Carter's intended assessment activity for students is designed to reveal their achievement of the process skills he has emphasized during the project unit, but he makes clear to the students that the structure of the assessment should not cause them concern. Recognizing that student understanding can be masked by distractions about performance and grades, Carter tries to strip away distracting information so that the assessment provide accurate information about student knowledge.

In addition to expecting students to become proficient in the naturalist's skills, and to develop competence in critically selecting relevant observations, Carter intends his curricular choices to help students improve their ability to construct interpretations of
events in their study plots. As quoted earlier, Carter describes the purpose of the lab practical to give the students an opportunity to “...use your natural history skills and make some determinations about those (specimen observations)” (River’s Edge Class 1/30/97). Since the examination samples will be different from specimens available during the project unit, students will be expected to select their best hypothesis based on the available data.

Carter frequently mentions his belief that student learning involves constructing new knowledge. In the River’s Edge unit, Carter expects students to develop new knowledge within the domain of habitat studies. In the EcoNet Handbook, he explains how student researchers can be expected to contribute to scientific understanding.

Student findings will be presented to local conservation commissions with recommendations for improving the quality of local habitat to be implemented by the student participants. Students will also present the profile of neotropical migrants and habitat improvement project to students throughout the United States via electronic mail. (EcoNet Handbook, p.2)

The expectation is that the observations students make during the Natural World course will have a local as well as a global impact on our understanding of our environment. Implicit in this expectation is the need for students to present their information clearly, and to defend their interpretations convincingly. Effective communication is a central theme at Parkside High School, and in Eric Carter’s class, students are expected to communicate in a very public fashion to their local conservation officers.

A summary of the key themes evident in Eric Carter’s statements about his expectations for student learning is presented in Table 4-11.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
Table 4-11

<table>
<thead>
<tr>
<th>Beliefs and Intentions Regarding Appropriate and Worthwhile Student Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher’s beliefs: Eric Carter believes students should know and be able to . . .</td>
</tr>
<tr>
<td>Construct new knowledge</td>
</tr>
<tr>
<td>Practice of scientific inquiry:</td>
</tr>
<tr>
<td>Observe, interpret, question, critically evaluate, consider alternative hypotheses</td>
</tr>
<tr>
<td>Share interpretations, have conversations about meaning</td>
</tr>
<tr>
<td>Communicate scientific understanding</td>
</tr>
</tbody>
</table>

As mentioned in a previous section of this chapter, no evidence of group conversation was observed during the researcher’s visits. Visits occurred only one day a week during the project unit, and the teacher’s lesson outline assigns time for group discussion on the short-block class meeting times. There are gaps in the data that result in gaps in the comparisons presented in these tables.

3. Actions: Students in Eric Carter’s class are required to demonstrate . . .

“Actions speak louder than words.” Each action section in this analysis is based on the author’s belief in the truth of this aphorism. Eric Carter, like many teachers, has clear beliefs and intentions about what students ought to know and how that knowledge should be evaluated. Students soon learn, however, that what teachers really value can be found not in what teachers say they value, but rather in what teachers include on their tests and in how they apply their scoring criteria. Carter is remarkably consistent in his beliefs and intentions related to what counts as appropriate and worthwhile student learning. Does he follow his ideals in designing assessment tools and in evaluating student learning?
This excerpt from one of Carter’s professional portfolio essays outlines his beliefs about assessment.

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 get there versus the standards we hold them by, we can validate and report on their work in meaningful ways. In addition, we then are able to report on a number of ways kids are able to demonstrate skills. . . not all kids are able to produce ‘products’ yet they are able to show demonstrable manifestations of their academic growth. (Professional Portfolio Essay 3, “Assessment and Feedback”)

Eric Carter poses a significant problem for himself in this excerpt. Evaluating student knowledge “products” is easy – we just ask them to tell us whether the owl pellet will contain bones or not. Evaluating the processes by which students arrive at their knowledge “products” is less clear-cut. Carter’s “winter signs experience” is his attempt to obtain evidence of student acquisition of scientific process skills by simulating the types of inquiry students carried out during the River’s Edge unit and that Carter modeled for them during their field work. Figure 4-6 repeats the excerpt from the lab practical that was presented earlier as Figure 4-5.

<table>
<thead>
<tr>
<th>Figure 4-6</th>
</tr>
</thead>
</table>
| **Name** _______________________________ **Our Natural World Seminar**  
**Winter Animal Signs Indoor Experience** |

**Part I: Animal ‘Signs’** 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 this sheet). (10 points each, 20 points)

1. Identify and describe at least 4 physical characteristics of the winter season that animals need to ‘cope with’ in order to survive.
2. Compare a warm-blooded organism to a cold-blooded organism in how each survives New England winters.
The two types of questions Carter posed on the "lab practical" reflect Carter's interest in obtaining information about student products and their thinking processes. He set out five samples of typical animal signs, including chewed twigs, scat, plaster molds of tracks, and regurgitated bird pellets, and asked the students to indicate what information could be gathered from the specimen about the organism which left it. Scores on the lab practical were based on the sophistication of the inferences made from the "clues." During the course of the unit, during fieldwork, and in class discussions, many signs had been mentioned and examples made available for students to observe, but the particular items presented in the assessment were new to the class. All students had dissected an owl pellet and reconstructed the vertebrate skeleton inside, but the absence of a bony skeleton in the pellet sample set out for the exam was a clue that the source of the pellet was not an owl. Similar types of logic were required of the students for each of the five specimens.

Carter's grading of the lab practical was individualized and comparative. Even if signs weren't accurately labeled with the correct species, he allowed credit for a reasonable argument of alternative evidence. For example, scales in the scat sample could indicate a river otter or a raccoon. Students whose responses were judged acceptable included in their answer the evidence they observed in the specimen and a logical relationship between the clue and the student's identification. Both kinds of knowledge were evaluated: "product" knowledge about animal form and function and "process" knowledge about the use of evidence to make inferences.

Field journals were used in deriving a more typical student achievement measure, completion of required activities. Carter had reminded students of the "checklist" he
would use to guide his review of their field journals. There should be notes describing observations made in the study plot, evidence of research about those observations and descriptions of student’s efforts to “construct a natural history” about the organisms over-wintering at the study site (River’s Edge Class, 1/30/97). Student scores depended on the completion of two required article reviews as well as the observations and answers to questions about the plants, birds, insects and mammals listed on the unit checklist.

Within the standards Carter set for completion of the unit tasks, he anticipates and accepts a wide range of skill levels. In an informal interview mid-way through the unit, Carter explains what he looks for as evidence of student learning:

(Because we’re outside in adverse conditions) what they need to do is make a quick rough sketch, a picture’s worth a thousand words, whatever. They add just notes. Then they have to go back to write the story. What the story is of that observation. The last couple of times I’ve had to be a little more directive with this group. It seems they need a little more structure about the project sheet. What’s the bird doing? What’s the bird eating? How’s that bird surviving? You have to get that just from your outdoor observation. But, what’s the story that’s being told?

Most of the time I give 3s. I grade on a scale of 1 to 4, 4 being tops and 1 being deficient. Rarely on these have I ever given 2s. Usually the kids get 3s and 4s. The 4s are spectacular and the 3s are good, they’re really good. . . This particular time I also wanted to see two reviews, article reviews. (Informal Interview, 1/16/97)

Carter’s fluid grading system depends not only on what the student presents in this one piece of evidence, but consistent with his stated effort to offer a variety of means of demonstrating growth, he brings his knowledge of student ability to his grading decision.

Looking at B’s field journal last September, he wouldn’t even write! He would just scribble on the paper. He was so self-conscious. So see where he is now? He actually wrote a paragraph this time. I was thrilled! He actually had one review done. But that still wasn’t good enough. He should have had the second review. See what we have in the heterogeneous environment? This is a better way to look at each
individual to help them make progress to reach their potential. (Informal Interview, 1/16/97)

Eric Carter’s grades reflect his beliefs about what is worthwhile for students to know about science as well as his beliefs about the variable nature of students themselves. His method of assessing student progress fits into the overall student-centered philosophy at Parkside. His scoring criteria honestly reflect his stated beliefs and his expectations for student learning.

In addition to the product and process expectations Carter holds for his class, he requires them to publicly present their findings to their classmates and to a larger audience. As the culminating event of the River’s Edge unit, Carter schedules a symposium during which the Natural World class will present its study of the conservation area to a student audience, and to invited professional naturalists.

What the grand scheme is, the goal is, to have three outside speakers, and also the students presenting their work, mostly to ninth and tenth graders who have kind of peripherally been involved in this. This is the first time doing this. What I’m hoping the kids will produce some videotape.

Tomorrow I’m just going to be playing coach. I want to get them excited. . . . So the idea is to have some of these well-known reputable people in the field to hopefully give some credibility to the kids and to confirm their value in what they’re doing in biodiversity. It’s going to be under the (essential) question, Can I make a difference? (Informal Interview, 1/16/97)

Carter enacts his belief that students ought to be able to demonstrate their knowledge in a public manner by scheduling the symposium segment of the River’s Edge unit. Just as he shared his symposium experience with a group of students in class another day, Carter expects students to become proficient in the presentation skills that are central to
the scientific enterprise. Including recognized experts in the field supports Carter’s goal of guiding student to use their knowledge and skills to “make a difference.”

A summary of the key elements among Eric Carter’s beliefs, intentions and actions about student learning in science are shown in Table 4-12.

| Beliefs, Intentions and Actions Regarding Appropriate and Worthwhile Student Learning |
|-----------------------------------|------------------|------------------|
| Teacher’s beliefs: Carter believes students should know and be able to... | Teacher’s intentions: Carter expects students to demonstrate... | Teacher’s actions: Carter’s students are required to demonstrate... |
| Construct new knowledge | Synthesize new knowledge | Synthesis of new knowledge |
| Practice of scientific inquiry: | Function as naturalists: Observe, collect data, interpreting data, construct life histories of animals, consider alternative hypotheses | Use of the naturalist’s techniques: Observe carefully, interpret data (‘clues’), propose hypotheses, construct a ‘story’ |
| Observ e, interpret, question, critically evaluate, consider alternative hypotheses | Communicate scientific understanding | Communicate clearly |
| Share interpretations, have conversations about meaning | (no evidence observed) | (no evidence gathered) |
| Communicate scientific understanding | Communicate clearly | Present knowledge for public review |

As mentioned earlier, the lack of data demonstrating Carter’s intentions and actions to promote student sharing of their findings is a result of the choice of observation days rather than the omission of this component of Carter’s decision-making. Carter used the single-block days to involve student in small and large group discussion. The researcher limited her visits to the double block class periods.

**Participant’s Reaction**

As mentioned earlier, the accuracy and authenticity of this case study is best judged by the participant himself. Two interviews were conducted following the construction of the preceding analysis. On the first visit, the researcher sat with Eric Carter as he read
through the summary for the first time. He was asked to comment on the accuracy of the representation made of his setting, his beliefs, his intentions and his actions. He was asked to comment on the authenticity of the description, whether it appears to a “reader” as a realistic set of events in the life of an experienced biology teacher. On the second visit, held one week after the first reading, Carter was asked if a second reading of the case revealed any inaccuracies or mistaken inferences about his curricular choices. Several selections from those response interviews are included here to support the claims of the case study.

[Response Interview 1, 12/11/97]
Interviewer: What’s your overall initial impression? Is it an accurate description of an authentic teacher, a veteran teacher?
EC: Um, Yeah!
Interviewer: Is it someone... can you see a relationship between yourself and ‘Eric’?
EC: Yeah! Yes. Yes. I do. I thought it was grand!
Interviewer: You sound surprised.
EC: No. No. I’m thinking a couple of things. It’s real, which adds to the authenticity of it. The fact that plans do change. I would be suspect if I was to be reading this and not having participated in this with you, if Parkside, if everything was just perfect, like Lake Wobegon. I think that’s an important part of its authenticity.
Interviewer: The whole idea here is the process of the creation of curriculum that you go through. Did you find them (the analysis charts and narrative) to be valid examples of the processes as you think back to those events?
EC: I felt relieved, quite frankly as I was reading it. I did. Yes! I felt, “good!” Because sometimes you never know, or I never know I should say, when you go with a plan B whether or not they are in fact meeting the needs of the kids and whether the overall curriculum works. So it’s nice to have an outside, objective confirmation of that, which I hope you would highlight even more if you could. Only because I think it’s important for a teacher to feel free enough to do that, to use that moment.

Carter’s first reading of the document revealed no factual errors and received a very positive response from him. He felt “relieved” because his hope for the coherence of his course plan was validated even on days when everything is working against the normal
routines. He indicates that the themes assigned to his statements appear to be accurate representations of his conceptions of his work.

During the follow up interview one week later, Carter was asked if a slower, more detailed reading revealed any inconsistencies between what he believes and what is asserted in the case study.

[Response Interview 2, 12/18/97]
Introducer: Do you have any corrections to make regarding the accuracy?
EC: No. As far as the original notes, I think it is very accurate as far as what I was hoping for with the scope and sequence of the project. To the fact that the way you reported it was quite accurate. As I mentioned last time I was very impressed that you brought back last year the images and so forth as I was reading through it. So that was fine.

Carter confirms that the presentation of his efforts in the case description retains the essential elements of the course he offered to his class. He was impressed that the reading of the report could bring back the images from the previous year.

In this second response interview, Carter quickly affirms the authenticity and accuracy of the report and directs the conversation to describe the thoughts this report triggered for him. He raises questions that occurred to him during his second reading.

[Response Interview 2, 12/18/97]
EC: The questions that I have when I read through this are, how do you know when kids get it? This is a question I'm struggling with right now. I'm going to break this down into two different areas... Now, the science types, I hear from them (after they've graduated)... And that's always been unbelievably reaffirming. Talking about how much they really enjoyed it and this, that and the other. But the kids that aren't (science types), we just don't know, looking at the broader scope at 'scientific literacy.'

The case report presented in the dissertation stimulated important professional questions for Carter. He appreciates the data that is reported about his own efforts, but, as mentioned in an earlier section of this chapter, for Carter a teacher's efforts are
unimportant if students aren't learning. This second side of the teaching-learning coin is missing in this dissertation project. Recommendations and plans to address that limitation of this study are presented in further detail in Chapter 7.

Carter goes further in our conversation to describe other ways his reading of this report has inspired questions for himself.

[Response Interview 2, 12/18/97]
EC: After our meeting last week, I was driving home. I was just kind of loose, driving, thinking, and thinking about my beliefs and looking at the accuracy and . . . Something that probably didn’t come out in this is and wouldn’t necessarily come out in this is the role of mentors in establishing those beliefs. Why did I even get involved in science education to begin with was my advisor, who was a really strong mentor.

Carter takes the discussion from professional mentors, like his advisor, to discuss the role of modeling, particularly his own modeling of scientific processes for his students.

[Response Interview 2, 12/18/97]
EC: This one (unit) tends to be a little more factual. If we’re going out looking at tracks, we’re trying to interpret, to synthesize. I do think that the point of raising questions, inquisitiveness, I think that part can always be modeled. And scientific habits of mind. It really (pointed out) to me, from reading this, it’s something I should really pay more attention to. Other than being out with the kids and seeing something and saying, “Yeah!” “Wow!” and, “Great!” Generating questions should probably play a more conscious piece in my curriculum design.

For Carter, reading the case study of his teaching inspired a different kind of critical reflection of his own. Having an “outsider” reflect his work back to him in an authentic way prompted a fruitful self-examination of his curricular decisions. In Chapter 7 is further discussion of pursuing a systematic use of the procedures applied to Eric Carter for teacher educators and practitioners.
Conclusion

The preceding summary of Eric Carter’s beliefs, intentions and actions in the project-based science classroom is only one of many interpretations that could be made of his teaching. Its usefulness will come from its ability to reflect back to Carter and to other veteran teachers a picture of how their beliefs and intentions are related to their teaching practice. In Carter’s case, there is a close correlation between what he believes about the nature of science and the types of activities he plans for his students. Similarly, there is a set of common terms and phrases that describe his beliefs and his intentions about what constitutes an ideal science curriculum which has close parallels in his actions to structure his student’s work. Finally, Carter sets performance expectations for his students that match what his belief about the value of process as well as product knowledge.

The preceding summary is a description of only three aspects of Eric Carter’s teaching persona. Of interest in making the summary useful to others is a comparison of the work of this one veteran teacher to the recommendations of major stakeholders in the science education enterprise, including professional organizations. To what extent do Carter’s actions promote the goals of science teaching described in the major reform documents? Are there instances where Carter’s beliefs influence his intentions and promote actions that are in conflict with prevailing goals for scientific literacy and science learning in secondary schools? Chapter 6 of this dissertation continues the analysis with a comparison of Eric Carter’s beliefs, intentions and actions with several of the teaching and content standards recommended by the National Research Council (NRC, 1996).
CHAPTER 5

ANALYSIS OF STEVE NOBLE’S BELIEFS, INTENTIONS AND ACTIONS

The research project presented in this dissertation proposes that the emergence of a coherent sequence of learning activities in a teacher’s classroom is a product of the interaction of the teacher’s beliefs about the nature of scientific inquiry, about the ideal goals of project-based curriculum, and about appropriate expectations for student learning. The intersection of these three key components of the teaching process influence the teacher’s design and selection of suitable learning activities. A teacher’s intentions are then translated into classroom actions in the context of a particular school culture in which he functions. The resulting learning experiences for students represent the enacted science ‘curriculum.’

A proposition similar to that presented in Chapter 4 will be argued in this chapter -- that Steve Noble presents a sequence of learning activities to his students that reflect his beliefs about his discipline, about the proper goals of science curriculum, and about what counts as worthwhile student learning. Within the context of the school culture in which he works, Noble translates his beliefs into intended lessons, which are acted out as classroom instructions, with modifications suited to the attitudes and aptitudes of the particular group of students assigned to the class. While the resulting project-based science ‘curriculum’ appears very different from the curriculum Eric Carter’s students encounter, from the teacher’s perspective there is a coherent relationship between his beliefs, his intentions and his actions. This chapter provides the reader with a detailed description of the beliefs and intentions that underlie the project-based curriculum Steve Noble enacts.
The analysis of Steve Noble's teaching involves looking at the available data for patterns and themes revealed by his statements. Three primary sources of data include the initial Interview about Instances, which offers insight into Noble's beliefs; statements made during classroom visits and informal interviews about the project-based unit, which are identified as evidence of his intentions or lesson 'plans'; and his statements to students and in interviews which define his standards and expectations for students, classified as Noble's 'actions.' Table 5-1 repeats the list of data sources and their corresponding category that was presented in earlier chapters.

<table>
<thead>
<tr>
<th>Category</th>
<th>Primary Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers' Beliefs</td>
<td>Initial Interview</td>
</tr>
<tr>
<td></td>
<td>Informal Interview</td>
</tr>
<tr>
<td></td>
<td>Teacher commentaries, essays</td>
</tr>
<tr>
<td>Teachers' Intentions</td>
<td>Course syllabi</td>
</tr>
<tr>
<td></td>
<td>Program of studies</td>
</tr>
<tr>
<td></td>
<td>Curriculum handouts</td>
</tr>
<tr>
<td></td>
<td>Classroom instructions</td>
</tr>
<tr>
<td>Teachers' Actions</td>
<td>Classroom observation</td>
</tr>
<tr>
<td></td>
<td>Evaluation instruments</td>
</tr>
</tbody>
</table>

The project presented here seeks to describe the interaction of teachers' beliefs, intentions and actions within each of three major topic areas: the nature of scientific inquiry, ideal goals of project-based science curriculum, and judgments about appropriate and worthwhile student learning. The nature of scientific inquiry is the specific aspect within the discipline of science that is the focus of this study and reflects the teachers' conception of how scientific investigation is carried out. The second topic, the proper goals of project-based science curriculum, captures the pedagogical understanding of the participating veteran science teachers. The third major topic area, expectations for appropriate and worthwhile student learning, encompasses the judgments teachers make.
based on their experiences with students who come to class with a wide range of abilities, aptitudes and interests. Together, these three topics form the key components of teachers’ conceptions of their role.

Within each of the topic areas, teachers’ beliefs, intentions and actions are selected from the data sources. Statements were classified into a category if they were felt to complete a suitable stem. For example, a statement reflecting a belief about the nature of scientific inquiry would complete the stem, Scientific inquiry involves . . . The set of stems for each category were shown in Table 5-2, which is repeated below.

<table>
<thead>
<tr>
<th>classification matrix</th>
<th>Beliefs</th>
<th>Intentions</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>nature of science/ scientific enterprise</td>
<td>scientific inquiry involves . . .</td>
<td>students should know that science is . . .</td>
<td>students learn what scientific inquiry is by . . .</td>
</tr>
<tr>
<td>ideal curriculum</td>
<td>a project approach to curriculum should . . .</td>
<td>my curriculum will provide opportunities to . . .</td>
<td>my classroom activities involve students in . . .</td>
</tr>
<tr>
<td>expectations for appropriate and worthwhile student learning</td>
<td>students should/ought to have an understanding of . . .</td>
<td>i (teacher) expect students to learn . . .</td>
<td>students are required to demonstrate . . .</td>
</tr>
</tbody>
</table>

Reliability of the classification of teacher statements was confirmed by comparing the researcher’s sorting with that of an independent reviewer, a fellow graduate student in education, who classified a sample of Steve Noble’s statements. Statements which were coded differently by the reader and the author were reviewed and reassigned to new categories as needed, following discussion with the reader. The final classification categories reflect a consensus decision of the reviewer and the researcher.

Steve Noble offered additional confirmation of the authenticity of the analysis. Upon completion of an early draft of his case study, Steve was given a copy for his review. He presented his reactions to the accuracy of the conclusions drawn by the
researcher in a taped interview. Selections from his responses are included at the end of this chapter.

In Chapter 6, the teaching experience Steve Noble designs for his students is compared with the recommendations of the National Research Council in its document, *National Science Education Standards* (1996). The degree of correspondence between the Steve Noble's curriculum and the vision of ideal science teaching described in the NSES will be used to recommend application of the case analyses in efforts to reform science education.

**Steve Noble, Sculptor**

It's a very frustrating situation to be in that situation and not have your hands molding. To me, that's what a teacher's got to do! I've said a couple of times here, 'my hands in the pot.' I've got to have my hooks in there! (Initial Interview, Instance 8)

As he indicates in the selection quoted above, Steve Noble believes that the key task of teaching is the shaping of student's understanding and attitudes. He admits that, while science learning does happen in settings outside of school during casual interactions with the natural world, the role of 'teacher' in the teaching-learning process is to focus student learning in particular directions, to define the appropriate shape of the knowledge that arises. The image of Steve Noble as sculptor helps capture some of the key beliefs that influence his design of classroom learning experiences for his students.

All of Steve's eighteen year teaching career has been spent at Lafayette High School*, a classic stone-faced building that fills an entire city block. Drawing students from the surrounding double- and triple-decker apartment buildings for more than eighty years, Lafayette has maintained its determination to educate a diverse student population in the content as well as the values that have served immigrant families well throughout the history of the moderate-sized city. Lafayette has undergone numerous additions and

* Pseudonym
renovations to its structure during its lifetime so that it can house the 1800 students in
grades 9 through 12 who fill its maze-like hallways every day. Despite the impact of
time and the number of bodies traveling through it, visitors quickly notice the absence of
graffiti, the cleanliness of the floors and windows, and other evidence of the pride of
ownership the community takes in this aging beauty.

One contribution to the diversity of students at Lafayette is the forty-percent of the
student body that come from a nearby suburb. Citizens of this upscale city neighbor have
chosen not to construct their own high school, instead paying tuition to Lafayette for each
of the secondary students its town sends to the city. The school undergoes regular
periodic reviews of its performance to maintain the tuition contract for these students,
creating an atmosphere of accountability rare in most public schools. Although totally
administered as a public city high school, Lafayette’s principal invites active participation
in policy discussions from the parents in the sending suburb.

The degree of similarity in school values between the city neighborhood and the
sending community might explain the business-like atmosphere at Lafayette. Duty
teachers with walkie-talkies greet visitors at each doorway. Students are rarely in the
hallways during class periods, nor can they leave school grounds without permission.
The message is that there is work to be done here, and that work requires students to
attend class regularly and to perform responsibly. Similarly, teachers are expected to be
at their tasks in their classrooms or in their offices. Parent contact, committee service and
professional development activities are required. The veteran principal models the
business-like tone of the building, circulating among students and faculty to maintain his
awareness of the work that is being done. Pride in the success of both students and
teachers is displayed on the lobby bulletin board which carries pictures of student leaders,
scholarship winners, and local, state and regional award recipients. Steve Noble’s picture
fills the plaque for Teacher of the Year, 1993.
The atmosphere in Steve’s tenth grade college-prep Biology class mirrors the atmosphere throughout Lafayette. Students are greeted at the door as they arrive, move promptly to their assigned seats, and gather their materials to begin class. Quiet conversation continues while the teacher checks the roll and attends to business tasks -- make-up work, permission slips, dismissal passes. Within five minutes of the scheduled start time, Steve Noble has moved to the front of the room and signaled his readiness to begin instruction for the day. Students in the college-prep class visited for this project are typical of Level 3 students in other classes in this school: attentive, respectful and prepared. In the course of Steve Noble’s day, he meets two college prep classes and three Level 2 general biology classes. The college prep classes meet for seven periods per week, staying for a double period on two assigned days. These classes typically house 22-24 students per section.

The watershed unit that forms the backbone of Steve’s ecosystem segment of the course is a statewide collaboration of students and state water quality analysts. Each fall for the past eight years, students in 50+ schools along the Central* River watershed have visited their designated study sites and collected data on the chemical and biological status of the river and its tributaries. The data from each site is shared electronically with other schools and with agents of the state Department of Environmental Services Water Quality division. Representative students from each of the study areas gather to share their results at an all-day conference later in the fall. Students not only gather scientific data that will be used for monitoring water quality but also experience the collaboration that characterizes the scientific enterprise.

Faculty, administrators and students at Lafayette share a common vision for what counts as a good school -- a well-managed classroom, a dependable routine to the school day, and dedication to success as measured by high scores on local and national standardized tests as well as a high college acceptance rate. Steve Noble is highly

* Pseudonym
regarded by his science colleagues and by his administrators for his contribution to the success of the school. Steve’s students respect the standards he sets for their work, and, while some neglect to meet his expectations, most appreciate his efforts on their behalf. It is within this context that this inquiry looks at Steve Noble’s process of curriculum development.

Steve Noble’s Beliefs, Intentions and Actions Related to the Nature of Scientific Inquiry

1. Teacher’s Beliefs: Scientific inquiry involves... 

Even in an environment as orderly and structured as that at Lafayette, a teacher’s philosophical orientation toward his/her discipline is likely to influence the selection and presentation of learning activities in the science classroom. In the case here, Steve Noble’s ideas about how scientific inquiry is conducted, and what its proper uses might be, are evident in his response to a hypothetical instance (Appendix A) in which the teacher is orchestrating a lively, interactive discussion of cell types.

[Initial Interview, Instance 8]

Interviewer: You mentioned briefly, or alluded to, one’s different beliefs about what science is all about. Is it a book type of thing or is it an interactive type of thing? What would be the impression you’d want your students to come away with, about what science is all about? Why study science as a . . .

SN: Because it’s really fascinating. It’s interesting, it’s interesting to me. And I’ll try to make it interesting to you. And I’ll try to show you some things you never saw before, maybe do some things you never did before. Knowing that 3/4 or more probably will never pursue science, but they won’t have a perverted view -- that it’s some boring old stuff somewhere that stuffy coats somewhere make up these rules and theories. How do they decide who’s right anyway? Who are ‘they’? For students to understand as best they can that information comes as part of the process. You do experiments to get information, to get data that somebody then interprets. . . . The process that I want them to do helps them see that maybe that’s what it is, as opposed to me saying ‘science is a process and here’s the steps, the scientific method is this, this, and this. Now, learn the scientific method.’ We do, you do. You study. You design an experiment. You ask a question. Sometimes you pose a question. Sometimes you pose an
hypothesis. And then you play around with it and you get some numbers and (ask) what do the numbers mean? Does it relate to what you read in the book or is it something new? . . . That's what we call 'science.'

Two aspects of Steve Noble's conception of science are clear in this selection: his belief that science involves active participation, and his wholehearted declaration that science is 'fascinating.' Steve expresses a fear that some students might move away from science because they have a 'perverted view' that science is done only by a select group of people, who typically dress in white coats and are viewed as 'stuffy.' He implies that what he finds interesting about science, what draws him to the field, is its invitation to actively participate in the search for meaning. In addition to posing questions and hypotheses about events in the natural world, one gets to design experiments and gather the data that is then interpreted to try to increase their understanding of the way the world works. The interpretation of data has some openness to it, which Steve refers to in another response during the initial interview.

[Initial Interview, Instance 9]
Interviewer: Here's the next one. (Students are instructed to collect acorns and sort them into similar groups.) Is science teaching happening here?
SN: Certainly, without a doubt. I assume they've already talked some about classification, about what it is as far as grouping things. Here you allow them to use that idea of what classification is all about, kind of extend it and play with it. 'Well how would you classify?' . . . And what's nice about this is you can go to the next level again. You can look at your acorn classification and hers and mine and maybe you didn't start doing them by cap shape, maybe you started by the pointed shape of the end, or weight, or overall perimeter shape or something like that. And it allows them discussion of, well, who designs these keys anyway? Well, people did. Because they think it works well. Well, are there other ways? Of course there are lots of other ways (of classifying).
In this response, Steve Noble indicates that one aspect of science important for students to experience is the variability in interpreting data to produce meaningful information. In the interactive discussion instance, he points out that sometimes “there are some arbitrary decisions made” because of the interpretive step in the process of identifying the laws of nature. In discussing acorn classification, he indicates he would find it helpful for students to understand that different systems might be equally valuable, and that that’s acceptable in the scientific process.

Steve’s response to the acorn instance also provided insight into another key element of his beliefs about science. Following his description of how this teaching situation could provide an opportunity for students to experience the variable nature of scientific knowledge, he explains how the diversity of classification schemes reflect a common principle.

[Initial Interview, Instance 8]
SN: . . . And it allows them discussion of well, who designs these keys anyway? Well, people did. Because they think it works well. Well, are there other ways? Of course, there are lots of other ways. It’s just an organized way to look. And you have an organized way and so do you and you. Maybe there are more logical ways, and maybe if you’re more experienced you can pull more information into a key but organization is something everyone does. It’s kind of cool to be able to do it! You’re being a scientist! You’re classifying.

According to Steve Noble, “being a scientist” means taking an organized approach to the process of inquiry. The ordering of observations, whether acorns or inherited traits or cell types, is a defining aspect of science for Steve.

One particularly revealing comment combines Noble’s beliefs about the active nature of scientific inquiry and his belief that its topics and methods are ‘fascinating.’ In describing how lower ability students are often given less opportunity to participate actively in science, Steve explains his attitude.

[Initial Interview, Instance 7]
SN: . . . Sometimes they (lower ability students) tell you they feel they’re treated that way. They just get worksheets and are told, ‘Do this and turn it in. You’re not smart enough to do the other stuff.’ It’s not that they’re told this outright, it’s just that, how many times are you going to be given a worksheet everyday and told to read and write this stuff, read the book and write this in. That’s really boring!

Interviewer: So when they come to you and they say, “We don’t wanna have to (do these activities), just make us fill in the blanks . . .
SN: That’s right. “Tough beans! You’re not filling in blanks! You’re going to get your fingers dirty and it’s going to stink and it’s going to smell and bugs are going to be walking around, and you have to touch them! Yes you do! You’re doing something. You’re not just sitting on your can!”

His excitement is audible in his tone of voice and visible in his gestures as Steve explains how science involves getting ‘your fingers dirty’ and ‘doing something,’ even for reluctant students who have been taught that they can’t participate in the process of generating knowledge. His enthusiasm recalls his post-college years as a facilitator for an outdoors experiential education program working with children and adults. He brings that background into his classroom efforts in as many ways as he can through the project unit he implements with his students. For Steve, one of the ‘fascinating’ parts of science is its messy side! Steve uses the kinesthetic aspect of the scientific enterprise to encourage even the reluctant student to enrich his/her understanding.

A summary of Steve Noble’s beliefs about the nature of scientific inquiry is presented in Table 5-3.

<table>
<thead>
<tr>
<th>Table 5-3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nature of Scientific Inquiry</strong></td>
</tr>
<tr>
<td>Teachers’ Beliefs: Scientific inquiry involves . . .</td>
</tr>
<tr>
<td>Being actively involved</td>
</tr>
<tr>
<td>studying, asking questions, designing experiments, gathering data, interpreting data</td>
</tr>
<tr>
<td>Doing interesting things</td>
</tr>
<tr>
<td>getting your hands dirty,</td>
</tr>
<tr>
<td>Taking an organized look at the world</td>
</tr>
<tr>
<td>Realizing the variability of interpretations</td>
</tr>
</tbody>
</table>
2. Teacher's Intentions: Students should know that science is . . .

One way to uncover what the teacher intends students to learn about the discipline is to look at the statements teachers make to describe the plan for the day's lesson. For this analysis, Steve Noble's classroom instructions and informal comments after class will be used to determine what aspect of scientific inquiry he tries to share with his students.

Most of Steve Noble's statements to his students are directed toward efficient completion of the project tasks, statements that will be explored in more detail in the "curriculum" strand of this analysis. The motivation for the task-completion focus of Steve's classroom instructions is understandable. Leading a group of 24 tenth-graders on a ten minute walk through city streets to access the study site at the river is always a challenge, even for Steve Noble who has been escorting his classes along this route for eight years. Concerns for safety, recognition of the time limitations of the daily schedule, and a concern for obtaining useful data from the research take priority in his classroom instructions. However, within the limitations of the school structure, Steve tries to impress on students a broader view of the purpose of their work.

[Watershed Class, 9/30]
(On the first day of the watershed unit, Steve Noble describes the type of news article that is required as part of their project portfolio.)

The part of the article I want you to read asks some interesting questions, like, what makes a clam edible? (Teacher reads excerpts from the article describe the standards for fecal coliform presence in the water from which the clam was harvested.)

That means 14 bacteria in a sample of this much (holds fingertips slightly apart) water. So it's not a 0 standard. There are a number of bacteria allowed. That's how much is considered safe. That's where the standard has been set.

I thought I'd share that with you so you could have a better focus for our study. You certainly want to drink clean water, eat clams if you like steamers or fried. What is clean to you may not be the same to somebody else. The standards may not be what you think they are. The standard doesn't go down to the '0' level.

We need to look at who makes the standards. Why are they the way they are? There's a dual focus of the project -- the historical as well as the chemical and biological parameters that describe this river.
... the goals (of this project) are to enhance your education as intelligent citizens about a resource in your community. Even if you live in surrounding towns, it is a major resource.

From the instructions he gives them, it seems clear that Steve Noble thinks students ought to recognize that scientific research is related to their own lives. He intends students to understand that groups of knowledgeable people set what may seem like arbitrary standards for water quality, and that Lafayette high school students ought to be aware of the importance of those decisions to their own health and to the well being of their community. Steve combines detailed description of their data-gathering tasks with this wider view of the nature of scientific inquiry as a way to help students recognize their role within the scientific enterprise.

Steve reminds the students that their work in this project serves as more than just a "school" exercise. In addition to achieving required proficiencies to receive a report card grade, Steve points out that their data gathering will contribute to the experts' database.

[Watershed Class, 9/30]
There are 50 schools involved (in studying this river and its tributaries). All schools will be testing on the same day. That provides a unique picture of the river water quality. The State tests at various sites all year, but it doesn’t have the manpower to do extensive, comprehensive study. We contribute our data to the state’s information.

In this overview of the project, Steve emphasizes that this set of tasks will be helpful in guiding policies and decision on water use and reclamation activities. He tries to lead students to an understanding that the process they will tackle contributes to the "real" science that will be completed at environmental regulatory agencies. Recognition of the importance of individuals contributing to the scientific enterprise is a significant component of Steve Noble’s intended understanding of the nature of scientific inquiry for his students.

A summary of Steve’s intentions regarding knowledge about the nature of scientific inquiry is included in Table 5-4.
Table 5-4

<table>
<thead>
<tr>
<th>The Nature of Scientific Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers' Beliefs: Scientific inquiry involves . . .</td>
</tr>
<tr>
<td>Being actively involved studying, asking questions, designing experiments, gathering data, interpreting data</td>
</tr>
<tr>
<td>Doing interesting things getting your hands dirty,</td>
</tr>
<tr>
<td>Taking an organized look at the world</td>
</tr>
<tr>
<td>Realizing the variability of interpretations</td>
</tr>
</tbody>
</table>

3. Teacher's actions: Students learn what scientific inquiry is by . . .

A teacher's intentions and beliefs may require significant modification as they become translated into actions. Modifying factors include class time limitations, school and district curriculum coverage requirements, along with the aptitude and attitude of the students. In addition to the time constraints and student attitudes that modify teachers' intentions, new understanding of how students interpret their learning experiences in unexpected and unique ways adds an additional consideration to teachers' decisions about their classroom activities. Since so many variables come into play in the enactment of teachers' beliefs and intentions, this section of the analysis will focus simply on a detailed description of the events that students encounter in Steve Noble's classroom during the project unit.

Teachers' assessments of student learning are one type of action that has the potential to influence student interpretation of their learning experience. In the case of the college prep students in Steve Noble's classes, there is an appreciation of the fact that what teachers test is what is important to know. Steve Noble uses a variety of assessment tools during the watershed unit. Some of the early tests and quizzes evaluate student recall of historical, cultural and geographical facts. The opening activity of the project
unit was a group presentation on one aspect of the river’s impact on the community. To assess the student’s skill in data collection, Steve designed a quiz for each team of students who had become “experts” in one specific water quality parameter. For the final examination for the unit, students worked in their study groups to analyze prepared water samples and to interpret class data and calculate the water quality index for the identified samples. A summary essay written by each student provided information about student’s ability to make qualitative assessments using the quantitative data that had been gathered by Lafayette students over several years.

Among the tools Steve Noble uses to evaluate student achievement, there is a strong emphasis on assessing the skills of data collection and evaluation. The water chemistry section of the final group test, labeled Figure 5-1 below, is typical of the performance expectations of students.
j) Water Chemistry

1) Each group must do their three chemical/physical tests on the water sample provided (NOT to include: inverts, bacteria or B.O.D. – B.O.D. groups will do a normal D.O test). Please write all test results on the front board (show all calculations on your answer sheet).

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

3) Each group would use the Q-value charts (for those you do not have, you may check the front desk) to determine the proper Q-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 necessary info 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 (assume the sample is from a nearby stream); effects of any present pollutants on local water conditions; possible polluting sources; and suggested solutions to any polluting problems which seem to be present.

The final group assessment required students to repeat the water tests their group had performed during the unit, using a simulated unknown sample the teacher had prepared. They had to apply the standards they used in the project to interpret the data obtained from the sample and to evaluate its quality. Students are also expected to recall class discussion and research on contaminants and their sources in order to prescribe a solution to any water quality problems that might have been identified in the simulated sample.

As he declared to them at the outset of the watershed project, Steve Noble expects students to understand that science is a process of gathering data and interpreting its meaning within the body of existing understanding. In an interview following the unit,
Steve was asked how he determined whether students were successful in the performance aspect of the exam.

[Post-Unit Interview, 11/4]
Interviewer: And how did you grade the actual performance section?
SN: If they showed me their results and showed me their calculations and if you have to sometimes do a multiplication. But they all pretty much got the 9 or 10 there. Using their judgment to select the single value for each parameter. (Each group had to ) look at both sets of data and decide if they're going to keep them both and if they're going to average them or what.
Interviewer: And it could represent an average or a single measure?
SN: Well, it could, but I said, whatever you do, give me an explanation for whatever route you chose. Some chose to throw out these data and explained why. For one class, it (the data) was 13, 13, 15 and 5 for oxygen. Um, and a couple of groups said, 'We're going to throw the five out because it's really different from the others.' Others said, 'We're just going to leave it in because it was there.'

Accurate water chemistry values were not the sole criterion for the grade on this exam. Instead, the focus of the teacher’s attention was the ability of the students to use the data obtained by their classmates ('colleagues') to construct an assessment of the quality of the water in the sample and to decide what data was valid. The group approach to the analytical aspects of the exam reflects Steve's understanding of the difficulty of this kind of higher order thinking for many tenth graders. Since he had originally structured the groups to include a range of ability levels, he had some expectation that group effort would reinforce each student’s analytical skills.

Do Steve’s actions reflect his beliefs and intentions for the presentation of an understanding of the nature of scientific inquiry as an active, participatory enterprise? From the example of his final unit test, it would seem that Steve has been effective in executing his stated intentions despite the typical constraints of the public school environment. While other sections of the exam required more traditional recall of historical and geographical facts presented in class lecture and group research, the performance section demonstrated for students Steve's belief that science is something to
be performed and thought about, without secure, fixed answers all the time. It is also
"messy" because of the possibility of mistakes by those taking measurements. The
expectation that students decide in their group whether to include all values equally or to
"throw out" some values reinforces the belief expressed by Steve and noted earlier that
science is a human endeavor, subject to the interpretation of human beings.

A summary of Steve Noble's beliefs, intentions and actions related to the nature of
scientific inquiry is presented in Table 5-5.

<table>
<thead>
<tr>
<th>Table 5-5</th>
<th>Nature of Scientific Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers’ Beliefs: Scientific inquiry involves...</td>
<td>Teacher’s Intentions: Students should know that...</td>
</tr>
<tr>
<td>Being actively involved studying, asking questions, designing experiments, gathering data, interpreting data</td>
<td>Gathering comprehensive data, collecting interpreting</td>
</tr>
<tr>
<td>Doing interesting things getting your hands dirty,</td>
<td>Related to their own lives</td>
</tr>
<tr>
<td>Taking an organized look at the world</td>
<td>Open to participation by everyone, (even students)</td>
</tr>
<tr>
<td>Realizing the variability of interpretations</td>
<td>Subject to varying interpretations</td>
</tr>
</tbody>
</table>

Steve Noble’s Beliefs, Intentions and Actions Related to the Ideals of Project-Based Science Curriculum

1. Teachers’ Beliefs: A project approach to science curriculum should...

The quote from Steve Noble’s initial interview at the beginning of this chapter
summarizes a central tenet of his beliefs about curriculum: “To me, that’s what a
teacher’s got to do. I’ve said a couple of times here, ‘my hands in the pot.’ I’ve got to
have my hooks in there.” (Initial Interview) The teacher is the sculptor, molding the
student’s understanding of the world by designating specific learning activities. For Steve Noble, the project-approach to science in the watershed unit is the vehicle through which students will learn how scientific inquiry works. This style of science curriculum allows him to directly influence — to mold — the development of realistic conceptions of the nature of scientific inquiry in his students minds.

Throughout the initial interview, in his analyses of the hypothetical instances presented for discussion, Steve Noble praises examples of science teaching where the teacher is moving the lesson in productive directions. In Instance 1 of the initial interview (Appendix A), students are working independently in the library gathering data on nutrition values.

[Initial Interview, Instance 1]
SN: In this scenario the teacher is very removed and the assignments may have come from the teacher. There’s learning going on as a result of the teachers’ assignments but the teacher himself or herself at this point (at least according to this scenario) doesn’t seem to have his fingers in the teaching. It’s more the student’s 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 teacher’s saying, “Okay, what did you get Jeff and Sabrina and Larry and Sue and George? Let’s see what we’ve learned here.” And the teacher’s bringing it back and saying, “You’ve taught yourself, you’ve played with this idea. Have you learned what I want you to learn out of this?” It’s a valid way of going at things and I’ve used this avenue, but the teaching isn’t going on here, but it happens later.

For Steve, having students complete research on their own is only part of a valid learning activity. He admits that learning happens even when the teacher is not there, but for there to be a “curriculum” or direction to the learning, the teacher must be involved as a guide to orient the learning in specific ways. In explaining a response to the guest speaker scenario, Steve says, “If I really wanted to get everything out of it I wanted, I would have to debrief the thing later. Because, as a teacher, that’s what I want: I want my fingers in the pot!” (Initial Interview, Instance 2)
Steve Noble admits that he doesn’t have the freedom to guide student learning in any
direction he chooses.

[Initial Interview, Instance 7]
Interviewer: So teaching has a direction, but the direction is in a sense defined by an informed teacher?
SN: It’s always defined by me, because you’re in my class and you’re doing what I want you to do.
Interviewer: But it’s not totally idiosyncratic. You’re not going off on your own weird tangent. Your choice is informed by other forces...
SN: That’s exactly right. That’s right.
Interviewer: So those other forces that keep you in check, that keep you from going off on a tangent, what would they be?
SN: Students play a part. Certainly I have a curriculum that’s defined by the department, by the city, by the state. There’s a book that’s helpful. I try not to let that be the defining factor, but it’s helpful. Certainly there are these other influences. Certainly my evaluations on how I’m performing as a faculty member has an impact too, so I can’t be totally off in my own little world.
Interviewer: So all those factors...
SN: There’s actions everywhere. Teaching is never boring. There’s something coming at you all the time, from every which angle!

In Steve Noble’s eyes, a teacher’s design of classroom events must take into account personal interests and skills as well as student characteristics and administrative/institutional factors. Constructing opportunities for students to learn in particular ways is a complex task!

Why does Steve think the project-approach he uses in the watershed unit offers students an opportunity to develop useful understandings about science? In reacting to some of the hypothetical instances in the initial interview, Steve elaborates on some of the characteristics of learning opportunities that he deems important.

[Initial Interview, Instance 9]
SN: And I always hate it, and I still do! If I’m in a class and the teacher’s giving filling-in-the-blank questions. He knows the answer and there’s only one answer and there’s only one word that will fit! That’s not teaching, or if it is, it’s awfully poor question-asking. This (Instance 9, Miss Panacek’s discussion) is good because she’s asking questions.

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

SN: Yes, yes. It’s interactive all the way! And she’s got her fingers in the pot because she’s the one directing this around, because they’re not kicking around ‘prokaryote’ and ‘eukaryote’ and mispronouncing it and not spelling it correctly and maybe switching the two in their notebook definition. But she’s directing it and she’s interacting and pulling it back. She’s guiding it because she’s going apparently where she wants to go. Hopefully she’ll get there, and it looks like she will.

Interviewer: You’ve been in a class like this, haven’t you?

SN: Yes, I like those classes. They’re interesting because it allows (student) questions (to) come up naturally.

Steve’s excitement with this hypothetical class is triggered by his recognition of the engagement of the students with the teacher in a collaborative discussion of the content. During the interview, his body language suggested his own desire to participate in the conversation! For Steve Noble, learning experiences that are worthwhile are those in which students (and teachers!) can become engaged as thinkers rather than as automatons. The curriculum must excite this desire to become involved.

Worthwhile curricular experiences can also be identified by their positive effects on student’s attitudes toward science. Steve realizes that the majority of his students are not destined to follow a career in science, but he does hope to enhance their ability to be knowledgeable voters by improving their attitude toward science.

[Initial Interview, Instance 9]

SN: There’s a difference in perception of what’s interesting. Science can become interesting this way (Miss Panacek’s interactive discussion). It’ not boring, rote, out- of-the-book kind of stuff. I would like to think that because it’s more interesting, that some of the academics would last longer. . . . But at 15 I’m not teaching them to be doctors. At 15, I’m trying to catch them and interest them in science. And if I can get some of them to want to be doctors, or to want to be vets or to want to be environmental technicians, who never even considered the possibility before because all they ever did was book stuff. That’s (fill-in-the-blank book research) lousy, uninteresting science. My goal in this kind of discussion would be that the students would become more interested. The affective things would happen.
Steve mentions his affective goals, the usually unwritten and often unrecognized beliefs about appropriate curriculum, again in responding to Instance 4 which describes students making muffins with a recipe they got in school.

[Initial Interview, Instance 4]
SN: That's a result of teaching. You've inspired someone to do something they're interested in or asked them to do something they hadn't tried before. Once they leave you, you're not teaching anymore but it's an extension or an effect of your teaching.

Interviewer: So would you say your intentions as a teacher, your objectives or goals, what you want to achieve, are they limited or do they end at your direct effect? Do they go into this indirect effect?
SN: Yes. My goal in teaching is to open the eyes and experiences of kids maybe with brand new stuff, maybe with old things they've heard about but to experience them in a lab or an exercise they haven't had before. Sometimes it's kind of boring (Laughs). But as much as possible to give them that experience where they walk out and say, "That's kind of neat stuff!"

To expand on his meaning, Steve relates an anecdote about students' positive reaction to a lesson in which they were asked to classify objects as living or non-living. The students in the anecdote had not been friends before the exercise, but their "polite" disagreement about the proper classification of the kidney bean in their specimen set created a connection that extended beyond the biology classroom.

[Initial Interview, Instance 5]
SN: And these two students, one of them didn't go to school much last year, so she's kind of turned over a new leaf, and the other is kind of marginal. They're arguing (about the bean classification), and the next day they're coming down the hall arguing about this thing. "No they're dead!" "No they're alive!" (Laughs). And that's the kind of example I would say I feel good about! They're interacting with my experience, my opportunity for them.

A curriculum that involves students in interesting ways with the material, making learning more likely to be durable, and that captures student's imagination and curiosity, inviting students to make a personal connection to the discipline, are some of the defining characteristics of Steve Noble's curriculum decisions.
A summary of Steve Noble’s beliefs about project-based approach to science
curriculum is shown in Table 5-6.

<table>
<thead>
<tr>
<th>Table 5-6</th>
<th>Appropriate Goals of Project-Based Science Curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher’s beliefs: A project-approach to science curriculum should...</td>
<td></td>
</tr>
<tr>
<td>Provide opportunities for student learning</td>
<td>present important skills and concepts</td>
</tr>
<tr>
<td>present a positive view of science as ‘interesting’</td>
<td></td>
</tr>
<tr>
<td>Engage students in exploring new ideas</td>
<td>invite a personal connection</td>
</tr>
<tr>
<td>carry on an interactive conversation</td>
<td></td>
</tr>
<tr>
<td>Allow teachers to guide learning in particular directions</td>
<td></td>
</tr>
</tbody>
</table>

2. Teacher’s intentions: My project-based science unit will...

Steve Noble’s ideal curriculum goals face the challenge of all curriculum goals as
they are implemented within the constraints of a traditional school setting. What are the
skills and concepts I will include this year, guided by local, state, and national curriculum
standards? What particular events will this new group of students find ‘interesting’?
How much of my class time will I have to spend on management issues, and how much
time will there be to engage the students in worthwhile learning opportunities? Steve
uses his years of teaching experience to construct a realistic teaching plan for the
watershed unit, and the underlying themes he proposes to carry out can be inferred from
his classroom conversations and from comments he makes to students as the unit
proceeds.

Four weeks into the new school year, Steve introduces students to the watershed
project 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 resources. Some of you may have parents or grandparents who remember how ‘yucky’ it was.

We’ll begin by looking at the history of the river, of its influence on the people who came to live here. Then we’ll do the testing part, connecting the biology and chemistry we’re studying to the river.

Several teaching goals are presented in Steve’s introduction to the project unit. Collecting data is a primary focus for the content component. Applying biology and chemistry knowledge to analyze a specific body of water is a second science content goal. In addition to the content pieces, however, Steve explains to students that they are expected to develop an appreciation of the river’s role in the historical development of their community, and to be proud of the river’s potential as a resource for current and future growth. The summary sentence of his introduction nicely captures both of these objectives: “There’s a dual focus of the project: the historical as well as the chemical and biological parameters that describe this river.”

Steve encounters an obstacle in the watershed unit that diverts his ideal plan. A key goal of the project unit is to conduct “real” science, as he mentions in the introductory speech to students. However, “real” scientists communicate with their colleagues and share the data and interpretations they’ve made. Despite careful planning during the previous school year, telecommunications connections at Lafayette are not complete. The students will be gathering the data on their study site at the river, but the usefulness of the data will be limited unless it can be shared with students along the river’s length.

* Pseudonym
The goal of engaging students in a real scientific investigation is so important that Steve decides to use his own connection to accommodate the need to share data with others.

[Watershed Class, 9/30]

Unfortunately, there is one part of the project we can’t do yet in these new labs we have, the telecommunications aspect, the message and data sharing. About half the schools have telecommunications in their buildings, about half don’t. We had it in the past, but the new renovations aren’t complete so we haven’t finished that wiring. I’ll use my own access at home. I’ll ask you for information and I’ll post the data and messages for you, bring in responses, but we can’t do it here in class.

The historical, cultural and scientific content is the primary focus of Steve Noble’s watershed curriculum. Two class days are dedicated to preparing group presentations on the historical, cultural, and geographical questions that form a context for the scientific study of the river. Two additional class days are used for the presentations themselves. Students spend one double-period lab class practicing with the water parameter test kits, one lab class for a “practice” visit to the river in preparation for the test day, and one lab class on test day in which all the schools visit their study sites. The balance of the time during the four week unit is spent on reinforcing the content and skills knowledge students need to accurately gather and evaluate the information on the water parameters. Steve Noble’s lesson plan notes show the sequence of class activities is reproduced as Figure 5-2, below.

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mon., 9/23</td>
<td>Chemistry review</td>
<td></td>
</tr>
<tr>
<td>Wed., 9/25</td>
<td>Water quality parameters; chemical cycles; nature of life – chemistry</td>
<td>Nitrates, phosphates</td>
</tr>
</tbody>
</table>

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thurs., 9/26</td>
<td>Pollute</td>
</tr>
<tr>
<td>Fri., 9/27</td>
<td>Pollute</td>
</tr>
<tr>
<td>Mon., 9/30</td>
<td>Introduce Presentations Groups</td>
</tr>
<tr>
<td>Tues., 10/1</td>
<td>Groups: read and notes</td>
</tr>
<tr>
<td>Wed., 10/2</td>
<td>Groups: organize presentations</td>
</tr>
<tr>
<td>Thurs., 10/3</td>
<td>Oral presentations</td>
</tr>
<tr>
<td>Fri., 10/4</td>
<td>Oral presentations</td>
</tr>
<tr>
<td>Mon., 10/7</td>
<td>Test kits: testing practice</td>
</tr>
<tr>
<td>Tues., 10/8</td>
<td>River visit: pd. A/B</td>
</tr>
<tr>
<td>Wed., 10/9</td>
<td>River visit: pd. C/B</td>
</tr>
<tr>
<td>Thurs., 10/10</td>
<td>Coliform bacteria</td>
</tr>
<tr>
<td>Fri., 10/11</td>
<td>Invertebrates</td>
</tr>
<tr>
<td>Mon., 10/14</td>
<td>Quiz</td>
</tr>
<tr>
<td>Tues., 10/15</td>
<td>Quiz</td>
</tr>
<tr>
<td>Wed., 10/16</td>
<td>Test Day pd C/B</td>
</tr>
<tr>
<td>Thurs., 10/17</td>
<td>Test day, pd A/B</td>
</tr>
<tr>
<td>Fri., 10/18</td>
<td>Analysis</td>
</tr>
</tbody>
</table>

Steve's plan to include the historical and scientific content during the unit are easy to recognize in the outline above. However, his efforts to implement his affective curriculum goals are less easily captured in an episode or artifact. Certainly his use of an interdisciplinary approach to the river study is one attempt to promote positive attitudes toward science. His skillful use of dramatic anecdotes and examples are another means by which he invites students to become engaged in the discussion of the river's role in community life.

[Watershed Class, 9/30]
Some of you may have parents or grandparents who remember how 'yucky' it (the river) was. The dyes and effluents from the mills ran right into the river. There were huge rats! I'll bring in some pictures from the meat packing company along one of the tributaries which used to put blood, gook and fat directly into the water! It is a gruesome fact of science.

Today the river is pretty neat, clean river. Its improvement is partial but not completely satisfactory.
The image of the slaughterhouse waste flowing down the river is one that is very likely to make an impression on the students. Relating other aspects of the river’s use, geography and role as a resource reinforces Noble’s intention to have students “appreciate” this waterway.

[Watershed Class, 9/30]
(Teacher uses transparency map of the state’s rivers to lead the students to highlight the watershed area.)

Starts right here at the highest elevation in the Central State Mountains*, into the narrow pass between these two peaks. Has anyone ever seen Profile Ledge*? The lake at the base is considered the source of the river... .

Any of you canoe? The Mussel River* is supposed to be a great canoe river. I’ll circle it here as part of the watershed.

The personal connection made by these references during class discussion continues Steve’s efforts to “try to make it interesting to you. And I’ll try to show you some things you never saw before, maybe do some things you never did before” as he had mentioned in the initial interview. He structures the unit activities to personalize the project, bringing in social, historical and personal aspects of the river, a respected tool to accomplish the affective objectives he declares to be his intention.

A summary of Steve Noble’s intentions for his project-based curriculum unit is shown in Table 5-7.

---

* Pseudonym
Table 5-7
Beliefs and Intentions Regarding a Project-Approach to Science

<table>
<thead>
<tr>
<th>Teacher’s beliefs: A project-approach to science curriculum should...</th>
<th>Teacher’s intentions: My project-based science unit will...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide opportunities for student learning</td>
<td>Provide opportunities for students to engage in ‘real’ science</td>
</tr>
<tr>
<td>present important skills and concepts</td>
<td>investigations</td>
</tr>
<tr>
<td>present a view of science as ‘interesting’</td>
<td>learn and practice data gathering skills</td>
</tr>
<tr>
<td></td>
<td>know historical and cultural context</td>
</tr>
<tr>
<td>Engage students in exploring new ideas</td>
<td>Make scientific inquiry interesting to students</td>
</tr>
<tr>
<td>invite a personal connection</td>
<td></td>
</tr>
<tr>
<td>carry on an interactive conversation</td>
<td></td>
</tr>
<tr>
<td>Allow teachers to guide learning in particular directions</td>
<td>Engage students personally with the content</td>
</tr>
</tbody>
</table>

3. Teacher’s actions: My classroom activities involve students in...

A teacher’s actions can provide clues to what the teacher values and who the teacher is. Students have a particularly keen eye and know that the most important teacher actions are those which define the evaluation tools for the lesson. They may assign a value to a learning experience in part by rating the degree of authentic enthusiasm for the subject modeled by the teacher. Less easily identified are the effects of particular teacher behaviors on student attitudes and interest in the topic. Since student learning is a direct product of their learning experiences and those experiences include content and skill activities as well as observations of teacher behavior throughout the unit activities, both classifications of teacher “actions” will be considered in this part of the analysis.

In his introduction of the watershed unit to students, Steve Noble defined two key content objectives for the unit: (1) know the skills in obtaining accurate data on water quality parameters and (2) know the historical and cultural role of the river in the life of the community. The following excerpt from the water quality analysis quiz identifies some of the expectations for student achievement.
**Quiz: Water Quality Analysis**

**Write out full sentence answers for ONLY those parameters which your group was assigned.**

1. **Phosphates**
   - a. What are two sources of phosphates in surface water?
   - b. Phosphates are necessary nutrients to all plants; why then are phosphates listed among pollution problems?
   - c. Is a total phosphate measurement of 5 mg/l high, medium, or low for most surface water? Explain your answer.

2. **pH**
   - a. What are two different, specific sources that contribute to acidic precipitation?
   - b. What problems (for aquatic organisms) are associated with overly acidic surface waters?
   - c. Is a pond with pH 5.6 acceptable for most aquatic organisms? Why/why not?

5. **Temperature**
   - a. What are three different specific sources of increased river water temperature (BESIDES direct sunlight warming the water)?
   - b. Why could widely fluctuating temperatures (especially increases) cause problems for river organisms?
   - c. If water temperature in a river was measured at 10 degrees Celsius, could any aquatic organisms survive? Explain.

For each of the three parameters his/her group is assigned, Steve Noble expects the student to know the sources of the contaminant, the effects of its presence on the living organisms in the river, and to evaluate the importance of a hypothetical value. To be successful on the quiz, a student would have to use simple cognitive skills, like recall of information, as well as analytical skills for the evaluation of the hypothetical situation. Steve’s evaluation of students on these two objectives is consistent with the goals he stated at the beginning of the unit.

Steve also intends his curriculum to provide students with experience in the actual gathering of valid data. The performance test at the end of the watershed unit requires each study group in the class to test prepared water samples and to analyze the data from
all group tests. Each group prepares an evaluation of the quality of the simulated water source using standards applied during the unit. Figure 5-4 shows a segment of the group test for the water shed unit.

**Figure 5-4**

Central River Project, Group Test (excerpt)

Names of Students in your group:
(Parts I, and II of the test require students to write brief essays on historical and geographic information from the unit.
Part III poses several questions on the fish species which have been an important aspect of the river's influence on the community.
Part IV requires students to evaluate hypothetical data on invertebrate species to assess the quality of the simulated water sample, and to evaluate hypothetical bacterial culture plates for evidence of pollution.)

Part IV, section J -- Water Chemistry
1. Each group must do their three chemical/physical test on the water sample provided. Please write all test 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 (for those you do not have, you may check the front desk) 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 necessary info 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 (assume the sample is from a nearby stream); effects of any present pollutants on local water conditions; possible polluting sources; and suggested solutions to any polluting problems which seem to be present.

Students had two class periods in which to complete the entire test. Noble allowed them to consult resources from the unit to correct or confirm water test procedures and to revisit notes from class discussion of appropriate standards for evaluating water quality.
Steve Noble’s actions in designing the final test as a performance test reflects his curriculum intention to offer students opportunities to actively participate in scientific inquiry. His scoring procedures mirror his belief in the variability and subjective nature of quality standards, as he described to the students in his introduction to the watershed unit on the first class session in September. He reflects on his assessment method in an interview following completion of the unit.

[Post-Unit Interview, 11/4]
SN: A couple of groups said, ‘we’re going to throw out the five because it’s really different from the others. Others said, ‘we’re 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. I’m not even sure (since I wasn’t watching how all the tests were done) if there is one better choice. 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.

Steve believes a project approach to curriculum is useful as a means of offering students opportunities to understand science by actively participating in scientific inquiry. His actions reflect the curriculum goals he declared to the students at the outset of the unit. Observing him during the unit provides evidence that Noble promotes his affective curriculum goals just as consistently.

[Watershed Class, 10/8]
[On the first class visit to the study site at the river, the teacher is demonstrating use of the net to sample water invertebrates. He is in wader boots about 10 feet from shore with student assistants holding a bucket and pan for surveying the sample.]
[Teacher lifts rocks with his feet and collects items disturbed by his feet using the net, then inverts the net into the enamel pan.]
I’m not going to identify anything today. I just saw three or four without looking very hard.
I’m going to do another a bit further out. You could see something on the bottom of a large rock. Wash it off into your container or pick it off the rock.”
Here’s a green caddisfly larva.” [Teacher pretends to eat larva. Students squeal, and groan “ugh”]
[Student comments wondering what people on the highway overlooking the river think about the ‘weirdo’ in the river.]
This is fun! I’d do this even without students. It looks strange, though!
Any questions? Ok. How are we doing on time? Let’s head back to the classroom. Anyone need to change?

The genuine curiosity Steve has for teaching these sampling techniques is evident in both his words and his actions. The students who have known this teacher for only four short weeks appear to be intrigued by his ‘weirdness’ and impressed by the efforts he makes to give them the kind of experience he so clearly enjoys. During the official watershed test visit the following week, there is no evidence of students refusing to participate in the water test experience. Although not a declared curriculum objective for this unit, inspiring student interest by modeling curiosity and enthusiasm is part of Steve’s standard teaching repertoire.

A summary of Steve Noble’s beliefs, intentions and actions related to a project-approach to science curriculum is shown in Table 5-8.
Table 5-8

<table>
<thead>
<tr>
<th>Beliefs, Intentions and Actions Regarding a Project-Approach to Curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Teacher Beliefs:</strong> A project approach to curriculum should . . .</td>
</tr>
<tr>
<td><strong>Teacher’s Intentions:</strong> My curriculum will provide . . .</td>
</tr>
<tr>
<td><strong>Teacher’s Actions:</strong> My curriculum activities involve students in . . .</td>
</tr>
<tr>
<td>Provide opportunities for student learning</td>
</tr>
<tr>
<td>present important skills and concepts</td>
</tr>
<tr>
<td>present a view of science as ‘interesting’</td>
</tr>
<tr>
<td>Provide opportunities for students to engage in ‘real’ science investigations</td>
</tr>
<tr>
<td>learn and practice data gathering skills</td>
</tr>
<tr>
<td>know historical and cultural context</td>
</tr>
<tr>
<td>Gathering data for use in real scientific analysis</td>
</tr>
<tr>
<td>evaluating data for validity</td>
</tr>
<tr>
<td>using valid data and historical and cultural ideas to make judgments</td>
</tr>
<tr>
<td>Engage students in exploring new ideas</td>
</tr>
<tr>
<td>invite a personal connection</td>
</tr>
<tr>
<td>carry on an interactive conversation</td>
</tr>
<tr>
<td>Make scientific inquiry interesting to students</td>
</tr>
<tr>
<td>Inspire student interest in science by modeling enthusiasm and curiosity</td>
</tr>
<tr>
<td>Allow teachers to guide learning in particular directions</td>
</tr>
<tr>
<td>Engage students personally with the content</td>
</tr>
<tr>
<td>Working collaboratively with peers</td>
</tr>
</tbody>
</table>

Steve Noble’s Beliefs, Intentions and Actions Regarding Appropriate and Worthwhile Student Learning

Steve Noble’s beliefs about the nature of scientific inquiry and about a project-based approach to science education are two important influences on his curricular choices. A third influence to be examined in this dissertation is Steve’s conception of student learning, his judgment of his student’s interests, abilities and needs. Teachers ask and answer questions about what students ought to know and what they are capable of knowing. Many concerned teachers also ask the question, what will inspire students to want to know what I deem suitable for them. This section of Chapter 5 reviews the interview transcripts and class observation notes to identify some of the underlying themes that describe the influence of Steve Noble’s beliefs about student learning on his curricular choices.
Students are a part of each teacher’s curricular choices, sometimes influencing the content or methods a teacher uses in visible ways, sometimes exerting a more subtle effect. Determining what counts as appropriate and worthwhile learning for his science students is one of Steve Noble’s central tasks. In an earlier part of this chapter, Steve indicates that a key purpose of his curriculum is to provide students “with an opportunity to experience things they may not have experienced before” (Initial Interview). The question for this section of the analysis is how Steve chooses from among the vast array of possible “opportunities” for his students, how he decides what lessons will be most likely to initiate student learning. Veteran teachers like Steve have years of informal, anecdotal evidence to support their curricular selections. We are curious why Steve has chosen a project approach to the watershed unit as the best opportunity for this particular group of science students. Further, how does this teacher’s beliefs about the nature of his discipline and about the purposes of science curriculum correlate with his beliefs about what counts as worthwhile student learning?

1. Teachers’ beliefs: Students should/ought to have an understanding of . . .

We would expect to see similarity among teachers’ beliefs about the core characteristics of their discipline, appropriate goals for teaching the subject and beliefs about what students ought to know when the unit activities are complete. Steve Noble’s beliefs about what students ought to know are revealed by his responses to the hypothetical instances presented in the initial interview. Along with his beliefs about scientific inquiry and science curriculum they give us one set of threads that are woven into his classroom experiences. He identifies certain activities as “valid” means by which student are able to experience and practice the scientific inquiry skills he considers essential.

In the first hypothetical instance (Appendix A), Steve reacts to the description of students performing a research task for a nutrition lesson.
[Initial Interview, Instance 1]
SN: It certainly is a valid way to learn things, to research things, to look up things, to list, to pick out. They’ve got to pick out the values, they’ve got to calculate. I mean, those are skills that are important. So there’s learning going on and there will be learning following up after this when they’re doing the calculating.

In the Punnett square scenario, Steve finds another example of valid skill teaching.

[Initial Interview, Instance 3]
SN: Very specific skill teaching. Not a lot of concepts, though I suppose you could pick out some concepts there. But she’s very specifically teaching what do you do with this window box, and these letters here and the fact that there are genes connected with them, mother’s genes and father’s genes and kid’s genes. A very direct, very directive example of science teaching.

In addition to learning the skills of science described in the two examples above, Steve indicates students ought to learn some of the values related to science. In Instance 6 (Appendix A), the teacher has the students collect campus trash on Environment Day.

[Initial Interview, Instance 6]
SN: . . . but the fact that he’s out there, that they’re doing something together, which they probably wouldn’t do on their own, when they got home from school, just grab a black bag. He’s teaching in the aspect of, “Here we are. We’re going to do this. This is something important. We’re not going to just talk about it.”

Interviewer: Does this fit into the skills or concepts or what kind of teaching would you call this?
SN: In one sense, modeling I suppose, if he’s out there picking up stuff too.

Interviewer: Would you consider this an example of teaching values?
SN: I suppose so. There’s a value in having a clean schoolyard. Maybe just because it’s environmentally ‘nice’ to do that, but maybe because it’s your community. If you see trash, pick it up . . . This is our environment, and if you want to be living in it and enjoy it, and be comfortable in it, do your part.

These examples support the inference that Steve Noble believes that students ought to acquire the skills and values that are an important part of science. Research skills, skills in demonstrating genetic pattern inheritance, or actions reflecting values acquired as part of a science unit are all appropriate goals for student learning. Even more
revealing than Steve’s positive judgments of some of the instances are Steve’s contrasting examples offered during the initial interview that he uses to highlight the difference between the kind of teaching activities that are likely to produce valid learning and those that he deems unlikely to be useful. In an extended conversation about the remote influences of a particular teaching event, inspired by the blueberry muffins instance, Steve explains that the teaching-learning relationship cannot be a mechanical one.

[Initial Interview, Instance 4]
SN: There are some [teachers] who just go through the motions and they couldn’t care less. That’s the perception you have. It’s just a mechanical thing. “You learn it, you don’t learn it. I don’t care. It’s your grade.”

That’s why I don’t think computers are ever going to take over the classroom. They’re going to be a tool. If a computer could take my job, it would be just a mechanical job. But I don’t have a mechanical job! I have a person job. So, if you want to be a mechanical learner I guess you could do that from a computer. But there are an awful lot of high school kids that don’t learn that way, an awful lot of them. They need other kinds of experiences.

Considerations of what makes a student want to learn, what engages a student’s interest in participating in new explorations are as much a part of Steve’s decision making process as is the list of skills that scientifically literate citizens should have. Steve clearly understands that a mechanical approach to student learning is ineffective. In addition to deciding what is appropriate for the ability level of the students, what will fit within the time limitations and the frameworks and standards recommended by others, Steve makes important choices about his curriculum based on what will make the learning experience worthwhile for the students. A focus on only skill acquisition, a typical focus of many science lessons, is too limiting a view. Steve’s comments on the first hypothetical instance when students are gathering nutrition data support this assertion.

[Initial Interview, Instance 1]
SN: There’s learning going on as a result of the teacher’s assignments but the teacher himself or herself at this point . . . doesn’t seem to have
his fingers in the teaching. And maybe the next scenario takes them
to the next level and that would involve more what I would call ‘real
teaching’.

Interviewer: And that next level would be?
SN: The next level would be Jeff and Sabrina back in class with their
columns with their percentages with their values and the teacher
saying, “Okay, what did you get Jeff and Sabrina and Larry and Sue
and George? And let’s see what we’ve learned here.”

Acquiring the skills for scientific investigation is not a sufficient learning goal for
Steve Noble. Steve expects students to reflect on their experience and to continue a
discussion about their ideas in relation to their classmates’ ideas, and, with the teacher’s
guidance, to relate their ideas to the prevailing ideas within the scientific community.

Having students engaged with the content beyond the classroom is evidence of just such a
reflection on learning. Steve has been able to observe this effect more than a few times.
One instance (cited previously in the discussion of Steve’s curriculum expectations)
clarifies Steve’s unwritten expectations for student learning. In this anecdote, the
students are reacting to a previous lesson in which they were asked to identify which of a
set of items are living and which are non-living.

[Initial Interview, Instance 4]

SN: But, as much as possible, to give them that experience where they
walk out and say, “That’s kind of neat stuff!” Or, as they walk out,
they’re arguing with someone and say, “This is what I thought. I
thought what you said was goofy!” . . . The other day . . . these two
kids . . . they’re arguing, and the next day they’re coming down the
hall arguing about this thing. “No, they’re dead! No, they’re alive!”
That’s the kind of example I would say I feel good about that.
They’re walking out of the class thinking about not Harry and Joe and
the relationships going on down at the cafe, but they’ve been
interacting with my experience, my opportunity for them. Now is that
teaching? That’s the result of teaching. It’s the result of providing
opportunities I’ve given them. I’m going to pull them back the next
class and I’m going to continue this discussion and, hopefully, we’re
gonna come to some answers, but it’s an example of things that
happen because of something I’ve taught.

For Steve Noble, students should be engaged in the content and should be expected
to examine their learning to explore the subject within its appropriate context. He agrees
that students learn on their own, informally, as he recognizes in the instance involving bridge builders waiting for the school bus and again in the muffin baker's instance. But Steve has different expectations for the kind of learning that takes place within the context of a structured school science experience. "Because it's not laissez faire. They're not off doing their own thing, creating their own learning all the time." (Initial Interview, Instance 8) Steve's vision of the teacher as sculptor fits his meaning here. He worries that students may not derive meaningful understandings without some guidance.

[Initial Interview, Instance 2]

SN: I guess that's part of what I look at teaching. I want my fingers in there. When I'm doing real good teaching, that's how I know how my students are getting what I, in the context of my plans, what I want them to get. If I leave them off on their own, although they may be active, they may not be active in the way I want them to be active. It's easy for an uninitiated student just to wander off in an activity and not really have a sense of where they're going and why they're doing it or what the end result might be. So I like to point them in the right direction.

Interviewer: So you see yourself as providing some sort of focus?
SN: I'm in the central position. I throw out this 'stuff,' you do all this 'stuff,' and then, I'll help you get it all together. You don't have to worry about being the smartest person in the world, and synthesize all this. I'll help you do that, but you have to do some work to get it to that point where I can help you.

Steve's conception of student learning as the result of an interaction between a teacher and a learner has a direct relationship with his choice of a project approach to the watershed unit. The project approach to this topic gives students a chance to learn and practice the skills scientists use. It also offers an opportunity for students to engage in an analysis of the data with their teacher, classmates and others. Steve's beliefs about how students learn and what counts as appropriate and worthwhile science learning outcomes can be accomplished efficiently and effectively through a project approach to teaching.

A summary of Steve Noble's beliefs about appropriate and worthwhile learning for students in science is presented in Table 5-9.
Table 5-9

<table>
<thead>
<tr>
<th>Beliefs Regarding Appropriate and Worthwhile Student Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher’s beliefs: Students should/ought to have an understanding of.</td>
</tr>
<tr>
<td>Skills required for scientific investigations</td>
</tr>
<tr>
<td>Gathering, evaluating, and interpreting data</td>
</tr>
<tr>
<td>Values associated with science</td>
</tr>
<tr>
<td>Curiosity, collaboration, critical review</td>
</tr>
<tr>
<td>Science as a participatory endeavor</td>
</tr>
</tbody>
</table>

2. Teacher’s intentions: I (teacher) expect students to learn...

Teachers declare their expectations for student learning most clearly in their classroom instructions: “Do this worksheet.” “Write this paper.” “Fill in these blanks.” Statements teachers make that begin with the spoken or understood, “You will...” are the focus of interest in this section of the analysis. Steve Noble declared quite thoroughly what he expected his students to know when he described the curriculum for the watershed unit to the class on the first day of the 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.
The focus is on students...doing a real study program. You will collect data on the current conditions of the river near our school.
As citizens of the city, you should be proud of this resource... “We’ll begin by looking at the history of the river, of its influence on the people who came to live here. Then we’ll do the testing part, connecting the biology and chemistry we’re studying.
Besides the historical record, we’ll look at the biological and chemical factors...
We will need to look at who makes the standards. Why are they the way they are?

This selection from Steve’s introductory comments to the unit defines two distinct types of expectations for student learning: content knowledge and attitudes. Within the content knowledge category, Steve tells students that they will be required to know the history of the river’s influence on the community, as well as demonstrate an understanding of the use of chemical and biological tests to define safety parameters for...
human use of the river water. The teacher assigns a research project for the historical and geographic content to be covered, and sets up water parameter activities during double lab periods to give students the opportunity to learn and practice the testing procedures. In addition, he explains that he expects them to collect articles from print media to demonstrate their familiarity with current issues related to the topic of water quality.

[Watershed Class, 9/30]

Another assignment for you: I want you to add to the collection I've started making on the bulletin board of articles about water quality. Scour newspapers which you have access to, and begin contributing to our board. It doesn't have to apply to our river. Anything about drinking water, recreation usage, food. That's the assignment.

In defining the learning expectations for students’ attitudes, Noble says he wants students to develop a pride in the river as an asset to the community, as a contributing force in the growth and development of the city and similar towns along the river's length. In addition to developing a sense of pride, Steve explains that students will be contributing to the river’s usefulness by sharing their data with appropriate agencies charged with monitoring water quality for the state.

[Watershed Class, 9/30]

Later in November there will be an all day congress of the students participating in this project. We'll be sharing data among the schools participating... We will participate in the big event. We'll all do the official river testing in mid-October. All schools will be testing the same day... The state tests at various sites all year, but it doesn’t have the manpower to do extensive study. We contribute our data to the state’s information... The goals are to enhance your education as intelligent citizens about a resource in your community.

The teacher raises the standard for the affective outcomes of the watershed unit by declaring that one goal is to enhance student's knowledge as literate citizens. At the end of his introductory presentation, Steve Noble adds a third affective goal to the list of expectations for students during this project unit.
Our overall approach to this project will be in teams. You’ll be in teams of four, but we’ll also be a team of 24. We’ll post our data as a team which will be shared with other schools.

Because this is a regular biology class not just an ecology class we can’t spend as much time as we’d like on this project. Each group will be doing bits and pieces of the whole. No group can do all the parts.

I’ve put you into groups. I have only brief knowledge of your work, who you are, but it’s not complete. My perceptions may be wrong, but it seems to be a good mix of strengths in these groups. . .

Our first assignments will be about the history and culture readings. When I read off the groups, get together at the benches. . . Introduce yourself. I’ll be shuffling groups all year long, so you’ll get to know each other whether you like it or not.

Part of my goal in any class is to get you to know and work with each other. Sometimes students complain that they can’t work with someone. We’re going to work through that. We have goal to accomplish, a task to do. You’ll have plenty of individual work, quizzes, papers, the newspaper article assignment. You will also receive a performance grade, and I’ve done a little of that already. I’ve watched your function in a group.

In addition to the expectation that knowledge of the river’s role in the life of the community will engender pride among the students, and that contributing to larger efforts to monitor the river’s health will enhance student’s growth as literate citizens, Steve Noble’s determination that students will learn to function effectively in a group is a third item in his list of expectations for student learning.

The expectations Steve Noble declares to his students for their content and value learning are consistent though not completely parallel with his beliefs about what counts as appropriate and worthwhile learning in science. A comparison of his beliefs and intentions is shown in Table 5-10.
Table 5-10

<table>
<thead>
<tr>
<th>Beliefs and Intentions Regarding Appropriate and Worthwhile Student Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher’s beliefs: Students should/ought to have an understanding of...</td>
</tr>
<tr>
<td>Skills required for scientific investigations</td>
</tr>
<tr>
<td>Gathering, evaluating, and interpreting data</td>
</tr>
<tr>
<td>Values associated with science</td>
</tr>
<tr>
<td>Curiosity, collaboration, critical review</td>
</tr>
<tr>
<td>Science as a participatory endeavor</td>
</tr>
<tr>
<td>Teacher’s intentions: I (teacher) expect students to learn...</td>
</tr>
<tr>
<td>The content and skills for ecosystem studies</td>
</tr>
<tr>
<td>Historical knowledge</td>
</tr>
<tr>
<td>Biological and chemical test skills</td>
</tr>
<tr>
<td>The values associated with scientific literacy</td>
</tr>
<tr>
<td>Pride in natural resource</td>
</tr>
<tr>
<td>Contribution to scientific inquiry</td>
</tr>
<tr>
<td>Skills of effective scientific investigation</td>
</tr>
<tr>
<td>Ability to work collaboratively</td>
</tr>
</tbody>
</table>

3. Teacher’s actions: Students are required to demonstrate...

The challenge for Steve Noble is to translate his intentions for student learning into events that he can assess with some degree of validity. Evaluating a student’s learning of content and skills is relatively easy – traditional tests and lab exams are designed to evaluate the recall of facts and the performance of practiced tasks. Assessing whether the affective goals for student learning have been attained is a more demanding responsibility.

Inferences about Steve Noble’s actions will be derived from a review of his assessment plan for students. The format through which Steve evaluates student learning of the historical, geographical and cultural content of the unit are the tests, quizzes and essays described in the curriculum section of this chapter. A major quiz on the group presentations was evaluated on its interest, accuracy, style and whole group participation. The Water Quality Analysis Quiz assessed student knowledge of the three parameters each group had practiced, and was graded on the accuracy of the responses. An essay assignment required students to present an evaluation of the river based on their own data and on data derived from the entire watershed project. Student scores were determined...
by the ability of students to identify significant factors from class discussion and group presentations, and to incorporate their knowledge of these indicators into a clearly written essay. Finally, the group test for the unit required collaboration on questions about the historical, geographic, and cultural aspects of the river, as well as testing and analysis of a simulated river sample.

In an interview following the administration and grading of the final group tests for the watershed unit, Steve Noble was asked if the grades agreed with his perception of student achievement.

[Post-Unit Interview 11/4]

Interviewer: Did it come out as you’d hoped? What does it (the performance portion) give you that the other, hypothetical (data) doesn’t?

SN: Another picture of performance. It helps me see that they can do the tests correctly, because two groups did each test and I could tell whether they were close or not. It helped me to see whether they knew how to do these Q values. Most groups did. A couple of them had real trouble.

Interviewer: How close was that to your observations beforehand, to the work during the unit?

SN: That part (that one group was confused) I wouldn’t have known.

Interviewer: You wouldn’t have, is that right? You wouldn’t have seen that? They worked as a class, is that right?

SN: Yes, they worked as a class. That was interesting. That one group of four just had no clue, and it wasn’t like they were ‘dummies’ or anything. I don’t even remember what group it was now, but I thought they would have done better than that. I had a range (in that class on the group test) from 60 out of 100 to 87 out of 100.

Having a performance component of the test revealed a gap in understanding Steve didn’t notice during the course of the daily classroom activities, which surprised him. Since the students had otherwise done well in the written work, this style of assessment provided an unexpected insight. Unfortunately, this new evidence that one group needed further reinforcement to perform the data collection procedures correctly came at the end of the unit, at the end of a marking period. Since Steve Noble considers class time available for this project to be constrained by the content to be covered for the year, he is
unable to review or revisit these skills with the students. He is unable to use the
information provided by the assessment to improve student understanding, leading to a
sense of resignation that the results reflect the best learning that could be achieved in the
context of the structure of public school experiences.

[Post-Unit Interview, 11/4]
Interviewer: But the test was effective in giving you that information
(about gaps in student understanding)?
SN: Oh, yes. Sure does.
Interviewer: Will this change your plans for how you operate the unit or
your plans for testing next year?
SN: No. Because there's nothing in there they hadn't studied on their
own, worked on in the group, discussed in class. And there's nothing
I didn't tell them the day or two before was going to be on (the test).
To top it all off, they had three days and they could continue studying
throughout the three days. From my point of view I couldn't do much
more than say, "Okay, you get an A, assuming you've kept up and
have a reasonable idea of what's going on."

While the test may have been a rich source of information about student learning,
Steve knows of few modifications that can change the amount of time he has to support
the weaker students. On the whole, grades on the performance test were consistent with
grades from earlier instructional units. Steve seems to be voicing every teacher's lament:
there is so much that could be done to enhance student learning, but little or no time
within the institutional structure for the teacher to try out new methods. Expectations for
student learning of content must be defined in the aggregate, and individual weaknesses
are unfortunately difficult to address.

[Post-Unit Interview, 11/4]
SN: I feel pretty good about it. Cs, C plusses on a test like this are pretty
good. It's a tough test, tough concepts. I didn't expect any As but
that one group came pretty close. Because they had an extremely
bright kid who took a lot of it on himself.

The challenge of assessing the affective attributes Steve expects students to acquire
from participation in the watershed project is not met through a formal measurement.
The group presentation score included a 10% “group effort” grade, which the teacher assigned based on observation of work habits during the planning and exhibition of the research they were assigned. Similarly, the group’s effort on the performance test at the end of the unit received a portion of its score value based on Steve’s judgment of the teamwork attitudes and skills of the group. Steve sounds somewhat uncomfortable with the subjective nature of his scoring system on this portion of the exam.

[Post-Unit Interview, 11/4]
Interviewer: And how did you grade the actual performance section? What did you do with that? Did you look at accuracy, or a more generalized holistic score?
SN: Subjective pretty much. Those are the criteria, the five areas I was looking for. They all got pretty much 9 or 10 on this section. If they showed me their results and showed me their calculation and if you have to sometimes do a multiplication but they all pretty much got the 9 or 10 there.

Steve’s expectation that students will learn how to work in groups is important enough to him to attempt to give student’s graded credit for their effort, but his narrow range of scores suggests he is not certain how to make his assessment more discriminating or more defensible. The two other outcomes he hopes students will achieve, pride in the river as a valuable community resource, and contribution to scientific research on water quality, were not measured in a formal way.

Measuring changes in student’s values and attitudes are not easily, accurately, or effectively accomplished even under ideal conditions. When the constraints of the time schedule, the curriculum, and school culture are considered, Steve’s omission of these traits from his assessment program are understandable. One ideal opportunity for students to enrich their appreciation of their class contribution to the state water resources data base is the regional congress where students from twenty testing sites will gather to share their results. Unfortunately, Steve is only able to take six students to the regional meeting.
[Post-Unit Interview, 11/4]
Interviewer: Now, in terms of planning between now and the conference. What will you be doing with the students then?
SN: I will take probably six kids. I don’t know how to choose. I have nine names (of volunteers who wish to participate).
Interviewer: And they’ll present the data? Do they do a poster session or something?
SN: No, just verbally. They have to present, they have to come up with different information from our site and present it to a small group, then to a regional group, then from the regional group to the whole conference.

Steve’s expectation that students will understand the value of their role in gathering data to be used to monitor local water quality is somewhat diluted by the restriction on the number of students who can actively participate in the watershed congress. He may be able to evaluate whether the six students who present the data gathered by Lafayette High School students have developed the values he expects, but the level of achievement of his affective goals for the other students will remain untested and unknown, except by evaluation of non-verbal clues. Steve may be feeling “good” about the unit because of his implicit understanding of the relationship between attitudes and degrees of participation among students.

A summary of Steve Noble’s beliefs, intentions and actions related to his expectations for student learning are presented in Table 5-11.
### Table 5-11
Beliefs, Intentions and Actions Regarding Appropriate and Worthwhile Student Learning

<table>
<thead>
<tr>
<th>Teacher’s beliefs:</th>
<th>Teacher’s intentions:</th>
<th>Teacher’s actions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students should/ ought to have an understanding of.</td>
<td>(teacher) expect students to learn...</td>
<td>Students will demonstrate...</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

| Skills required for scientific investigations | The content and skills for ecosystem studies | Knowledge of content |
| Gathering, evaluating, and interpreting data | Historical knowledge | Historical, geographic, cultural |
| Knowledge of skills | Biological and chemical test skills |

| Values associated with science | The values associated with scientific literacy | Knowledge of skills |
| Curiosity, collaboration, critical review | Pride in natural resource | Biological and chemical tests |
| Contribution to scientific inquiry |

| Science as a participatory endeavor | Skills of effective scientific investigation | Evaluate data and apply standards |
| | Ability to work collaboratively |

---

**Participant’s Response to the Case Description**

Like Eric Carter, Steve Noble’s first reading left him with the impression that the analysis in this chapter presents a truthful and realistic picture of his curriculum planning.

[Response Interview 1, 12/11]

Interviewer: What’s your first reaction?

SN: I think it’s a pretty good picture. If I were to write down my perceptions of what I think I’m doing, this describes it pretty well I think. There’s nothing in there that I would say doesn’t sound like what I did, or what I thought I was doing. I like the sound of it actually!

Interviewer: Do you?

SN: I do. I really do! It’s the kind of projected activity and goals and things that I would hope I’m projecting, but never know if I am or not. And this is, I think, at least for me, this is a confirmation that what I think I’m doing, I’m doing!
Steve appreciate having an opportunity to confirm his own intentions to promote a curriculum that meets his standards. In an earlier section of the interview, he commented how helpful he found a videotaping exercise during his Master’s degree program at the University. Unlike many preservice and novice teachers who disdain the videotaping experience, Noble recognized how well he was able to make use of it to recognize where changes needed to be made to enhance his teaching.

In judging the accuracy of the inferences after this first reading, Noble agreed that the themes collected into the summary tables match his own beliefs, intentions and actions, and are supported by the excerpts included in the narrative. He was asked if there were other details that a reader might find helpful in coming to understand the watershed experience.

[Response Interview 1, 12/11]
Interviewer: Are there details you can think of off the top of your head that might make it more real?
SN: What do the kids do down at the river? You caught me in a picture doing the sampling with some comments they made and I made. But what were they doing? Did that follow what my expectations were when I was talking in the classroom or demonstrating?

Steve Noble would like to see more information about student activity during the project unit, particularly during the river sampling class. Unlike the classroom, where he can watch students expressions and body language, the study groups at the river are on their own, with brief visits from Steve as he oversees their work. Like Eric Carter, Steve hints that he wants the information about student performance to be able to judge the effectiveness of the unit he presented. In Chapter 7, the author presents several suggestions for the use of the case study process to obtain reliable information about teacher and student performance simultaneously.

In the second response interview, one week after the initial reading, Noble repeated his confirmation of the accuracy and authenticity of the case study. When prodded to
identify whether the watershed unit represented a “typical” unit he would present, he revealed a few more details about his curriculum beliefs.

[Response Interview 2, 12/18]
Interviewer: Let me ask this question: Is this little snippet, this snapshot I have of you, is this representative of your whole effort (throughout the school year)?
SN: Yes, I think so.
Interviewer: So this is not different than any other things you do during the year?
SN: No, it’s an ideal one. Because it’s where I get to do all the pieces and parts all at once, and put it into a package. I don’t do as much project work in the sense of extended project work like this. But I do attempt to develop their thinking skills and their performance skills and those kinds of skills in a less rigorous way, in a less formal way. But this (the watershed unit) is the thrust of my whole perspective!
Interviewer: That’s important for me to know. It’s not some off-the-wall thing you do once a year.
SN: If I had my ‘druthers,’ if I could teach the way I wanted, where I wanted, with the facilities I wanted, I would teach like this all the time!

Steve feels more limited in his curriculum options than does Eric Carter, in part because of the peer context in which they work. Lafayette, Noble’s school, embodies a traditional conception of the work of schools while Parkside, Carter’s school, endorses a progressive conception of learning that presents different challenges to the teachers.

The response interview revealed a previously unseen similarity between Carter and Noble. Carter wanted the researcher to offer more information about whether the students “get it.” Likewise, Noble asks the researcher if she knows how to measure the important affective outcomes that appear as a frequent theme in the analysis of his statements.

[Response Interview 2, 12/18]
SN: These little boxes all seem fine. I put OKs here as I read them. I’m on this page: “learning experiences are worthwhile if they have a positive effect on student attitude toward science.” Are there, or do there exist good assessment tools for attitudinal results?
Interviewer: Good question. I’ll review. I know I’ve seen references to some.
SN: No one around here much cares about those kinds of things. But to me they’re very important. But we don’t measure that! The only measurement of that is when a student comes back three years later and says, “I had a great time in that class and I learned so much! Now I’m a biotechnologist or something.” And I think, “Wow! That’s great!” But I would like to have a handle on that.

Steve Noble, like Eric Carter, is not satisfied to rest on his previous successes. He wants to find new ways to reinforce the ideals he hopes students will achieve. He knows the value of the assessment device to send a message to students about what’s important in science. His request for additional information from the researcher is evidence of his commitment to continuing professional growth.

Conclusion

Steve Noble’s beliefs about the ideal conception of scientific inquiry reflect his experience of science as a field researcher and as a veteran science teacher. His efforts to translate his beliefs into meaningful learning experiences for his students are for the most part successful, particularly in the watershed unit studied for this research project. He acts on his beliefs by providing activities that engage students in real scientific research protocols that will contribute to the regional database for use by regulatory agencies. He models the enthusiasm and curiosity he hopes his students will develop toward science. In keeping with his own metaphor, Steve Noble shapes this engaging curriculum as a master sculptor forms his image, knowing clearly the strengths and limitations of his medium. Despite the limitations typical of public school --rigid class time periods, structured content coverage demands, and diverse student aptitudes, interests and abilities -- Noble’s watershed project unit captures his beliefs and intentions for presenting an accurate image of science as an interactive, participatory process. The influence of his
beliefs and intentions can be seen in the actions his students are expected to demonstrate as indicators of their achievement. The description presented in this chapter attempts to show some of the relationships among those influences on the creation of science curriculum by another exemplary teacher.
CHAPTER 6

COMPARISON OF TWO EXEMPLARY TEACHERS’ CURRICULAR CHOICES
WITH THE NATIONAL STANDARDS

A purpose of this dissertation is to contribute to the growing body of knowledge about teaching and learning in science by describing the process through which two exemplary teachers enact a curriculum in their project-based science classrooms. In the previous two chapters, each teacher’s beliefs and intentions are shown to play an important role in determining the learning experience the students encounter in their science classrooms. The value of this kind of descriptive study comes from the ability of practitioners, curriculum developers and policy makers to recognize the influence of teachers’ existing conceptions on the enactment of any particular curriculum prescription.

This type of research can serve an additional purpose. The emerging importance of proficiency standards on the development, implementation and assessment of students, teachers, and school programs, including science programs, increases the need for a greater understanding of how classroom events come to be. The recent release of the National Science Education Standards (NSES) (National Research Council, 1996) invites educators and policy makers to compare the curriculum experience students presently encounter with the types of experiences depicted in documents like the NSES. The invitation to consider the relationship between standards ideals and actual practice is hard to resist. Even though the original purpose of this research project did not include an assessment of the role of standards in the evolution of curriculum, the relationships
between current practice and reformers' ideals begs to be addressed. The purpose of this chapter is to present just such a comparison between the curriculum created by Eric Carter and Steve Noble with the goals and expectations described in the National Science Education Standards (National Research Council, 1996).

The influence of the standards movement on classroom practice has yet to clearly defined, but has the potential to be far-reaching. Currently, a number of states are following the lead of the National Council of Teachers of Mathematics and the American Association for the Advancement of Science in defining their own curriculum frameworks and from those frameworks defining proficiency tests to measure individual, school and district achievement (Ravitch, 1992). It is very likely that from those assessments will come decisions about resource allocation. Discussions are underway in several locations to develop assessments of teacher effectiveness as well, using state and national standards statements (Gilbert, 1997). Numerous education agencies are offering recommended implementation measures that claim to promote the type of learning described in the standards literature (Sigma Xi, 1994; Layman, 1996). As these processes gain momentum and mature into powerful forces guiding the direction of education, serious questions need to be addressed. IF we agree that the standards define what we want students to know and be able to do, and IF we agree that those proficiencies are worthwhile aims for the education process, how can we know what actions must be taken to promote achievement of the standards for all students?

Four documents constitute the major library of reform recommendations in science education: The National Science Education Standards (National Research Council, 1996); Project 2061: Science for All Americans (American Association for the Advancement of
Science, 1989); *Benchmarks for Scientific Literacy* (AAAS, 1993); and *Scope, Sequence and Coordination of Secondary School Science: Volume 1—The Content Core* (National Science Teachers Association, 1992). Each of these documents was developed using the input of scientists, engineers, mathematicians, and science educators, and in some cases historians and philosophers. Major discussion of the impact of these documents on science education has focused on their theoretical foundations and their political implications (Donmoyer, 1995; National Standards: Who benefits? 1993). Research on the direct implications of the science standards on classroom practice and student learning is in its early stages. Presently, local curriculum leaders and classroom teachers are intent on reviewing the alignment of existing content topics with the recommendations of state frameworks which must necessarily precede efforts to evaluate the effectiveness of the standards on student learning. Questions of the alignment of science teaching practice with national recommendations have yet to be addressed.

We can gather some hints to guide our research on implementation efforts in science by looking at similar work in other countries and in other disciplines. Joanna Swann and Sally Brown (1997) interviewed teachers in Scotland to determine changes in their conception of their teaching and their students following implementation of Scotland’s national curriculum for students ages 5-14. Evidence they gathered indicated that teachers had not integrated the content, aims and methods of the new curriculum into their classroom practice. Similar objections to national tests (the operationalized aspect of national standards that most teachers confront) among English teachers in Great Britain reflects teachers’ disagreement with the underlying aims and purposes represented by national standards (Cooper Davies, 1993).
A particularly revealing study of preservice mathematics teachers in the United States confirms the conventional wisdom that implementing reform standards for teaching will require a long-term commitment to change at all levels of professional development (Frykholm, 1995). Frykholm studied 44 preservice mathematics teachers over a two year period to identify their beliefs about the standards proposed by the National Council of Teachers of Mathematics (1989) and the novice teachers' intentions and effort to implement them in secondary mathematics classrooms. The summary of his findings hint at what science reformers might expect to encounter:

A summary of the findings leads to the following chain of reasoning. First, student teachers feel pressure from the teacher education program, not cooperating teachers, to teach like the Standards documents recommend. . . Further, they perceive themselves to be teachers who implement the Standards regularly. Lesson observations, however, do not confirm the perceptions of student teachers that they teach like the Standards recommend. Rather, their practices are largely in opposition to reform-based ideals. (Frykholm, 1995, 21).

Frykholm's conclusions support the expectation that change in practice will require an extended effort to change beliefs and intentions. He goes on to point out there were few if any opportunities for the student teachers in his study to see ideal practices modeled for them either by their cooperating teachers or in their preservice university program. Can we expect the same to be true for preservice science teachers? Are there good models of teaching practice that correspond with the NSES national recommendations? This chapter represents an attempt to answer that question in at least two classrooms staffed by teachers the community has defined as 'exemplary.' Perhaps if we know more clearly what current practice looks like and can see some of the relationships between a teacher's practice and his/her beliefs and intentions, we'll be able
to target our reform efforts more effectively. (More extensive discussion of the applications of this study to future reform efforts will be presented in Chapter 7.)

Several cautions must be declared at the outset of this chapter. First, the data that forms the basis for the preceding descriptions of teachers' choices reflect only one unit of a yearlong sequence of topics in the biology program. The project-based unit represents a snapshot of each participant's beliefs, intentions and actions as they relate to the key concepts under consideration in this study. No claim is made that the representation of each teacher is a complete picture of his efforts. Consequently, the comparison presented is expected to reflect only a small portion of the ideals presented in the NSES.

Second, the data collected for this investigation inferred key themes describing teacher beliefs, intentions and actions, not student outcomes. The bulk of the NSES volume refers to the proficiencies student should acquire as a result of their participation in a 'minds-on' science program. While we can make inferences about student learning from a rich description of teachers' actions, this research study did not gather the necessary empirical data to support those inferences with any certainty. The data for this study is not suitable for evaluating teacher effectiveness as judged by student performance. However, we can feel confident that the data offers a clear picture of the experiences students encounter within the framework the teacher defines. We can also feel confident that students will not become proficient in skills if the teacher omits them from the set of classroom activities she/he defines. Indirectly, we are likely to be able to draw some conclusions about the likelihood of student 'success' by examining the expectations of the teacher.
A third caution must be repeated about inferring cause and effect relationships between the NSES and teachers’ actions. The comparison presented in this chapter may tempt the reader to presume a causal relationship between the national standards and the practices of Eric and Steve. The similarities between the best practices of these teachers and the standards proposed in the literature could not be the product of a cause-effect relationship. The teachers spotlighted in this dissertation developed their teaching beliefs, their intentions and their practices over 20 years of experience in schools with secondary science students. The earliest nationally recognized expression of the current vision of ideal science teaching and learning was published in 1989, *Project 2061: Science For All Americans* (AAAS, 1989). The *Project 2061, NSES* and the other major standards documents were developed with input from practitioners, from scientists, educators, researchers and political leaders. They present a consensus summary of what students should know and be able to do, as well as how teachers ought to practice to promote student learning. While it may be true that the standards documents reflect the best practices of exemplary teachers, it is not true that the teachers described in this study were consciously attempting to achieve the vision presented in the NSES or in any local or national standards statement! During informal conversations, Steve Noble described his familiarity with the National Science Education Standards as “minimal (Response Interview 2, 1/18/97).” Eric Carter said he was “very familiar” with the NSES recommendations, and he found them “affirming” of his beliefs about best practice (Response Interview 2, 12/18/97). Neither teacher claimed to have changed his beliefs or his practices as a result of knowledge of the reform advice.
Three areas of influence on teachers' curricular choices are the focus of this dissertation: the nature of scientific inquiry, the ideal goals of a project-approach to science curriculum, and expectations of appropriate and worthwhile student learning. Aspects of the NSES that parallel the beliefs, intention and actions of both Eric Carter and Steve Noble will be selected and reviewed. These will include both content standards, defining what students should know and be able to do as well as teaching standards, how teachers ought to function to provide the best opportunity for all students to achieve these high ideals.

A. The Nature of Scientific Inquiry

In the previous chapters of this dissertation, teachers' beliefs about the nature of scientific inquiry were distilled from their interview and classroom statements. In contrast, the authors of the National Science Education Standards declare their conception of the nature of the scientific enterprise in very clear terms:

Content Standard A: As a result of activities in grades 9-12, all students should develop
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry. (National Research Council, 1996, 173)

"Abilities" in the NSES document include those activities often referred to as scientific process skills. Five statements specify what the NRC writers mean by 'abilities':

- "Identify questions and concepts that guide scientific investigations.
- "Design and conduct scientific investigations.
- "Use technology and mathematics to improve investigations and communications.
- "Formulate and revise scientific explanations and models using logic and evidence.
- "Recognize and analyze alternative explanations and models. (NRC, 1996, 175)
The vision offered by the NSES for student learning about scientific inquiry includes the idea that students ought to be able to develop an experimental plan that follows logically from an original hypothesis. In expanding on the bulleted list of abilities, the NSES authors explain that students are expected to employ appropriate safety precautions in the selection and use of suitable equipment for the implementation of their experimental design. The document includes a recommendation that teachers include opportunities for public presentation of the results of their investigation and critical analysis by their peers as one of the topic of “abilities” for doing scientific inquiry (National Research Council, 1996).

The second component of Content Standard A calls for students to develop “understandings about scientific inquiry,” a reference to the values and attitudes about science and the relationship between science and society. The expectation captured in this standard is that students will recognize that scientific inquiry is only one form of human questioning and that it has limitations in its subject matter as well as its conduct. New scientific knowledge ought to be recognized as building on existing knowledge, and benefiting from advances in mathematics and technology for new insights into the way the world functions. Students should also be given opportunities to practice identifying the criteria that distinguish science from other forms of inquiry, namely its logical consistency, its dependence on specific rules of evidence, and its openness to modification in light of new evidence.

How does the conception of the nature of scientific inquiry offered by the National Science Education Standards compare with the beliefs, intentions and actions of the two
exemplary teachers described in this research project? Eric Carter* presents a set of beliefs about science that focus on the activities of scientists – observing, questioning, proposing hypotheses, searching for patterns. Likewise, an analysis of Steve Noble’s* statements suggest that he sees inquiry as an active process in which one asks questions, designs experiments, gathers data and takes an organized look at the world. Both teachers design classroom lessons using a project approach as a method by which students can engage in learning and doing science just as scientists do. Steve’s students participate in a regional watershed analysis project; Eric’s class is engaged in a long-range study of the interrelationships found in the local stream ecosystem.

Steve Noble and Eric Carter also offered opportunities for students to develop the “understandings” described in Content Standard A, a dependence on evidence and logical argument to support a particular interpretation of their data. Both required students to publicly communicate their results, Carter’s by way of a school-wide symposium and Noble’s through in-class presentations and submission to a regional watershed database. On final project assessments, both Carter and Noble required students to support the reliability of their conclusions with reasonable arguments. Carter’s students were given animal signs and asked to hypothesize a source for the sign and the evidence they used to derive their hypothesis. Noble’s students were asked to decide which entries on the class data chart were reliable enough to use to accurately interpret the quality of a simulated water sample. Although Noble and Carter worked with students at different grade levels and in different school cultures, they both determined that an accurate presentation of the process of scientific inquiry would require their students to practice the critical analysis

* Pseudonym
skills often called "higher order" skills. Noble focused his effort with his tenth graders on the critical review of the accuracy of experimental data. Carter expected his seniors to observe carefully and select suitable features on which to base a reasonable hypothesis as part of their final unit examination. Were the fish scales in the scat sample evidence of otter or beaver residence? Did the bird pellet have visible bones from the bird's last meal, indicating an owl was the source, or were the bones likely digested, as they would be with if they came from a hawk? The types of questions Carter expected students to address mirror the expectations that the NSES declares under the "inquiry" content heading.

Several aspects of the National Standards vision of the nature of scientific inquiry were not clearly observed in the units visited for this research project. In both classrooms, there was limited use of technology to collect, analyze and display data. In Carter's habitat study, field journals were the medium of choice for students working in less than ideal weather conditions rather than hand-held sensors and monitors or portable computers. Following the completion of the winter adaptations unit, each team of students was required to enter data on the resident and migrant species they had observed onto the EcoNet database using the single classroom computer, limiting the time for individuals to use the computer to develop their own analysis skills. For the school-wide symposium at the end of the winter adaptations unit, Carter required students to use presentation software for their large group demonstrations. The major assessment of student work during the previous term project was a Power Point presentation demonstrating not only student understanding of the content topic, symbiosis, but also
proficiency in the use of the software and skill in group presentation. Similar expectations were not part of the winter adaptations unit observed for this study.

Noble's students were hampered in their efforts to share data with the other watershed study sites because Internet access wiring in the renovated science classroom had not been completed before the river testing unit concluded. Noble used his home computer connection to post his group's data to the database. Both Noble and Carter would be judged to be above average in their computer competence, and both made every effort to provide adequate experiences for their students in the uses of technology for data collection and dissemination, but not to the extent that seems to be recommended by the NSES vision. Each teacher faced obstacles to their own conception of ideal technology implementation during their project unit, and made accommodations for those obstacles. Carter had accepted the need to give up time from field work earlier in the year in order to allow time for computer skills training. Noble was prevented from considering a similar choice because of the lack of technology infrastructure beyond his control and chose to complete the task himself rather than omit it from the unit.

A second aspect of Content Standard A that was not addressed to any great extent during the observation period were opportunities for student to "recognize and analyze alternative explanations and models." (NRC, 1996, 173) In both classrooms, students had limited opportunities to engage one another directly to critically review data analysis and interpretation decisions. In Steve Noble's class particularly, students were expected to collaborate about analysis options, but interaction between teams to discuss differences among their choices was minimal. Carter's seniors also had collaborative team decisions to make, but most of this portion of the habitat study unit required individual analysis.
As noted in the earlier chapters, the researcher visited Carter's classes on the double-block periods which were usually the classes during which students pursued their data gathering and observation of their study sites. Carter reserved discussion of articles and issues for the single-block class periods, which were not observed for this study.

The vision of the nature of scientific inquiry offered by Content Standard A of the National Science Education Standards is detailed further in sections of Content Standard G: History and Nature of Science. This standard repeats some of the characteristics of scientific inquiry described in Standard A, particularly in its discussion of science as a human endeavor and the nature of scientific knowledge (NRC, 1996, p. 200). These include expectations that by grades 9 – 12, students should develop an understanding that both individuals and groups have contributed to scientific knowledge. The national standards also anticipate that students should have opportunities to become familiar with the ethical traditions of peer review, truthful reporting, and public announcement of methods, results and conclusions that characterize science. The NSES recommends that aspects of scientific inquiry that reveal the societal, cultural, and personal influences on scientists should be included in classroom lessons so that students can consider these biases when critically evaluating reported findings.

We can see evidence of attempts to address the concepts proposed by the National Standards in Eric Carter's curriculum more than in Steve Noble's lessons. Carter often engages his twelfth graders in discussion of dilemmas. In one lesson he asks students to consider funding sources as an influence on the interpretation of research data. In one of his essays for his professional portfolio, Carter describes meeting with one of his exchange students during a tutoring session after class. The student objected to his
refusal to "give" her a direct answer to one of her questions. "This isn't science! In my country, science is dogmatic!" Carter makes an effort to offer at least some opportunities for students to consider the probabilistic nature of scientific 'facts,' though this concept doesn't appear to play a central role in his teaching plan.

Steve Noble's tenth graders see fewer opportunities to consider the biases inherent in the interpretation of scientific data. In the opening discussion of the watershed study unit, Steve mentions the common misconception that contaminant levels ought to be set at "0" rather than some arbitrary 'safe' amount. No further discussion of the social or cultural impact on the use of scientific data was observed during this unit. Steve's choice not to include social and cultural contexts of science and the growth of scientific knowledge as a major topic of his curriculum activities does not appear to be a deliberate omission. Limits on time weigh heavily in Steve's curricular decisions, and discussions of complex issues like the prevalence of personal biases require extended time for student reflection, reaction, and response. Concerns about 'coverage' of topics defined by the department curriculum guide overshadows Steve's interest in presenting students with authentic science experiences.

A comparison of the key themes related to a conception of the nature of scientific inquiry presented by Eric Carter, Steve Noble and the National Science Education Standards are shown in Table 6-1. The themes complete the sentence stems used in the analysis presented in the preceding chapters: "Scientific inquiry involves..."; "Students should know that science is..."; "Students learn what scientific inquiry is by..."
| Acting as scientists:          | Actively involved in inquiry –  |
| Acting as scientists:          | Asking questions                |
| Observing, gathering data, evaluating evidence, making inferences | Designing experiments          |
|                              | Gathering data                 |

| Content Standard A:           | Abilities necessary to do      |
|                              | scientific inquiry –          |
|                              | Question,                     |
|                              | Hypothesize,                  |
|                              | Design investigations         |
|                              | Use technology                |
|                              | Construct explanations        |
|                              | Revise explanations           |
|                              | Recognize alternatives        |
|                              | Communicate                   |

| Searching for patterns        | Taking an organized look at the world |

| Understandings about          | Scientific inquiry –          |
|                              | Empirical content            |
|                              | Discover, explain, test      |
|                              | Accurate methods             |
|                              | Apply rules of evidence      |
|                              | Clear and truthful reporting |

| Making interpretations       | Interpreting data            |

| Content Standard G:          | History and Nature of Science – |
|                              | Social and cultural influences |
|                              | Ethical traditions            |
|                              | Rules of evidence             |
|                              | Subject to change             |

| Making a difference          | Contributing to expert’s knowledge |

| Being open to new ideas      | Applying ideas to new situations |

| Eric Carter | Steve Noble | NSES |

B. Appropriate Goals of Project-Based Science Curriculum

For the purposes of this dissertation, the term ‘curriculum’ refers to the learning opportunities teachers construct that are intended to help students acquire the knowledge and skills essential to the subject matter. The beliefs and intentions for a project-based science curriculum as defined by the exemplary teachers spotlighted in this research
project were identified by searching the interview and observation transcripts for
statements that describe teachers' actions. The vision of ideal science curriculum
presented by the National Research Council is presented in detail in the “National
Science Education Standards, Chapter 3, Science Teaching Standards” (pp. 27-53). The
six teaching standards in Chapter 3 of the national document offer a wide-ranging set of
guidelines for teaching science. How does the national vision compare with the
curriculum beliefs and intentions of Eric Carter and Steve Noble?

When the expectations defined in the national standards documents are compared
with the curriculum intentions of our exemplary teachers, there is a striking similarity of
beliefs and ideals. Even though only one brief content unit was observed for this research
project, both Eric Carter and Steve Noble made their curriculum expectations clear by
their words as well as their actions. For Eric Carter, a project-approach to science
promotes student participation in the process of science and encourages students to
construct new knowledge. Steve Noble presents a similar set of expectations for the
learning opportunities that he offers his students, that they engage in the inquiry process
and inspire interest in science. Teaching Standard A (p. 30) in the NSES document
mirrors the beliefs expressed by these teachers:

Teaching Standard A: Teachers of science plan an inquiry-based science
program for their students. In doing this, teachers
• Develop a framework of yearlong and short-term goals for students
• Select science content and adapt and design curricula to meet the interest,
knowledge, understanding, abilities, and experiences of students
• Select teaching and assessment strategies that support the development of
student understanding and nurture a community of science learners
• Work together as colleagues within and across disciplines and grade levels.
(NRC, 1996, p. 30)
The opening stem of the first teaching standard offered as the ideal by the National Research Council speaks directly to Eric and Steve's choice of a project-based approach in their science classrooms — "an inquiry-based science program." Bullet item 3 declares that ideal teaching will "support the development of student understanding," a phrase that is evident as a central theme in both teachers' statements. In several interview comments, Steve Noble mentions his desire to inspire an "interest" in science among his students, even though he realizes few of them will pursue science as a career. Bullet item 2 proposes that teachers should adapt curricula to meet student interests and relate to their experiences. Steve's use of specific examples in describing the river's role in the cultural history of the community relates students' school work in science to their lives as citizens of their community. Eric Carter's students study local rather than exotic animals and plants to enhance their appreciation of the natural balance that exists even in their own backyard. Each of the exemplary teachers described in this study describe their project plans in terms of a yearlong program as recommended by Bullet 1 in this Teaching Standard. In an informal interview midway through the project, Carter explains how the proficiencies in this sequence follow on earlier skill development efforts, and will lead up to students' Senior Projects. Steve Noble explains in his response interview that the Watershed unit is a special case within his yearlong plan for its methods though not for the content. He recognizes, as does Carter, that there is a need for consensus among colleagues on at least some common elements of a worthwhile science program. Both Carter and Noble are strong contributors to their subject-matter community.

Numerous other similarities between the ideals proposed by the National Standards and the conception of ideal science teaching held by the teachers in this study can be
offered. Teaching Standard B defines the specific acts teachers should carry out to effect their desired goals:

Teaching Standard B: Teachers of science guide and facilitate learning. In doing this, teachers
• Focus and support inquiries while interacting with students
• Orchestrate discourse among students about scientific ideas
• Challenge students to accept and share responsibility for their own learning
• Recognize and respond to student diversity and encourage all students to participate fully in science learning
• Encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science. (NRC, 1996, p. 32)

Eric Carter expects his senior students to accept responsibility for their own learning, offering guidance and structure only when needed. His description of the students’ embarrassed responses to his scolding when they came unprepared for a discussion class is an indicator of his success in promoting this ideal. Steve Noble invites student engagement and interest by his insistence that the classroom experience for even low level students will “smell and [it’s going to] stink, and there are going to be bugs crawling around, and, yes, you will have to touch them!” He intends to do all he can to ensure that every student, even those who are identified as reluctant or impaired learners, will become engaged in the inquiry process. There are several examples from the unit observed in each of these classrooms in which teachers “orchestrated discourse among students about scientific ideas.” Steve Noble organized his students into groups and required that the group decide which test results were valid for determining final quality assessments. On Eric Carter’s disrupted day, he presented an impromptu lecture in which he gave students two different scientific explanations of the same habitat observations. He shared some aspects of the argument for each position, and asked the students to
consider the strength of the two points and decide among themselves which case seemed to be strongest.

Other examples that suggest agreement between the practice of these teachers and the ideals of the Standards reflect the “modeling enthusiasm” aspects of Teaching Standard B. Eric Carter’s insistence on joining the student groups in the field in spite of the freezing rain, and the reward of watching the red-tailed hawk breakfast on her prey is a superb example of a teacher’s modeling of the curiosity and enthusiasm that the national vision proclaims. Steve Noble’s wading into the river, pretending to eat a leech, paraphrasing the passing motorist’s impressions of the “weirdo,” is an even more vivid example of the teacher as model of scientific inquiry as envisioned in this Teaching Standard. Eric Carter and Steve Noble embody the spirit as well as the letter of this component of the vision of ideal science curriculum.

Some aspects of Teaching Standard C (NRC, 1996, p. 37-38) have parallels in the beliefs, intentions and actions of Eric Carter and Steve Noble during their project unit. Teaching Standard C focuses on several ways assessment can be a critical part of a quality science curriculum.

Teaching Standard C: Teachers of science engage in ongoing assessment of their teaching and of student learning. In doing this, teachers
• Use multiple methods and systematically gather data about student understanding and ability
• Analyze assessment data to guide teaching
• Guide students in self-assessment
• Use student data, observations of teaching, and interactions with colleagues to reflect on and improve teaching practice
• Use student data, observation of teaching, and interactions with colleagues to report student achievement and opportunities to learn to students, teachers, parents, policy makers and the general public. (NRC, 1996, 37-38)
Three distinct themes about assessment run through this standards statement. First, assessment of student learning should include multiple methods and should be systematic. Second, assessment of student learning should be used to guide teaching and influence teaching practice. Third, assessment of student learning and teaching practices should be the focal point for collegial discussion and ought to enrich the conversations between schools and other constituencies. The case studies created for this dissertation contain direct examples of the first two assessment themes, but information about the efforts of Carter and Noble to pursue efforts similar to those described in the final two bullet items of Teaching Standard C is less directly available.

Assessment of student learning in Eric Carter's class is heavily performance based. Field journals, essays, and a lab practical serve as the basis for student's grades for this unit. He expects students to demonstrate competence in the science skills of observation, data collection, interpretation and analysis as well as the necessary communication skills required for the symposium presentations. As mentioned in Chapter 4, Carter applies standards for the performance of these skills along a continuum, using student's previous performance as a guide for evaluating growth. Informally, Carter uses his interactions with students during their field work and in class to judge individual progress and to modify assignments to accommodate students in his heterogeneous class.

Steve Noble combines traditional paper and pencil testing with a performance component on the final unit exam to obtain information about student learning. During the post-unit interview, Noble expresses concern that he was unable to take more time to address the weaknesses of a few student groups, but he reiterates his judgment that the time allotted should have been sufficient for most students to reach an acceptable level of
understanding. His comments assessing student performance as group members ("It's a tough test, tough concepts. I didn't expect any As but that one group came pretty close, but because they had an extremely bright kid who took a lot of it on himself") suggest that he uses informal observation during class time to evaluate student proficiency on the team-building goals he desires for his curriculum. Anonymous student evaluations after the completion of the watershed project offer him further input on generalized group performance and the effectiveness of his efforts to inspire student "interest" in science.

For both Carter and Noble, the information gathered about student learning and attitudes is valuable for its potential to influence future plans for the project unit. Carter's curriculum includes further habitat analysis using a project-approach similar to the winter adaptations unit. He intends to use the assessment data from this unit to refine plans for the next topic. For Steve Noble, however, the watershed unit is the only project-based unit in his yearlong plan. Information gathered from the assessment of this year's project will be used to refine the structure and implementation of the watershed study for next year's group of students.

No data about collegial interaction was gathered during the case study research. It is unclear how much the professional culture of the two settings encourages involvement like that described in Teaching Standard C regarding the use of assessment data to improve teaching. Only incidentally was I able to determine that each school staff was involved in department-wide analysis of data from the statewide student testing program. Follow-up interviews took place just as data from the previous spring was being reported to the individual schools as well as to the media. In the third year of the testing program, expectations were that scores would be more likely to offer usable data for evaluating
programs and practices in each district. Incidental comments from Steve Noble and Eric Carter suggested that they were occupied with their colleagues in just such an analysis.

A comparison of the vision presented in Teaching Standard D of the National Science Education Standards and the efforts of two exemplary teachers highlights the interdependence of teacher and institutional efforts to promote ideal science learning opportunities for students. Teaching Standard D focuses on the creation of a safe, productive learning environment that can encourage high levels of student achievement.

Teaching Standard D: Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science. In doing this, teachers

- Structure the time available so that students are able to engage in extended investigations
- Create a setting for student work that is flexible and supportive of science inquiry
- Ensure a safe working environment
- Make the available science tools, materials, media, and technological resources accessible to students.
- Identify and use resources outside the school
- Engage students in designing the learning environment. (NRC, 1996, 43).

As described in Teaching Standard D, concern for an appropriate environment that allows and encourages student learning in science exists on two levels, the classroom and the building or school district. Making necessary resources accessible to students is a responsibility of the classroom teacher as well as the building administrator. Providing safe conditions for student learning is also a shared responsibility of the teacher and principal. It is encouraging to note that, despite perennial concerns about lack of funds, neither Eric Carter nor Steve Noble suggested that it was any less their duty to provide a safe, inviting, productive learning environment in their classroom.
A concerned community, as mentioned in Chapter 4 supports Eric Carter in his efforts to create a quality science curriculum. Carter was involved in pre-construction decisions about the design of science classrooms six years ago and has a direct influence on budget requests and allocation as department coordinator. As a result, his students have sufficient electronic resources, print media, and specialized equipment to carry out the projects derived from the habitat analysis. Through his own research, he is acquainted with recognized experts in ecosystem studies, and has invited some of them to present their work to his classes. Where existing funds cannot support a renowned guest’s visit, Carter has managed a modest “fund raising” effort to pay the guest’s honorarium. Carter uses the authority over his own course and time schedule to structure the unit to allow students sufficient time to visit their study sites and gather the relevant information on which they can base their “life histories.” In the time of this study, he restructured the unit time line in order to accommodate bad weather, his own professional commitments, his student teacher’s program requirements for ‘solo time,’ as well as his student’s assignment load from classes they attend during the rest of their day. Carter is required to invest much of his energy in scheduling the unit activities around all the other demands on class time.

Steve Noble has also gone out of his way to provide students with sufficient time to complete their research project, but faces a stricter structure than Eric Carter does. He allows “extra” time for students to prepare their presentations at the beginning of the unit, and allows “extra” time for students to complete their group final exam, despite significant concern about the influence of the standing curriculum on the timing of his project unit. He also provides what district funds cannot, as in his use of his own internet
access for posting of class data to the regional database. In a large school district with three high schools, Noble has a more challenging problem with limited funds. However, Noble’s students benefit from the efforts of a politically powerful principal who has led Lafayette for twenty years. Visitors to Lafayette notice significant differences between the accessibility of resources in its science classrooms and those available in other city high schools. In addition to the principal, Steve’s savvy and energetic department chairperson has used creative ways to get district leaders to complete a major renovation of the science facilities to meet the electronic and safety needs of Lafayette students. Old computers are found or borrowed to run first and second generation data analysis programs or simulations. Chemical supplies for the water testing activities are carefully monitored but always available. Media and technology from the library/resource center serve other learning needs of Noble’s students. Local Audubon Society resources complement Steve’s collection for student research projects. Steve Noble manages to find, bring, beg, or borrow the resources his program needs, all without complaining that this is not part of his job.

My experience with exemplary teachers is that Eric Carter and Steve Noble are typical of that population of professionals. If their students need pond water samples to study, they bring in pond water samples. If they need Internet access or print media, these teachers will find a way to make those resources available. For Carter and Noble, being a science teacher means providing whatever it takes to create an environment that is conducive to good science learning for all students. Noble’s comment that he does not permit his low level students to do worksheets as the common method of learning in science is a rule he applies to himself- he will not settle for an austere, paper- and pencil-
based science curriculum. The attitude and efforts of Steve Noble and Eric Carter reflect the vision described by the National Research Council in Teaching Standard D.

The National Science Education Standards include in Teaching Standard E the expectation that science teachers are responsible for promoting particular attitudes toward science among their students.

Teaching Standard E: Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning. In doing this, teachers
• Display and demand respect for the diverse ideas, skills, and experiences of all students
• Enable students to have a significant voice in decisions about the content and context of their work and require students to take responsibility for the learning of all members of the community
• Nurture collaborations among students
• Structure and facilitate ongoing formal and informal discussion based on a shared understanding of the rules of scientific discourse
• Model and emphasize the skills, attitudes and values of scientific inquiry. (NRC, 1996, 45-46).

Just as Teaching Standard D defines expectations for efforts on two levels, the classroom and the building, to promote an appropriate environment for learning in science, Teacher Standard E speaks to outcomes that are promoted by two parts of the teaching-learning process. The development of attitudes and values that reflect a particular perspective about the collaborative nature of science is as much influenced by what students bring with them to the classroom as it is by the particular activities a teacher defines as part of his/her curriculum. Resourceful teachers can acquire the resources needed to implement a quality science program, as described in Standard D. It seems like more than a matter of resourcefulness on the part of the teacher to bring students to the affective goals described in Standard E.
Neither Eric Carter nor Steve Noble would be surprised that the national vision should include a standard like Standard E. In elaborative comments expanding on the definition of the standard, the writers of the NSES explain more explicitly the values and attitudes they include in this goal. The NRC authors expect students to have opportunities to develop collaborative work skills, to take personal responsibility for their own learning, and to demonstrate effective communication skills. More difficult to observe and therefore to identify are the NSES expectations that students display wonder and curiosity, and develop positive attitudes toward science.

In the interviews and during classroom observations, Eric Carter and Steve Noble both mention their belief that the science curriculum they present ought to be ‘interesting’ to the students. They frequently and explicitly model the wonder and curiosity Teaching Standard E mentions. Eric Carter makes as many “oohs” and “ahs” while watching the hawk devour her prey as do the students. On the walk back to the school after the practice visit to the river-testing site, Steve Noble mentions to students that he would do this kind of work even if he wasn’t with students, because he finds it so exciting. Students can be observed moving closer to him to get a better view when he enthusiastically shows off a rare freshwater sponge he found on the practice trip. These two teachers bring their own attitudes and values to the science classroom, as well as modeling the skills of scientific inquiry. How the teachers’ behaviors influence the development of student attitudes and values is a question that cannot be addressed by the current research study. All that can be claimed is that students in Eric Carter’s and Steve Noble’s classes are offered the opportunity to see their teacher model wonder, curiosity, and inquiry in a number of situations.
Another component of Teaching Standard E is the development of “communities of science learners” who engage in collaborative inquiry. An extensive body of research addresses the complexities of developing collaborative teams in classrooms, and a frequent conclusion is that the development of effective group behaviors requires careful, systematic effort. A question can also be asked whether the actions of one teacher can have an observable effect on students’ perceptions of the value of collaborative work if other elements of the school culture promote individualistic ideals.

At Parkside High School, students are immersed in a collaborative approach to learning in all their classes. When they come to science class, their expectation is that the work of learning science and scientific inquiry skills will occur within the context of a collaborative team. In contrast, the traditional culture at Lafayette promotes the view that individual effort is valued and rewarded. Periodic excellence programs honor students who have achieved individual excellence in academics as measure by traditional tests such as the SAT. While Steve Noble includes group work is a goal for the students during his watershed unit, he has limited time to promote positive attitudes toward collaborative effort, or to teach essential team skills. In achieving Teaching Standard E, it is reasonable to assert that more than an individual teacher’s efforts will be satisfactory.

The final teaching standard delineated by the National Research Council addresses each teacher’s role in the design, development and implementation of a comprehensive science program in their school. In Teaching Standard F, the NSES authors address teachers’ responsibilities to their profession as a means of bringing appropriate learning opportunities in science to their students.
Teaching Standard F: Teachers of science actively participate in the ongoing planning and development of the school science program. In doing this, teachers
• Plan and develop the school science program.
• Participate in decisions concerning the allocation of time and other resources to the science program
• Participate fully in the planning and implementation of professional growth and development strategies for themselves and their colleagues. (NRC, 1996, 51)

Teachers of science are expected to contribute not only to their student's growth in understanding, but also to improvement in their own knowledge of their discipline and their profession. The NRC defines teachers' professional duties to include integrating curriculum among science colleagues and across disciplines within a building or district. The standard includes expectations that teachers will address both personal science teaching goals and goals related to program development. Teaching Standard F encourages science teachers to become leaders in their district.

Information related to the professional activities of Eric Carter and Steve Noble outside of their classrooms were not the focus of this research project. However, conversations during the observation period, and attempts to schedule interview sessions revealed that indeed, these two exemplary teachers have their "fingers in the pot" as Steve Noble likes to say! As department coordinator, Eric Carter organizes staff development programs for the science faculty. He is involved in numerous programs for faculty as well as community outreach. Steve Noble is a frequent presenter at building and district staff development workshops. Both teachers mentioned some involvement in their home school districts, as well as participation in the development of state science standards and assessment protocols. While their primary conception of their role in the school is focused on promoting their student's understanding of science, they generously
contribute their time and expertise to the growth of the entire science and school program.

A comparison of the major themes derived from the case study of Eric Carter and Steve Noble and the national vision of ideal science curriculum is shown in Table 6-2. Statements that reflect teachers' beliefs about the appropriate goals of science curriculum are those that complete these sentence stems: “A project approach to curriculum should . . .”, “My curriculum will provide opportunities to . . .”; and, “The curriculum I design includes classroom activities that involve student in . . .”

<table>
<thead>
<tr>
<th>Table 6-2: Appropriate Goals of Project-Based Curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eric Carter</strong></td>
</tr>
<tr>
<td>Promote student participation in inquiry</td>
</tr>
<tr>
<td>Promote understanding of the nature of scientific inquiry</td>
</tr>
<tr>
<td>Provide insight into student learning</td>
</tr>
<tr>
<td>Advance student’s construction of new knowledge</td>
</tr>
<tr>
<td>Direct students to use scientific skills and knowledge in authentic research</td>
</tr>
<tr>
<td>Engage students in conversations about their new understandings</td>
</tr>
<tr>
<td>Help students develop a global perspective on local habitats</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
C. Expectations for Appropriate and Worthwhile Student Learning

The claim in this dissertation is that teachers' beliefs about what counts as worthwhile student learning is an important influence on the planning and implementation of any collection of student learning opportunities. Along with teachers' beliefs about the nature of scientific inquiry and their conceptions of a project-approach to science curriculum, an understanding of teachers' expectations for student learning can provide useful insights into the evolution of science curriculum in a variety of settings.

The previous two sections of this chapter laid out a comparison of the beliefs of two exemplary science teachers regarding scientific inquiry and project-based curricula. This section will compare the expectations of these two teachers for student learning in science with the expectations embodied in the national vision of learning in science defined by the National Science Education Standards (1996).

A comparison of the beliefs of Eric Carter and Steve Noble with the NSES about appropriate and worthwhile student learning addresses the content component of school science programs. The collection of themes inferred from the interview and observation data used in this research project creates a sketch of each teachers' beliefs about what counts as important for their students to know and understand. Concepts that parallel the participants' major themes can be found in numerous places throughout the seven Content Standards defined by the National Research Council in the National Science Education Standards, as well as in Science For All Americans (AAAS, 1989), and The Content Core (NSTA, 1992). Four common areas of student understanding emerge from a review of the proficiencies described for all science disciplines and provide the substance for fruitful comparison: (1) science as inquiry; (2) understandings about the
interdependence of living and non-living systems; (3) limitations and use of natural resources; and (4) science as a human endeavor.

It is interesting to note that two of the four relevant content standards address issues not usually considered "content" topics. Items (1) and (4) which are common to the teachers’ beliefs and the national vision both reflect non-traditional conceptions of curriculum content. For example, "Science as inquiry" (Content Standard A, p. 173) refers to the process of learning in science, not to the results or facts defined by science, the material that has traditionally been considered science 'content.' However, as explored in detail in the first section of this chapter, both Eric Carter and Steve Noble highlight the learning of science inquiry processes as the central focus of their project based science units. Eric Carter's primary content expectation for his students is that they develop the skills of the naturalist—the ability to observe, interpret and devise explanations of their experiences. Similarly, Steve Noble expects students to learn to accurately define the physical and biological features of the watershed, with the same accuracy and care that environmental professionals employ. By placing Content Standard A first among the student knowledge standards, the authors of the National Science Education Standards echo the beliefs of these two exemplary teachers that the primary content of science in grades 9-12 ought to be an understanding of the methods by which science operates. Since conceptions of the nature of scientific inquiry were discussed in detail in the context of teachers’ beliefs earlier in this chapter, the discussion of this content standard will be limited to this brief review.

Item (4) of the common content themes refers to science as a human endeavor. Content Standard F, from which Item 4 is derived, reflects on the values and attitudes of
science more than on the results of scientific investigation or the accepted interpretations of observations. Both Eric Carter and Steve Noble explicitly address with students the fallible, human side of science. Traditional textbook-based science programs rarely address this complex concept. Yet it can be identified in the practice of the two exemplary teachers studied for this dissertation as well as in the National Science Education Standards. An interesting congruence of non-standards conceptions of science content!

Items (2) listed above as one of the common elements among teachers' beliefs and the national vision address more traditional content topics. The projects which Eric Carter and Steve Noble use with their students both fall under the topic of environmental studies. The Life Science Content Standard describes expected student knowledge of ecosystems, among other topics.

Content Standard C: As a result of their activities in grades 9-12, all students should develop understanding of

- The cell
- Molecular basis of heredity
- Biological evolution
- Interdependence of organisms
- Matter, energy, and organization in living systems
- Behavior of organisms. (NRC, 1996, 181)

Bullet item 4, “interdependence of organisms” and bullet item 6, “behavior of organisms” are the selections from the life science standards that most directly relate to the activities in Carter’s and Noble’s classrooms. The authors of the NSES explain the expectation for student understanding of the “interdependence” concept to include living and non-living components of the biosphere, energy flow, interactions among living organisms, stability and instability of populations, and human influence on the world’s
ecosystems. (NRC, 1996, p. 186) According to the description in the NSES, understanding of the "behavior of organisms" requires students to demonstrate how nervous systems offer survival advantages to multicellular organisms, to describe how learned or innate behaviors respond to external stimuli, and to explain how evolution has acted on behavioral traits as well as genetic ones to contribute to the survival of species. (NRC, 1996, 187)

Through the watershed unit, Steve Noble’s classes are involved in the description of the biological and physical characteristics of the river flowing through their community. The performance of tests on several parameters is an expected learning outcome of the unit. Likewise, students are made aware of the role of physical features such as temperature, pH, and oxygen concentrations, on the living systems in the river. Interactions such as predation, parasitism, and commensalism are some of the important biological factors guiding judgments about the health of the waterway. This unit offers students the opportunity described in Content Standard C to develop appropriate understandings of the interdependence of living things.

Eric Carter’s Rivers Edge unit focuses on habitat analysis of resident species during the winter months. The students in his classes are engaged in activities addressing the behavior of organisms who don’t migrate from the local habitat. Inquiry focuses on the survival advantage of physical features as well as the interdependence of consumer and food source. There is heavy dependence on indirect inferences from scant observations to deduce some explanations for the success of particular species in the area.
Another common feature in the curriculum Carter and Noble create is the attention paid to the relationship between human activity and natural systems. The National Science Education Standards speak to this as a content topic in Content Standard F.

Content Standard F: As a result of activities in grades 9-12, all students should develop understanding of
- Personal and community health
- Population growth
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national and global challenges. (NRC, 1996, 193).

Bullet items 2 and 3 relate clearly to Carter's and Noble's goals for their students. According to the NRC, student understanding of 'natural resources' should include appreciation for the limitations of natural resources and an understanding of human influence on their use. Understanding of "environmental quality" is defined in the NSES as an ability to describe natural processes, to illustrate human impact on them, and to explain likely responses to human interaction. In addition, bullet item 6 is addressed in Eric Carter's River's Edge unit. From the NSES perspective, students can demonstrate an understanding of "local, national and global challenges" by explaining how science and technology are tools which require human decisions to guide their use. The interplay between social issues and scientific inquiry are another aspect of this content standard.

Steve Noble explains to his students that their data from the watershed unit will be shared with other students, and will contribute to the database from which water quality experts will define the health of this resource. Eric Carter involves his classes in adding their observations and analyses to a database which can be accessed by students in other states, and which will serve as background information for researchers considering global
interactions among migrating species. Test items on the final examination for the watershed unit required students to evaluate the quality of a simulated water sample given the measurements of key parameters. The symposium at which Carter's students presented their conclusions about resident species engaged students in critical analysis and preliminary assessment of regional and even international population impacts.

A final theme, which appears in the project units in the two participating classrooms (mentioned briefly early in this section), speaks to the historical and cultural perspectives on the scientific enterprise. Content Standard G in the NSES declares the expectations for appropriate and worthwhile learning within this topic.

Content Standard G: As a result of activities in grades 9-12, all students should develop understanding of
• Science as a human endeavor
• Nature of scientific knowledge
• Historical perspectives. (NRC, 1996, 200)

The content topics included in the first bullet has the clearest parallel to events in the observed classrooms. According to the national document, students ought to understand that individuals and teams from diverse backgrounds have contributed to scientific knowledge. A key aspect of "science as a human endeavor" is that societal, cultural, and personal beliefs influence the work of scientists but that accepted traditions of peer review, truthful reporting and public disclosure of methods and conclusions have enhanced the reliability of scientific knowledge. The learning concepts listed in bullets two and three were not as clearly demonstrated. Teachers' beliefs about the nature of scientific knowledge and their intention to provide students with opportunities to consider this complex concept were not evident from the interview or observation data. Likewise,
few if any examples of teacher’s discussion of changing perspectives of ecosystem analysis emerged from the research.

As mentioned above in reference to Content Standard F, Steve Noble explains to his students that their data will provide needed material for state experts to make judgments about the quality of the watershed. In his introductory remarks on the first day of the unit, he explains that standards for contaminants are rarely defined as “0,” but rather there is an acceptable value that experts define as ‘safe’. His emphasis on the variability of the standards for contaminants presents students with a local example of “science as a human endeavor.”

Eric Carter uses a current debate among naturalists to help his students understand the variable nature of explanations and interpretations in science. During the later part of the River’s Edge unit, when half the students are missing due to other school events, Carter asks students to practice their critical analysis skills by considering two contrasting explanations from expert population studies. He asks students to consider both interpretations and to identify what factors might influence the choice of one explanation over another. He then asks them to choose one interpretation and to defend their choice. From this type of exercise, students can experience the complexity of science, and explore the role of personal beliefs on the conclusions scientists promote.

A summary of the comparison between teachers’ expectations for worthwhile student learning and the vision of content knowledge proposed by the National Science Education Standards is shown in Table 6-3. Statements which refer to teachers’ expectations for student learning are those which complete these stems: “Students
should/ought to have an understanding of...”; “I expect students to learn...“;

“Students are required to demonstrate...”

<table>
<thead>
<tr>
<th>Table 6-3: Appropriate and Worthwhile Student Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eric Carter</strong></td>
</tr>
<tr>
<td>Engage in the practice of inquiry: observe, interpret,</td>
</tr>
<tr>
<td>question, evaluate</td>
</tr>
<tr>
<td>Construct life histories of organisms</td>
</tr>
<tr>
<td>Construct a ‘story’</td>
</tr>
<tr>
<td>Research and interpret local data</td>
</tr>
<tr>
<td>Synthesize new knowledge</td>
</tr>
<tr>
<td>Communicate clearly</td>
</tr>
<tr>
<td>Share interpretations, have conversations about</td>
</tr>
<tr>
<td>meaning</td>
</tr>
</tbody>
</table>

**Conclusion**

There is striking congruence between the learning expectations of these two experienced teachers and the life science content standards of the National Research Council for secondary school science students. Likewise, the efforts Steve and Eric make to create an inquiry-based science curriculum exemplify the Teaching Standards proposed by the National Research Council in the NSES. Since the National Research Council based its document at least in part on the work of exemplary teachers, it is not surprising that we see so much similarity between the enacted curriculum in Carter’s and Noble’s classrooms and the ideals defined in the NSES. We would have been more surprised to see any less alignment! After all, the socialization of teachers is a process similar to the socialization of scientists so carefully described by Thomas Kuhn (Kuhn,
1971). Eric Carter and Steve Noble have been judged to be “exemplary” because they are successful within the predominant “paradigm” of school science, the same paradigm within which writers and reviewers of the National Science Standards function.

What is a surprising finding from the preceding comparison is the number of standards which Carter and Noble are able to incorporate into a single six to eight week teaching unit. One common complaint among early reviews of the NSES is that the national vision is unrealistic. How can any teacher, department or district address the comprehensive list in the NSES of pedagogical, content and program standards within existing institutional limitations? However, the exemplary teachers described in these case studies demonstrate that limitations of time, space and resources, or variations in student ability and attitudes, or any other perceived impediment need not constrain efforts to achieve worthwhile teaching and learning. They are able to enact a surprisingly “dense” learning experience for their students within the normal constraints of public schools. “Density” may be a concept worth considering in evaluating teaching ability. Perhaps it is Eric’s and Steve’s beliefs about the nature of scientific inquiry, their conception of ideal science curriculum and their actions to engage their students with their ‘vision’ of science that enable them to implement the national vision of science teaching and learning. If further review reveals that this is, in fact, the case in other classrooms recognized as promoting high standards, then science educators ought to explore the means by which teachers’ beliefs can be modified to reflect similarity to those held by Noble and Carter.

However, it would be safe to say that the authors of the National Science Education Standards and similar documents are not seeking to be valued because their goals agree
with existing exemplary practice. The ultimate purpose of standards effort is to reform learning in science, which means promoting change in current and future teaching practice. A first step in achieving that goal will be to understand more confidently how existing conceptions of science teaching influence a teacher’s curricular choices. We know from previous experience with the curriculum reforms of the 1960s and 70s (Gallagher, 1991) that curriculum change imposed from “outside” makes little long-term impact. We know from the experience of the mathematics education community that learning new standards does not translate into practices that meet the ideals defined by the standards (Frykholm, 1995). We have evidence from England (Cooper and Davies, 1993) and Scotland (Swann and Brown, 1997) as well as our own curriculum reform history (Tobin, Tippins and Gallard, 1994) that imposing new curriculum or assessment tests meets with resistance among practitioners. Reform advocates are challenged to consider teachers’ role in curriculum design in their discussions of effective ways to promote improved teaching and learning in science.
CHAPTER 7

CONCLUSION

The examination of teachers' beliefs, intentions and actions in Chapters 4 and 5, and the comparison of teachers' actions with national standards recommendations in Chapter 6 of this dissertation lead to three observations: (1) there is a high degree of similarity among the beliefs, intentions and actions of the participating teachers; (2) both Steve Noble and Eric Carter design project-based curriculum units that meet the teaching standards promoted by the National Science Education Standards (NRC, 1996); and (3) the project-based units address a surprising number of NSES content standards within a short period of time. The balance of this chapter will try to construct a "story," in Eric Carter's words, that explains how these observations of teaching in two classrooms can support our efforts to understand and improve science education.

Observation 1: There is a high degree of similarity among the beliefs, intentions and actions of the participating teachers:

There are at least three possible explanations for the observed similarities in Eric Carter's and Steve Noble's beliefs, intentions and actions. It could be argued that the common themes are present only as an outcome of the classification and sorting process used in the research. Since the researcher is looking for similarities, it could be claimed that she has assigned terms to participants' statements that encourage the perception of similarity within the teachers' statements.
Efforts to avoid influencing the identification of common themes included inviting unrelated readers to examine a sample of the interview and classroom transcripts and classify teachers’ statements into predefined categories. The high rate of agreement between the reviewers’ and the researchers’ classifications suggests that the similarities are more than artifacts. Comments from the participants confirming the suitability of the themes assigned to their beliefs, intentions and actions also refutes the claim that the similarities are not an accurate representation of teachers’ ideas. The argument that the perceived similarities are an outcome of the research process rather than derived from the participants’ thoughts is not strongly supported.

A second explanation for the presence of common themes among the beliefs, intentions and actions of each participant proposes that exemplary teachers present themselves as consistent in their beliefs, intentions and actions in order to maintain their status within their school. Being identified as exemplary places a burden on a teacher to present a coherent, integrated professional image to the community and to visitors. Teachers with an established reputation within their institutions will “talk the talk” that is considered suitable to someone of their status. Participants may have chosen to respond to the researcher’s questions in a way that they think the researcher expects, rather than presenting an honest, but confused and at times incoherent, impression.

The interview protocol used to identify beliefs was designed to reduce the possibility that teachers could present deceptive or incomplete information to the researcher. The Interview about Instances asked teachers to respond to hypothetical instances about other teachers, not about themselves. Efforts were made to avoid instances that might be too similar to the participant’s own context. The participants’ beliefs were inferred from
responses to ten distinct situations rather than asked directly. Each situation was vaguely described, so that the respondents were required to supply their own details in order to reveal the essential characteristics they deemed important. While teachers had a general description of the project's goal to identify patterns and relationships before the initial interview, the process of analyzing the interview transcripts was not clear to the participants so that their responses could be assumed to be sincere.

A corollary to this explanation for the presence of similar themes proposes that teachers using project-based science curricula develop beliefs about their discipline, about curriculum and about worthwhile learning activities for their students as a result of their implementation of this particular curriculum model. This explanation has significant intuitive appeal. The traditional method of preparing teachers depends on the ability of novice teachers to emulate effective practices, with the expectation that experience and reflection will inspire corresponding beliefs about the teaching-learning process. Practicing particular behaviors may lead to the development of corresponding beliefs. However, the data obtained for this study isn't suitable for use in examining whether the explanation that practices lead to beliefs and produce the consistent patterns seen in the teaching of Eric Carter and Steve Noble. An exploration of whether participants' beliefs about science preceded their choice of a project-approach or developed from their participation in project-based units was not completed for this study. Recommendations for future research suited to examining the influence of practices on the emergence of beliefs is discussed later in this chapter.

A third explanation for the presence of similarities among the themes describing participants' beliefs, intentions and actions is more strongly supported with the evidence
obtained in this project: “Teachers teach who they are” (Hawthorne, 1992). The common themes connecting the three elements in the planning and implementation of a curriculum unit indicate more than an accidental occurrence. The similarities suggest that teachers’ beliefs exert a strong influence on their curricular plans and on their implementation of those curricular intentions.

A key piece of evidence supporting the claim that teachers’ beliefs influence their curricular choices comes from Eric Carter’s “plan B” days. On two occasions during the unit, Carter was forced to make last minute alterations to the original plan for activities during the class. When the weather prevented a walking field trip to a bog, Carter quickly put together alternative activities for students that retained the purposes and intentions supporting the primary unit goals. On a second occasion, when a field trip, a math scholarship exam, and a ski meet reduced his class to half its normal size, he discarded his planned lesson and pursued a small group discussion that complemented the learning goals promoted by the project unit.

Steve Noble’s efforts to implement the project unit in the face of rigid school bell schedules and tedious permission requirements, as well as his allegiance to the department curriculum plan, adds further to the claim that teachers’ beliefs exert a strong influence on their curricular choices. Noble is the only one among a respected, veteran ten-person science department to adopt a curriculum model that requires extensive effort to fit into the traditional school format. “Why bother?” he was asked. His response was that he thought it was the “best” way to teach, and even though he can’t find the time to implement project-based units for the rest of the year, he felt it was important to do as much as he could to expose his students to an authentic research experience.
The conclusion asserted above, that similar themes imply a strong link between teachers' beliefs and actions, complements and clarifies the findings of other researchers who have examined the role of teachers' beliefs on their teaching practices. Clark and Peterson's (1986) summary of research on teachers' thought processes included teachers' theories and beliefs as one category of thought that influences and is influenced by teachers' actions. The Clark and Peterson description suggests a broad role for teachers' beliefs in the development and implementation of curricular plans. The research presented here complements the model presented in the Clark and Peterson review by describing in greater detail the links between beliefs, intentions and actions in three categories as teachers confront typical challenges to their planned activities.

Despite the presence of common themes connecting beliefs and actions, the data presented here does not support a claim that beliefs necessarily cause the classroom actions in these two cases. Confirming the explanation made by Shavelson and Stern (1981) that simple behavioral models of teaching decisions are inadequate because they cannot account for differences in behavior based on teachers' judgments and beliefs, the present study of Carter and Noble show a 'messier' situation. As Fischler (1994) describes, teachers' choices do not demonstrate a direct, logical connection with their beliefs. While themes appear to link beliefs and actions in the two cases described here, belief themes do not map directly onto action themes. The full transcript of teachers' statements includes many more ideas that reflect their thoughts, but which were not included because they represented minor rather than dominant themes. Fischler explains this "messiness" by asserting that teachers make pedagogical judgments based on experiential evidence rather than a logical appeal to theoretical reasoning (Fischler,
1994). The interviews with Carter and Noble support Fischler’s claim that teachers’ thoughts on a number of issues related to their professional activities are interwoven in inconspicuous ways with their dominant ideas.

While we cannot claim that Carter and Noble make curricular choices which show a direct link with their beliefs, we can say that their choices show much more logical consistency than the choices of less skillful or less experienced teachers. Brickhouse and Bodner (1992) describe a novice teacher’s effort to reconcile conflicting aims for his students and the resulting inconsistency between teachers’ beliefs and actions. In one example, ‘McGee’ was faced with institutional expectations for student achievement which were in conflict with his desire to promote student curiosity and positive attitudes toward science. The experiences he created for students reflected his conflict, making it difficult for students to perform to both sets of expectations.

The descriptions of the assessment strategies used by Carter and Noble contrasts with the mixed messages in the study of novice teacher ‘McGee.’ Both exemplary teachers were careful to share with students their expected outcomes and to construct assessment devices that are true to the stated expectations. Unlike novice teachers, exemplary teachers’ curricular choices, as seen in their choice of assessment tools, are more consistent with stated intentions and provide students a clearer definition of performance expectations.

In contrast with the findings of Duschl and Wright (1989) that accountability pressures exert the greatest influence on teachers’ pedagogical decisions, the evidence from this examination of Carter’s and Noble’s choices suggests a more student-centered focus. The fifteen members of the science department surveyed by Duschl and Wright
worked in a traditional setting, much like Noble's Lafayette. They were under the influence of self-imposed competitive pressures when a math-science magnet high school was opened nearby just prior to the start of Duschl and Wright's research visits. The teachers in this setting made individual and group curricular choices that considered the perception of success that would be presented to the community as a result of their choices.

There is a remarkable absence of competitive impulses in the statements of Carter and Noble. In a number of cases, including interview responses, classroom statements, and professional essays, Carter and Noble point out the importance of the impact of their decisions on student learning. Noble's lament over a previous class in which disruptive students thwarted every effort to involve students in his preferred curriculum plans highlights the importance he places on student engagement. When asked how he decides whether he's doing a good job, Steve lists student evaluations as the first criteria, then supervisor's comments, then the assessments of colleagues.

Carter has a similar interest in presenting learning experiences that are worthwhile to students, with no concern mentioned for their appeal to peers or supervisors. He recognizes his duties to his students and to the community as the dominant influences on his curricular choices. Both exemplary teachers enjoy a degree of autonomy in their ability to make curricular choices, due in part to their recognition as exemplary practitioners. Duschl and Wright's teachers, though veteran, allowed perceived competitive pressures to define their curriculum, in contrast to the relative freedom that exemplary status allows Carter and Noble when making their decisions. Carter specifically noted his respect for community input into curricular choices, but expressed
confidence in his status to make professional decisions that might contrast with the preferences of certain community members.

Within the individual categories examined for these case studies, the evidence further complements and clarifies the findings of other research efforts. Lederman and Zeidler (1987) were unsuccessful in their attempt to identify specific behaviors that reflected teachers' conception of the nature of science. The evidence from this study of Carter and Noble supports Lederman and Zeidler's conclusion that behaviors do not directly reflect beliefs. However, the restrictive analysis categories used by Lederman and Zeidler limited their ability to see any patterns or links between beliefs and actions. Lederman and Zeidler used teachers' responses to the Nature of Scientific Knowledge Scale (Rubba, 1976) to classify teachers' beliefs about their discipline. Observed behaviors were classified and grouped by common features, and these behaviors represented teachers' actions. While understandable as the most efficient way to evaluate data from eighteen different teachers, the sorting method concealed possible connections.

The examination of the beliefs of Carter and Noble using the CTS protocol (Hewson, Kerby and Cook, 1995) allowed greater flexibility in characterizing teachers' thoughts related to their conception of the nature of scientific inquiry. The similarities that are revealed between beliefs, intentions and actions would not have been evident if Lederman and Zeidler's procedures had been used. Rather than contradicting the findings of the previous study, the conclusions of this research serve to reinforce methodological concerns that Lederman himself noted (Lederman, 1992).

Use of the CTS protocol allowed teachers to describe their beliefs in their own terms, allowing them to define their beliefs about the nature of science in the context of
science teaching. It is important to distinguish among the many conceptions of the nature of science that individuals might hold, as Pomeroy (1993) found when comparing the beliefs of scientists, secondary science teachers, and elementary teachers. Scientists held beliefs that were quite traditional, inconsistent with the more recent characterizations of science as tentative and socially influenced. Elementary teachers described science in the most contemporary terms, highlighting its changeable nature. Secondary science teachers were more traditional than contemporary in their views, but their conceptions did not have the rigidity characteristic of scientists' beliefs. Pomeroy's secondary teachers were not necessarily exemplary, which may explain the difference between her participants and the non-traditional efforts of Eric Carter and Steve Noble. Again, while Pomeroy's teachers were veteran, they were not necessarily outstanding representatives of their profession, as Eric and Steve have been identified.

Pomeroy concludes that each group incorporates evidence from their own practice into their conceptions of the discipline. We can see this in Carter's and Noble's beliefs about the nature of scientific inquiry. Carter sees science as a process of constructing a story of the way the world works. His experiences as a researcher on a rain forest ecology project sponsored by a national environmental advocacy group requires him to construct careful hypotheses ('stories') to share with colleagues at national symposia, an event he describes with the Natural World class on one of the "plan B" days. He blends his researcher science experiences with his science teacher experiences to construct a comprehensive conception of scientific inquiry.

Steve Noble's conception of the nature of scientific inquiry is based on childhood experiences with his father/ecologist, experiences as a student-researcher in graduate
school, and from beliefs that have emerged during his teaching practice. Noble's blended view is similar to the conceptions of science Brickhouse (1990) describes as characteristic of the veteran teachers she studied. Graduate course work, research experience, and beliefs outside of the professional role they serve all make an impression on the beliefs and actions of teachers. The discovery of extensive similarity among themes related to beliefs, intentions and actions supports Brickhouse's (1990) conclusion that teachers' beliefs represent a complex interweaving of numerous factors.

The complexity of teachers' beliefs about the nature of science is certainly confirmed by this analysis of Noble and Carter. Teachers' conceptions of their role as curriculum planners are similarly complex. The evidence of common themes in the beliefs and intentions of Carter and Noble regarding curriculum complements Briscoe's (1991) research on the interactions of beliefs, curriculum intentions, and teaching practices. Carter and Noble recognize the importance of local and state defined curriculum, but reserve some degree of professional freedom to decide the form in which the defined concepts and skills will be brought into their classrooms. Briscoe focuses her attention on the role metaphors of 'Brad,' an experienced teacher trying to implement a new curriculum model. After a summer workshop in which he "practiced" cooperative learning strategies, 'Brad' was expected to implement them with his students. Briscoe observed 'Brad's' classes and interviewed him during the implementation process. Briscoe found that, while able to manage students according to the requirements of the cooperative plan, 'Brad' had significant difficulty integrating the new pedagogy with other aspects of his professional role, particularly his assessment beliefs. 'Brad' describes his role as the deliverer of information, a metaphor inconsistent with
cooperative methods. He described students as “workers” charged with the task of completing assignments in order to receive grades. Briscoe concludes that this classroom-as-workplace metaphor does not support the behaviors that will encourage and maintain the new teaching model ‘Brad’ is trying to adopt.

When the data gathered from Carter and Noble are examined, their personal role metaphors are revealed. Eric Carter is a “storyteller,” engaging his students in writing the “life histories” of the animals in their habitat sites. Carter finds a “story” in which he can involve students, so that the content of their lessons can become meaningful to them. Carter “reads” students’ reactions to guide the pace at which he moves the unit along.

Steve Noble is a sculptor, with his hands “molding” student ideas. Several times during the Instances Interview he refers to teacher’s work in similar ways: “have my hooks in there,” “got to have my hands in the pot.” In Steve’s mind, learning is directed by teachers in specific ways, just as a sculptor molds clay into particular forms.

The interesting correlation revealed by this research, complementing Briscoe’s findings about ‘Brad,’ is the degree of consistency between the metaphor each participant implies and the types of learning activities he designs. Carter encourages students to explore a variety of means to obtain the material they need to write their habitat stories. Noble, on the other hand, is very clear and direct in assigning tasks to be completed each day. In an informal interview after the project unit, Noble expressed reluctance to go “off on tangents” when interesting events occur, because there is a tight schedule to meet in order to complete the required curriculum coverage. Carter quite easily wanders into adjacent topics with individual students, but always connects the conversation to the overarching concepts of habitat analysis. Assessing student progress is a subjective,
variable process for Carter, since students have encountered different opportunities to
explore the key ideas within the unit topic. Noble expresses a belief that students ought
to be encouraged to be creative and original, but is unable to integrate that belief with his
traditional assessment practices.

One final area where the conclusion that teacher’s beliefs influence their curricular
choices complements and clarifies other’s research relates to teachers’ conceptions of
appropriate and worthwhile student learning. As mentioned above, the role metaphors
Carter and Noble use to describe their function as teachers has an impact on students as
well. Rebecca Killen Hawthorne (1992) found important influences between teachers’
beliefs about learners and the curricular choices they made. Teachers who saw students
in terms of their deficiencies narrowed their range of curricular options, mistakenly
assuming that funnelling energy into a single strategy for learning would improve
students’ chances for success. Teachers who were assigned honors classes typically
broadened their range of pedagogical strategies, assuming that honor students were able
to “handle” variety and diversity. Student learning opportunities were defined by
teachers’ beliefs about what counted as worthwhile and appropriate learning
opportunities for any particular class.

Steve Noble believes all students can learn science best by participating in the
activities of science. He says teasingly to even a low level class, “It’s going to stink and
it’s going to smell and there are going to be bugs crawling around and you’re going to
have to touch them, yes you are!” His dismay when he must limit student activities
because of a few disruptive students one year highlights how strongly he tries to give
students an authentic, engaging, rich experience.
Similarly, Eric Carter’s belief that students construct their own knowledge by participating in authentic scientific research motivates his curricular choices. His thrill at the effort made by a student with learning difficulties and motivational problems is genuine and revealing. Carter works harder at constructing an inviting learning experience for his students than many experienced teachers.

Linda Cronin-Jones (1991) found that teachers’ expectations for student learning was the primary factor in defining curricular choices among the middle level teachers she observed. Carter and Noble integrate their expectations for students with their beliefs about their discipline and their conception of their own role as curriculum planners. When woven together, the curriculum experience they create provides students with a variety of opportunities to experience and understand science in a realistic context.

The research reported in this dissertation, complemented with other’s research on the linkage between teachers’ beliefs and their curricular choices, makes it clear that teachers are the creators of classroom curriculum. The learning experiences that students encounter are significantly influenced by teachers’ beliefs about their discipline, the goals of curriculum and students abilities. If we assume that student learning is a product of their classroom experiences, then we can summarize the findings of research this way: Teachers get what they ask for. The conclusion that teachers’ beliefs are an important influence on their curricular choices impacts the work of several education constituents.

Implications of Conclusion 1:

What are the implications of concluding that teachers’ beliefs influence their curricular choices? For practitioners, this finding implies both challenges and rewards. The challenge for teachers is to admit they hold a great deal of responsibility for
structuring learning opportunities for students. Despite the interaction with factors outside the classroom that are often cited as limiting student achievement, exemplary teachers are able to provide experiences that support their intentions and beliefs. The findings of this body of research support the claims of accountability advocates that teachers have a professional obligation to design curriculum experiences that promote appropriate and worthwhile student learning. Teachers will need to expand their awareness of pedagogical strategies and monitor the response of students to specific curricular events in order to discharge their responsibilities in the most effective way possible.

The reward for teachers implicit in this finding is an enhanced status for their professional expertise. "Outsiders" who presume to identify classroom or program strengths and weaknesses from a cursory review of syllabi or written curriculum documents can be challenged in their conclusions. Without observation of classrooms to identify the characteristics of the implemented curriculum, experts will be unable to predict the impact of change recommendations or reform efforts. Policy makers and curriculum developers will need to develop partnerships with teachers to enact programs that meet desired standards.

An appreciation for the range of beliefs that play into teachers' choices is closely associated with the conclusion that teachers' beliefs influence their curricular decisions. Three categories of belief were examined for this study: beliefs related to the nature of scientific inquiry, the ideal goals of project-based curriculum and expectations for student learning. Similar categories of beliefs have been identified in related studies, but not interwoven with the others. Researchers have recognized that systems as complex as
teachers’ beliefs and decisions cannot be studied in traditional ways (Zeichner, 1994) and cannot provide the predictive insight that is a desired product of research (Laursen, 1994).

If teachers’ beliefs influence their actions in complex, dynamic, fluid, unpredictable ways, then it is likely to be unproductive to examine individual beliefs out of context. The image of a weaver clarifies the implication that is intended here. A teacher is like a weaver who has woven a variety of threads into a particular piece of fabric. The researcher may be able to tease apart the individual threads and identify some of the relationships among the threads composing the entire fabric. However, knowing the characteristics of an individual thread cannot predict whether the final pattern is a tweed, a plaid, or a hounds tooth check. Without a complete description of the relationship among all the threads, the researcher cannot fully describe the existing pattern. Even with a full description of the completed fabric, the researcher will be unable to predict what pattern the weaver/teacher will produce next, since virtually infinite variations are possible given the number of threads/beliefs teachers bring to their work.

Does that imply that research on teachers’ beliefs and actions should be abandoned? Certainly not. What it does imply is that a comprehensive picture of a teachers’ curriculum decisions will require intense effort extending over many years. A more practical research model will be similar to the methods used to investigate habitats, as Eric Carter’s students conducted in the River’s Edge Unit. Careful observation and a search for clues can lead to the construction of useful “life histories” of teachers as they produce their classroom experiences for students. Traditional expectations of validity and reliability may not suit new research models.
The conclusion that teachers’ beliefs influence curricular choices in complex, dynamic and unpredictable ways has implications for curriculum developers as well as for practitioners and researchers. Recognizing that curricular decisions happen at the classroom level requires a change in the assignment of responsibility for appropriate choices. Brickhouse (1990), Cronin-Jones (1991), Briscoe (1991), and Hawthorne (1992) demonstrated that teachers make significant transformations of prescribed lessons. Steve Noble found a way to “sneak” in a favorite curriculum unit despite time and coverage concerns. Eric Carter drew on personal experiences to complement a planned curriculum when disruptions interfered with prepared lessons. Curriculum development must involve the teachers who are constructing the classroom experience.

Movement toward collaborative curriculum design is already underway. Models of collaboration show the direct classroom impact of involving teachers in critical decisions about what and how to teach (Burns, 1995; Glatthorn, 1994; Oja, 1995; Pate, 1997; Warger & Pugach, 1996). Some use the design of effective curriculum as a vehicle for teacher development (Bell and Gilbert, 1996). Others invest the time and energy in collaborative curriculum efforts to meet newly imposed performance standards (Mitchell, Wallis and others, 1995). Research identifying the importance of teachers’ beliefs on the implementation of curriculum plans has encouraged these movements toward collaboration and the enhancement of teachers’ professional roles.

Implications from this research and related studies include suggestions that teacher preparation programs involve preservice teachers in activities that help them explore their existing beliefs about their discipline, their role in curriculum planning, and their expectations for student learning. One document includes the recommendation that
preparation programs "encourage reflection" and "model effective practice" as well as providing opportunities for prospective teachers to become proficient in knowledge of the learner, pedagogy and content (New Hampshire Preservice Education Review Project, 1997). A draft version of proposed national standards for science teacher preparation include expectations that prospective teachers become proficient in engaging students in a curriculum that is consistent with local, state and national standards (CASE Project, 1997). In addition, prospective teachers are expected to implement a curriculum that is appropriate to the "needs, interests and abilities of their students" (CASE, 1998). By making prospective teachers aware of their obligation to consider their discipline, the ideals of science curriculum, and the needs of their students, teacher education programs are addressing the implications of the research conclusions presented in this dissertation.

Policy makers are another constituency who must consider the implications of research that concludes that teachers' beliefs influence their curricular choices. Policy makers who wish to modify the learning experience of students will need to find a way to modify teachers' choices. Earlier efforts to impose curricular expectations that treated teachers as consumers of a curriculum product have been shown to be ineffective in producing the desired classroom changes (Kyle, 1984; Roth, 1992). Publishing elaborate standards and evaluating teachers' practices based on those standards may result in similar disappointment. A more holistic approach is recommended by the research, including a collaborative effort involving classroom teachers in the design of evaluation systems for effective practice.

Traditional efforts to evaluate teaching focuses on teachers' classroom actions as exemplified by the clinical supervision model (Acheson & Gall, 1992). Recent efforts to
define accountability standards for teachers have shown more consideration of the 
complex nature of teaching practice (Gitlin and Price, 1992). For the most part, though, 
proposed national models for licensure and assessment continue to emphasize 
observation of classroom behaviors separated from the context of teachers' beliefs and 
intentions and knowledge of school and classroom contexts (National Board for 
Professional Teaching Standards, 1991). Absent from the process are the underlying 
beliefs that have been shown to play a significant role in shaping the learning experiences 
students encounter. Standards emphasizing the rating of practices alone will present an 
incomplete (and likely incoherent) picture of teaching and learning interactions. If 
teacher assessment is to be used as a diagnostic device, then new methods of evaluation 
must be designed to take into consideration the full complement of factors that bring 
about student learning opportunities.

A more important consideration for policy makers is the decision to allocate 
resources for 'improvement' efforts. Assessment tools that examine practices dissected 
from teachers' beliefs present a distorted view of the "problem." Assumptions inherent 
in the assessment devices promote the perception that changing behaviors will change 
learning outcomes. The research described in this study raises questions about that 
assumption. Change efforts that seek durability must consider the complex network of 
interactions that comprise the experience students encounter in science class. Allocating 
resources to activities designed to raise teachers’ awareness of their current beliefs, and 
the impact of their beliefs on existing practice might be more productive than attempting 
to change behaviors alone.
The research on Eric Carter and Steve Noble complements an existing broad base of research that directs our attention toward the role teachers’ beliefs play in the definition of classroom learning experiences for students. A prevalent finding of these studies is that the specific direction of influence between beliefs and actions is unpredictable. Do teachers’ beliefs about the tentative nature of science, for example, limit or expand teachers’ pedagogical choices? We have some evidence to help us answer questions like this, but our ability to integrate all the data into a coherent explanation of the role of beliefs in directing behavior is limited by our methods. Perhaps we can learn from other disciplines, like atmosphere studies and human systems research, to advance our ability to interpret complex interactions. Modeling complex systems has enhanced scientific explanations and predictions about behaviors that seem chaotic. Systems capable of monitoring continually changing pressure and humidity data and correlating that with topography and long-term climate patterns has improved the predictive capabilities of meteorologists. Improving our understanding of teachers’ beliefs and choices will require the development of similar new research methods and new ways of conceiving of the teaching-learning process suited to an analysis of intricate systems.

Observation 2: There is a high degree of consistency between exemplary teachers’ practices and the recommendations of the National Science Education Standards.

The comparison presented in Chapter 6 revealed that Eric Carter and Steve Noble implement a curriculum plan that is consistent with the Teaching Standards recommended by the National Science Education Standards (NSES) (NRC, 1996). At least two explanations for this observation are plausible.
As exemplary teachers, Eric Carter and Steve Noble are expected to maintain familiarity with current trends in science education. One explanation for the observed similarity could be that both teachers selected their project-based unit because it suited the national recommendations. The complexity of managing and implementing a project-based unit requires careful planning and much effort. Most teachers would not pursue curricula as demanding as this without being motivated by the recommendations of respected authorities.

Other evidence from the study of Eric and Steve contradicts the first explanation. In interviews following their review of Chapters 4 and 5, both teachers reported limited familiarity with the National Science Education Standards. Eric explained that he felt somewhat familiar with Project 2061: Science for All Americans (AAAS, 1989), a document outlining the broad framework of a science education system that would promote scientific literacy for all citizens. Eric served on the writing team for the state curriculum frameworks which were based on principles outlined in the AAAS volume and which mirror the NSES in the definition of student proficiencies. Steve served on review committees for the state assessment examinations based on the state curriculum frameworks. Neither teacher, though, expressed knowledge of the standards related to teachers in any of the reform literature.

Chronologically, the argument that Steve and Eric selected their curriculum units to comply with the NSES Teaching Standards can't be upheld. Eric began his River's Edge unit in 1993, and Steve implemented the Watershed unit in 1989, well before the publication of the NSES in 1996.
A second explanation for the similarities between the practices of Carter and Noble has more plausibility and support. Both teachers began teaching in the late 70's, in the midst of an earlier 'wave' of science education reform. It is likely that their preparation programs promoted the Piagetian notions of learning on which most of the “alphabet soup” curricula were based (Yager, 1981). Post-positivist conceptions of the nature of science were emerging as important (though by no means the dominant) considerations in science curriculum (Duschl, 1992). The explosion in scientific knowledge in the post-Sputnik years made the traditional content-based curricula unwieldy, leading to curriculum designs centered on the skills and processes of scientific inquiry (Roth, 1992). Becoming socialized into the profession within this context has had an significant influence on the beliefs Carter and Noble developed about their discipline, the ideals of curriculum and about student learning (Berger and Luckman, 1966).

A review of the principles underlying the recommendations of the NSES authors leaves the impression that the standards are designed to reinforce the best ideals of the earlier reform movements (NRC, 1996). Closing the chapter on Teaching Standards is a chart titled “Changing Emphases,” a list of preferred practices contrasted with less desirable teaching patterns (NRC, 1996, p. 52). The list includes recommendations for less emphasis on “treating all students alike” and more emphasis on “responding to individual student’s interests, strengths, experiences and needs.” Teachers are advised to reduce their rigid adherence to a prescribed curriculum in favor of taking the responsibility for selecting and adapting curriculum. One recommendation that has strong flashback impact suggests less emphasis on “presenting scientific knowledge
through lecture, text and demonstration” and more emphasis on “guiding students in active and extended scientific inquiry” (p. 52).

The explanation that best fits the observed correspondence between the practices of Carter and Noble and the standards in the NSES follows from the brief summary presented above. Given the similarity between the “new” reform recommendations and the “old” reform movement within which Carter and Noble developed their teaching beliefs and practices, it is apparent that teachers designated “exemplary” within the earlier model of ideal teaching would also be classified as exceptional within the new standards framework. Certainly there are new elements in the NSES document that are not highlighted in the earlier proposals for ideal science education, but the dominant themes remain parallel if not identical to the dominant themes in science education of the 70’s. The most convincing explanation for the correspondence between the practices of Carter and Noble and the NSES Teaching Standards is that the new standards do not represent a major change in science education when examining teachers’ practices only.

**Implications of the finding that the NSES Teaching Standards do not represent a major change in teaching behaviors.**

For practitioners, the finding that the work of our best science teachers meets the recommendations of the NSES should be comforting. It implies that the newest reform standards are not significantly different from the ideals under which science educators evaluate their practice at the present time. Continuing efforts to support and emulate our recognized colleagues will produce efforts that meet the ‘new’ standards.

For reform advocates and researchers, the correspondence between existing practice and the NSES teaching standards should raise concerns. The high degree of similarity
between the work of Carter and Noble and the new standards could indicate that the
NSES represents very little change in the goals of science education. If few differences
exist between current practice and new ideals, then improvement in student learning is
unlikely to result from the reform effort.

An alternative implication might be more appealing to researchers and reform
advocates. Closer examination of the “Changing Emphases” table at the end of the
Teaching Standards chapter of the NSES (NRC, 1996, p. 52) reveals a number of
problems associated with relying on observation of teaching practices to determine
whether teachers’ promote the reform objectives. Movement from the left-hand column,
the list of practices that should de-emphasized, toward the right-hand column, the list of
practices that should receive more energy and attention, requires minor behavioral
changes. However, the conceptual change required to believe in the principles promoted
by the new recommendations is significant. Steve Noble quite comfortably uses “lecture,
text, and demonstration” (NRC, 1996, p. 52) on some class days during the project unit,
and quite comfortably “guide(s) students in active and extended inquiry” (Ibid.) on other
days.

The themes representing Noble’s beliefs about student learning and curriculum
indicate a similar diversity. He agrees that students need inquiry experience but firmly
believes that teachers have a duty to direct learning in specific ways. He designs a
learning experience for his students that correspond with both sides of the “changing
emphases” chart!

This expanded analysis of the similarity between current best practice and reform
recommendations suggests to researchers and reform advocates, as well as teacher
educators and policy makers, that a focus on teacher practices in classrooms may not produce an accurate assessment of the overall teaching environment. Experienced teachers are like Steve Noble, able to move between practices that are classified ‘traditional’ and those that reflect contemporary standards. The concern that is raised is the impact of teachers’ minor actions and incidental comments on the development of student’s understanding of the discipline. Do teachers consistently promote original thinking and interpretations or do they test for recall of classic theories? Subtle actions may have a significant impact on students’ knowledge than we could determine from occasional or cursory observation of teachers’ practice.

Caution should be urged against using the NSES as a tool for assessing teacher effectiveness. As demonstrated in Chapter 6, a focus on the Teaching Standards alone results in a narrow view of teaching as a collection of behaviors. It is difficult (if not impossible) to identify a single set of teaching practices which would contribute to student learning of the nature of science, or scientific habits of mind. These understandings develop from extended experience with science, in school and in other places.

A quick reexamination of data gathered from visits to Carter’s and Noble’s classes illustrates the distortion that a focus on teachers’ actions alone can present. Steve Noble holds a teacher-centered view of science classrooms. Teachers are “molding,” with their “fingers in the pot.” Eric Carter’s view is much more student-centered, continually making adjustments and directing energy to suit the interests and needs of his students. Yet, both are able to implement a unit that shows admirable correspondence with the recommendation of the NSES for ideal science teaching. Underlying beliefs vary
between the two exemplary practitioners, yet an observer to their classrooms would find few differences in the specific activities that are expected of students.

The implication of this observation for supervisor and policy makers implementing evaluation protocols is serious. One classroom visit will not identify agreement or conflict between the curriculum students experience in a teachers’ class and the desired goals of science education. Even multiple visits focused on observing teacher behavior will not be likely to reveal implicit conflicts or conformity with recommended ideals. If an observer were to spend time in Steve Noble’s class while the students were completing the unit on cells, there would likely be a very different level of agreement between his practices and the NSES recommendations.

If there are sincere interests in promoting durable change, teachers’ beliefs must be coherent with the reform ideals. Just as students arrive with diverse beliefs about natural laws, teachers come to their profession with diverse beliefs about appropriate and worthwhile learning, about the ideal goals of curriculum, and about the nature of scientific inquiry. Identifying the conceptions of their role that promote consistent practices should be an important effort among researchers and among teacher educators. Posner, Strike, Hewson, and Gertzog (1992) offer a promising model for promoting conceptual change among science students. A number of researchers and teacher educators have discussed ‘conceptual change’ as a model for use in promoting changes in science teachers’ thinking (Bell and Gilbert, 1996; Briscoe, 1996; Duschl & Gitomer, 1991; Prawat, 1992). Many of these authors express optimism that such change is possible, but almost all caution that changing deeply held beliefs requires long-term effort by the science education community, most importantly the teachers themselves.
Ethical concerns must be considered when advising efforts to change another’s deeply held beliefs. The science education community must examine its expectations and motives carefully before promoting a single ‘vision’ of ideal science teaching and learning. Discussion with practitioners, parents, and political stakeholders will be required before wholesale efforts to promote the reform recommendations are permissible.

Observation 3: The project-based units address a surprising number of NSES content standards within a short period of time.

A comparison of the project-based units implemented by Eric Carter and Steve Noble with the NSES Content Standards for grades 9-12 reveals that the project units address a surprising number of content proficiencies within a relatively small part of the school year. Is this a significant observation or merely an artifact of the comparison process? Two equally likely explanations can be offered to support the conclusion that the density of the project units is an important feature of science curriculum.

Of course, it cannot be conclusively shown that the perceived “density” of the classroom events observed in this research is not a product of the researchers’ selection process. Only project units were observed for this research, and only exemplary teachers were invited to participate. Whether ‘density’ of content coverage would appear under other conditions is unknown. For the concept of curriculum density to be valuable, other curriculum models and teaching examples would have to be examined.

The two potentially useful explanations for the content density that appears to describe the project units address the factors in the implementation process: the teacher and the curriculum model. Do the River’s Edge unit and the Watershed unit display a
high content density because exemplary teachers implement them? Or, do the units cover a large number of content topics because of the nature of the project-based approach to science teaching? Each explanation has some merit.

Evidence that exemplary teachers construct dense learning experiences is available from a number of research studies comparing more effective from less effective teachers. “Time on task” has been shown to be a useful measure of teacher effectiveness (Capie and Tobin 1981; Tobin, Tippins, and Gallard, 1994), and studies of exemplary teachers highlight their capacity to manage multiple learning tasks in complex environments (Treagust, 1991). A higher number of tasks in a fixed period of time results in a ‘dense’ learning experience for students. Carter and Noble make efficient use of class time as typical of “more effective” teachers, but their efficiency extends beyond completing the “business” aspects of classroom life without encroaching on learning time. Their efficiency extends to the number and depth of content topics they expose their students to during a typical project unit class.

Arguing against the claim that exemplary teachers intentionally create content dense learning experiences is the lack of evidence from the studies of Carter and Noble of any purposeful effort to address multiple content topics. The concept of content density was not specifically probed during interviews because it arose after completing the comparison process. Several times Steve Noble mentioned the constraints of the bell schedule and the overstuffed science curriculum when describing his plans for the project unit, but decisions affected by a concern for density were not explicitly stated. Eric Carter’s block schedule alleviates some of the constraints of short class periods, but the trimester school calendar imposes deadlines for completion that Carter must honor.
Again, Carter never explicitly mentions the "amount" of content he covers so it seems unlikely that he makes a conscious effort to construct a "dense" experience for his students. However, since it is not probed, it is difficult to claim that density isn't a factor in his curricular decisions.

The second likely explanation, that the content density observed in the units implemented by Carter and Noble is an important and useful concept, deals with the nature of project-based curricula. In one description, project-based science is identified by the presence of five distinctive features: "driving questions, investigations, artifacts, collaboration and telecommunication." (Project-Based Science, 1997). Content Standard A in the NSES is titled, "Science as Inquiry." Content Standard A calls for students in grades 9-12 to develop the abilities and understandings of scientific investigation. It is reasonable to assume that a curriculum model that meets the qualifications to be called "project-based science" would necessarily provide opportunities for students to acquire the proficiencies described in NSES Content Standard A.

Other content standards include recommendations for students to acquire competence in the use of technology, in collaborative work, and in an understanding of how society influences the direction of scientific development (NRC, 1996). A project-based approach to science engages students in collaborative group work with local and long-distance colleagues via electronic communication tools. As adapted by Carter and Noble, the project-approach leads easily into conversations about the impact of science on society and the corresponding impact of society on the direction of science. The intrinsic nature of project-based science forces teachers to "cover" a number of content topics within the project context.
The most convincing explanation for the presence of a content-dense experience in the classrooms of Steve Noble and Eric Carter is their choice of a project-based approach to science teaching. Their expertise as exemplary teachers likely contributes to the smooth flow of multiple events during the course of the unit, but the primary element in creating a dense learning environment is the nature of the curriculum model that they select.

**Implications of content density as a product of project-based science curricula**

If project-based science is inherently a content dense experience, then teachers and researchers must address several questions. First, is a content-dense learning environment a desirable goal for science teaching? David Berliner and others have demonstrated that efficient use of class time is a trait that distinguishes more effective from less effective teachers (Berliner, 1980) as measured by student achievement. We need to determine if content density is a concept that parallels the impact of effective time management on student learning. Are students in a project-based science classroom just busier, or is more learning happening due to the density of the curriculum format?

If the density of a particular curriculum model can be shown to exert a positive impact on student learning, then reform advocates and policy makers can promote the project-based approach to science for that advantage. The authors of the National Science Education Standards make it clear that their purpose is not to promote particular curricula, but to specify the proficiencies that students ought to acquire from whichever teaching strategy teachers or districts select (NRC, 1996). Teachers faced with expectations from supervisors to provide a variety of learning experiences for their students may be attracted to curriculum models that promise broad content coverage in a
structure that appeals to student interests and is suited to all ability levels, as many project-based approaches do.

For teacher educators, the concept of density as a characteristic of project-based science might prove useful as a focal point for methods courses. Since methods classes typically face time constraints similar to those in K-12 science classrooms, a curriculum model that is content-dense may offer solutions to perennial problems. Project-based science by definition addresses the key content area of inquiry concepts and skills. If preservice and novice teachers practice implementing a project-based unit, they can gain experience in the management styles that have been shown effective in Berliner's work with expert teachers (Berliner, 1988).

Applications to Current Practice and Recommendations for Future Research

Each of the three conclusions described in this chapter inspires its own set of questions for future research:

1. Teachers' beliefs influence their curricular choices.

   Many researchers have explored aspects of this idea resulting in a significant body of literature that reveals a diversity of approaches and conclusions. One important contribution to the understanding of teachers' roles in the definition of learning experiences would be a collection, summary and review of this line of thought.

   The conclusions asserted from the study of Eric Carter and Steve Noble represents a useful but only partial explanation for the role of teachers' beliefs in their curricular decisions. An interesting follow-up project would explore the influence of teachers' beliefs on curricular choices, and the corresponding influence of the actions on their
beliefs. The interactions of beliefs and actions are more complex than those reflected in the conclusion reached by this study.

Curiosity about the consistency of teachers' beliefs with their intentions and actions raises an interest in pursuing research that examines the work of novice teachers and non-exemplary veteran teachers. Could consistency be a useful tool to guide teacher development? Adaptations of the Instances Interview used for this study, as well as case study methods, could be employed to help teachers to examine their own and others' beliefs. Comparing beliefs with intentions and actions could be a useful tool for reflection and potentially for encouraging change.

Without understanding the origin of teachers' beliefs, many gaps remain in our discussion of ways to classify or modify teachers' existing beliefs. A close collaboration with motivated participants would be needed to pursue a longitudinal examination of the changes in teachers' beliefs as professional experience proceeds. A longitudinal study of teachers undertaking curriculum change or facing reassignment to a new teaching area would provide opportunities to broaden our picture of the role of beliefs in shaping curricular choices.

2. Teaching practices alone do not provide clear evidence of teachers' beliefs.

This conclusion is based on a comparison of the practices of the two participating teachers with the recommended practices of the NSES. The high degree of consistency between both teachers' practices and the NSES Teaching Standards is surprising, particularly since their underlying beliefs are quite different. More research must be done to explain how teachers' beliefs and intentions are translated into curriculum over a larger sample of the teachers' year. Are each teacher's practices consistent with the national
standards in each unit of the year, or are there inconsistencies when teachers cover certain topics or face particular obstacles?

The variations in teachers' practices across several stages of teaching service could be compared to the NSES Teaching Standards to identify characteristics that might be suitable for creating a taxonomy or spectrum of practices. Guiding preservice teachers to identify consistent and inconsistent practices in videotapes of their own work might be a worthwhile task for cooperating teachers and supervisors.

Implicit in the recommendations of the NSES are particular conceptions of teachers' role in the classroom, of student learning, and of the nature of scientific inquiry. A conceptual analysis of the NSES recommendations would make explicit the underlying premises and assumptions on which the document is based. Further examination of the philosophical and political orientation of the NSES would be useful in making judgments about the value of its standards.

To answer questions about the relationship between the Teaching Standards and student understanding of conceptions of science and scientific habits of mind, research into the factors that influence student acquisition of these concepts should continue. Investigators who have explored this topic have discovered its frustrating complexity (Meichtry, 1992, 1993). It is likely to require improvements in methodology to make sense of the factors that are influence the development of complex understanding.

If we accept that practices alone are inadequate windows into curricular intentions, it might be helpful to reorient research interests to the learner. What evidence can be gathered to show whether students who participate in learning experiences presented by teachers who consistently meet the NSES Teaching Standards achieve worthwhile
knowledge goals? Are the expected proficiencies attained? If not, what then can be said about the desirability of the NSES standards?

3. Project-based curricula promote a content-dense learning experience for students.

As mentioned in the earlier discussion, a critical question for further research asks whether a content-dense curriculum is accessible to students. Do students take in the minor as well as the major content goals that are embedded in the project-based science unit? Dissecting the numerous objectives embedded in the project unit and examining student achievement in a variety of settings could help determine whether density ought to be a curriculum ideal.

What other curriculum formats promote a similar content-dense experience for science students? Are there variations that should be recommended to teachers and practiced by preservice students? If the density of a learning event is an appropriate goal for students, promoting the selection of suitable curriculum models should become an important policy initiative.

Summary

In the current reform environment, research on the factors that influence teachers’ selection and implementation of learning experiences for their students can be useful. The descriptions of the efforts of Eric Carter and Steve Noble to create an authentic project-based unit reveals some of the elements that influence the design of their curriculum; namely, teachers’ beliefs about their discipline, the goals of ideal curriculum, and judgments about appropriate and worthwhile student learning. The findings from the case studies of Steve and Eric strengthen and clarify similar research on teachers’
thoughts and actions. The comparison of their classroom events with the Teaching Standards presented in the National Science Education Standards reveals potential confusion if the NSES are used to identify exemplary practitioners. The discovery of the content-density of project-based approaches to science teaching suggests possible supports for less experienced teachers who seek to accomplish all that is required of them within unrelenting time limitations. The findings of this dissertation confirm that teachers' beliefs and intentions are important factors in the design, implementation and evaluation of student learning opportunities.
REFERENCES


Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.


Klein, M. F. Alternative curriculum conceptions and designs. *Theory into Practice* 25(1), 31-35.


Chicago: University of Chicago Press.


Project-Based Science: Real investigation, real science. (7/14/96) [On-line] Available: http://www.umich.edu/~pbsgroup


Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
APPENDIX A:

CONCEPTION OF TEACHING SCIENCE INSTANCES

Part I: 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 they’ll get started calculating the percentages of minimum daily requirement.

2. Paula’s father, Dr. Matthew Connors, volunteered to visit her class during Parent’s 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 Darwin’s 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 mother’s pair of genes along the top of the box, then the father’s 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, we’ve 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 Kev’s 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. Carter’s 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 winter’s 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 Panacek’s schedule.
   “What’s the difference between eukaryotes and prokaryotes? Jason?”
   “That’s close. The prokaryotes don’t have the same organization as eukaryotes. What does that mean, Sarah? What do we mean by ‘organization’?”
   “Ok. If that’s true, that bacteria don’t have nuclei, then how are their functions controlled? I mean, we called the nucleus the ‘control center’. Do bacteria have no ‘control center’?”

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?

Part II: Follow up questions.
The following questions will be the starting point of the interview. Each instance will be presented on a separate card, then the respondent will be asked to answer each question. Additional probes will be inserted as needed to clarify teachers’ use of terminology.

1. In your view, is there science teaching happening here?
2. If you cannot tell, what else would you need to know in order to be able to tell? Please give reasons for your answer.
3. If you answered “yes” or “no,” what tells you that this is the case? Please give reasons for your answer.

Part III: Informal Interview Questions
The set of questions below will be used to probe teachers’ intentions and plans immediately before and after class observations.

Before:
What do you have planned for today?
Are these the same plans as when we talked last time?
What changes have you made? Why?
How do you anticipate the changes you’ve made will influence what students learn from the lesson?

After:
Did the lesson go as planned?
Why or why not?
What do you think students got out of today’s class?
Does that concept fit into your long term goals for the unit/ semester/ year? Explain.
CORRELATION BETWEEN RESEARCH QUESTIONS AND ANALYSIS CATEGORIES

The chart below indicates which aspects of teacher’s conceptions of their role is intended to be elicited by each instance from the CTS Interview Protocol. The categories are defined in detail here:

1. Teacher understanding of the nature of science (AAAS, 1989)
   - Methods of science: What are teachers’ beliefs about systematic approach to inquiry, computation and manipulation skills, communication skills,
   - Values of science: How do teachers speak about openness, skepticism, and curiosity as central values of science?
   - Content of science: What do teachers include in their description of the content of science? Do they consider facts and theories as well as organizing themes and historical perspective in their meaning?

2. Teacher perceptions of the goals of the designed curriculum:
   - Methods: What manipulative, inquiry, and communication skills are intended to be learned?
   - Values: What values are encouraged?
   - Content: What facts, theories and ideas compose student outcome expectations

3. Teachers beliefs about appropriate and worthwhile science learning for students
   - Methods of science: what inquiry processes are developmentally suitable? What level of manipulation skills, accuracy, communication skills are reasonable for my students?
   - Values of science: Can students take a skeptical view of science? To what extent should curiosity direct learning? What practical limits must be placed on student inquiry?
   - Content of science: What concepts, themes and ideas are accessible for students? What external standards or expectations for student achievement must be met?
12/05/96: Student presentations of Symbiosis project
12/06/96: No class meeting; students at Senior Project advisory meetings
01/06/97: Introduce Winter Adaptations unit, hand out checklists, articles
01/07/97: Discuss article 1
01/09/97: Field work -- walk to site with groups; students identify signs and evidence of activity
01/10/97: Research on resident and migrant species
01/13/97: Research continues
01/14/97: Inside or outside research
01/16/97: (Icy rain) Students given the option to do indoor work or go outside. Several groups and teacher go outside.
01/17/97: Snow, delayed opening, changed plans
01/20/97: Student teacher solo week; EC away
01/21/97: Student teacher solo week; EC away
01/23/97: Student teacher solo week; EC away
01/24/97: Student teacher solo week; EC away
01/27/97: Reading discussion
01/28/97: Reading discussion
01/30/97: In-class work day; some students completing required field work, majority inside work
01/31/97: Field manual work
02/03/97: Dissected owl pellet
02/04/97: Making inferences from observations and graphs
02/06/97: Lab practical, test
02/07/97: Make-up test; enter data on habitat data bank
02/10/97: EC away: Sub plans, Kingsolver article “Seeds”
02/11/97: EC away: Sub plans: NPR and other radio clips on biodiversity issues
02/13/97: Small class, schedule conflicts disrupt plans for discussion class
02/14/97: Begin entering data on computer data base with few students expected to attend due to additional activity conflicts
02/17/97: Article discussion
02/18/97: Brainstorm Biodiversity symposium
02/20/97: Symposium preparation
02/21/97: Symposium preparation