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A SUBSTANTIVE-LEVEL THEORY OF HIGHLY-REGARDED SECONDARY BIOLOGY TEACHERS' SCIENCE TEACHING ORIENTATIONS

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ABSTRACT

Pedagogical content knowledge (PCK) has been used as a heuristic for examining a specialized knowledge base for teaching. One proposed overarching component within the PCK model for science teaching is teaching orientations, defined as teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level. Nine different orientations to teaching science have been identified in the science education literature, yet there are few empirical studies specifically examining science teachers' orientations. This qualitative case study re-examines science teaching orientations using grounded theory methods. The study focused on the nature and sources of the science teaching orientations held by four highly-regarded secondary biology teachers. Data collection consisted of a card-sorting task, semi-structured interviews, and classroom observations. Inductive data analysis led to the construction of a substantive-level theory of science teaching orientations.

In regard to the nature of science teaching orientations, the use of central and peripheral goals, as well as the means of achieving these goals, better represents the complex nature of science teaching orientations. Although the participants were secondary biology teachers, they held more general teaching orientations than science-specific orientations. The participants held goals in the affective domain, e.g., the development of positive attitudes toward biology, as well as general schooling goals, including preparing students for college and the development of life skills. Although each participant held science content goals, these goals were not always a central component of their teaching orientation. In addition, goals and purposes shape the means that a teacher chooses, but a limited repertoire of means can also restrict the teacher's purposes and goals.

In regard to the sources of teaching orientations, participants were influenced by a multitude of factors, including prior work experiences and professional development. Professional development served as a feedback loop, as participants selected professional development that re-enforced their teaching orientation. The school context, with its perceived time constraints, was another contributing factor. The participants' teaching orientations were strongly influenced by their daily interactions with students. The teachers' beliefs about learners and learning were major sources of their teaching orientations. Implications are given for practice, research and policy.

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ACKNOWLEDGEMENTS

I dedicate this dissertation to my husband, Jed, and to our daughter, Claire. Throughout our relationship, Jed has been my greatest supporter. Twice, he has quit his job and packed the moving van for me to continue my education. Jed has graciously offered one more re-start on his career, as I search for an academic position. As a small second grader, Claire offered her support by courageously stating, “Mother, if you want to go to school, then I’m willing to move.” My hope is that I will be able to support her continued education in the same spirit she has shown me. In return for riding the school bus while I collected dissertation data, Claire negotiated that Almonzo be included in the acknowledgements. Almonzo waited faithfully by the door to enthusiastically greet each family member as we returned home at the end of the day.

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Chapter 1

SETTING THE STAGE

1.1 Introduction

Imagine walking down the hallway of the science wing in a high school. What would you see teachers and students doing as you peered into each classroom? Even when comparing classrooms across the same subject, for example, biology, you would likely see teachers using different instructional approaches. You might see a classroom where students are copying vocabulary terms from the overhead screen, looking up definitions in textbooks that are open on their desks. In the next classroom, you might see small groups of students engaged in lively discussions as they try to analyze and interpret data collected during a long-term investigation. Why do biology teachers, given the same state academic standards and district curricula, school setting, and student population, choose different approaches to teach their subject matter? To better understand the instructional choices observed in each classroom, it can be useful to understand each teacher's purposes and goals for science teaching. This dissertation tackles the issue of teachers' purposes and goals for teaching biology.

The teacher in the second classroom described above gives us a glimpse of reform-based science teaching and learning (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996; National Association of Biology Teachers [NABT], 1990). This chapter begins with an overview of reform-based science teaching as described in the National Science Education Standards (NRC, 1996) and then compares the vision of current reform to many current secondary science classrooms. To better understand teachers' thinking in regard to their changing roles, the construct of pedagogical content knowledge (PCK) will be used as a heuristic. Pedagogical content knowledge The PCK literature will be reviewed including a discussion of issues related to the assessment of teachers' PCK. To narrow the study, one theoretically overarching component within the PCK model, orientations to teaching science, is the focus. An orientation to teaching science is defined as "a teacher's knowledge and beliefs about the purposes and goals for teaching science at a particular grade level" (Magnusson, Krajcik and Borko, 1999, p. 97). A review of the literature on teaching orientations will follow, with an emphasis on science teaching orientations. Based on the lack of empirical studies on science teaching orientations in the extant literature, this study examines the construct of science teaching orientations as held by a set of exemplary, biology teachers. As the purpose of this study is to gain new insights in an area ill-defined and well-studied, this study can be considered a bounded case of science teaching orientations using a grounded theory approach -- an approach in which theory is derived inductively from data (Strauss and Corbin, 1998).

1.2 The Problem: Visions of Reform vs. Today’s Teaching Practices

"Contemporary goals of science education require not only that students learn the products of science (facts, laws, principles) but that they understand science as a principled process of inquiry," state Magnusson and Palincsar (1995, p. 43). In providing guidelines for achieving this goal, the National Science Education Standards (NSES) call for teachers to place more emphasis on "understanding scientific concepts and developing abilities of inquiry" (NRC, 1996, p. 113). Rather than having students memorize scientific terminology and isolated facts, NSES call for students to develop conceptual understanding across eight content standards: "Unifying concepts and processes in science, science as inquiry, physical science, life science, earth and space science, science and technology, science in personal and social perspectives, and history and nature of science" (NRC, 1996, p. 104). Within the Science as Inquiry Standard, students need to acquire the "abilities necessary to do inquiry as well as understandings about inquiry" (NRC, 1996, p. 105). When students are engaged in inquiry, they "mesh these processes [science process skills] with scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science" (NRC, 1996, p. 18). To meet the "abilities necessary to do scientific inquiry" component of the Science as Inquiry Standards, students need opportunities to generate testable questions, design and conduct experiments over extended periods of time, collect and manipulate data, and build evidence-based explanations. Student collaboration and public communication of ideas are emphasized. In having students use data to create models and build explanations, science is portrayed as a process of knowledge generation based on data-driven arguments and explanations (NRC, 1996; NRC, 2000). As part of the Science as Inquiry Standard, students also need to develop understandings about scientific inquiry. The NSES state, "Understandings of scientific inquiry represent how and why scientific knowledge changes in response to new evidence, logical analysis, and modified explanations debated within a community of scientists" (NRC, 2000, p.21).

In order to meet the vision of the reforms described in the National Science Education Standards, practicing teachers will need to change the ways in which they have traditionally taught science**.** Weis (1994) states, "While use of hands-on activities has increased since the mid-1980s, lecture/textbook methodologies continue to dominate science and mathematics education" (p. 15). The 1993 National Survey of Science and Mathematics Education reports that 60% of high school science students listen to lectures and take notes on a daily basis, while 43% of high school students never engage in a science project that is beyond a few days' duration (Weiss, 1994). If science teachers are to meet the goals outlined by reform documents, teachers will need to alter their current roles as information transmitters (Zucker, 1997).

A complication for the vast majority of current teachers is that they have not experienced science teaching or learning as it is described in the Standards. To help practicing teachers consider new teaching roles, as demanded by current reform documents, it could be fruitful to examine teachers' knowledge and beliefs about teaching science. Knowledge and beliefs about teaching influence teaching practice. Borko and Putnam (1996) state, "To be successful, efforts to support teachers' learning must recognize that teachers' knowledge and beliefs about teaching, learning, learners, and subject matter will play a critical role in determining whether and how they implement new instructional ideas" (p. 702). Teaching orientations have been proposed as an overarching component with the PCK model (Grossman, 1990). Carefully executed research is needed to better understand teachers' goals and purposes for teaching subject matter.

1.3 A Specialized Knowledge Base for Teaching: PCK

What teachers know and can do makes a critical difference in what students learn (National Commission on Teaching and America's Future, 1996, p. 5). To support teachers in developing standards-based teaching practices, teacher educators and researchers need to better understand teacher thinking. Borko and Putnam (1996) state, "The knowledge and beliefs that prospective and experienced teachers hold serve as filters through which their learning takes place. It is through these existing conceptions that teachers come to understand recommended new practices" (p. 675). Based on work with beginning teachers in the Knowledge Growth in Teaching Project, Shulman (1986) proposed a specialized knowledge base for teaching, with content knowledge as one of the domains. Within this domain, Shulman introduced the subcategory of pedagogical content knowledge (PCK), defined as "subject matter knowledge for teaching" and “the ways of representing and formulating a subject that make it comprehensible to others" (p. 9). Shulman offered the following elaborated definition of PCK:

> Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. If those preconceptions are misconceptions, which they so often are, teachers need knowledge of the strategies most likely to be fruitful in reorganizing the understanding of learners, because those learners are unlikely to appear before them as blank slates. (pp. 9-10)

Shulman and his colleagues outlined a theoretical framework for examining a knowledge base for teaching (Shulman, 1986, 1987; Wilson, Shulman, and Richert, 1987). They proposed seven categories within a professional knowledge base for teaching: content knowledge, general pedagogical knowledge; pedagogical content knowledge; curricular knowledge; knowledge of learners and their characteristics; knowledge of educational contexts; and knowledge of educational philosophies, goals and objectives. This theoretical framework was based on research with beginning secondary teachers in the areas of English, mathematics, social studies and biology.

Grossman, as a researcher in the Knowledge Growth in Teaching Project, examined the beliefs and practices of beginning secondary English teachers. In The Making of a Teacher, Grossman (1990) offers a well-articulated model of a professional knowledge base for English teachers. Grossman merges and rearranges the original categories listed above and provides a model with four general cornerstones of professional knowledge for teaching: subject matter knowledge, general pedagogical knowledge, knowledge of context and pedagogical content knowledge. PCK, as a construct itself, becomes better articulated (see Figure 1.1). Grossman identifies four major components of PCK: “1) knowledge and beliefs about the purposes of teaching a subject at different grade levels. . . 2) knowledge of students’ understanding, conceptions and misconceptions of particular topics in a subject matter. . . 3) knowledge of curriculum materials available for teaching particular subject matter, as well as knowledge about both the horizontal and vertical curricula for a subject. . . and 4) knowledge of instructional strategies and representations for teaching particular topics" (pp. 8-9). In Grossman's model, the first component of "knowledge and beliefs about the purposes for teaching subject matter" is placed as an overarching conception within the PCK domain (p. 12). Grossman (1990) identifies this overarching component as a “form of conceptual map for instructional decision-making, serving as a basis for judgments about textbooks, classroom objectives, assignments, and evaluation of students" (p. 86).

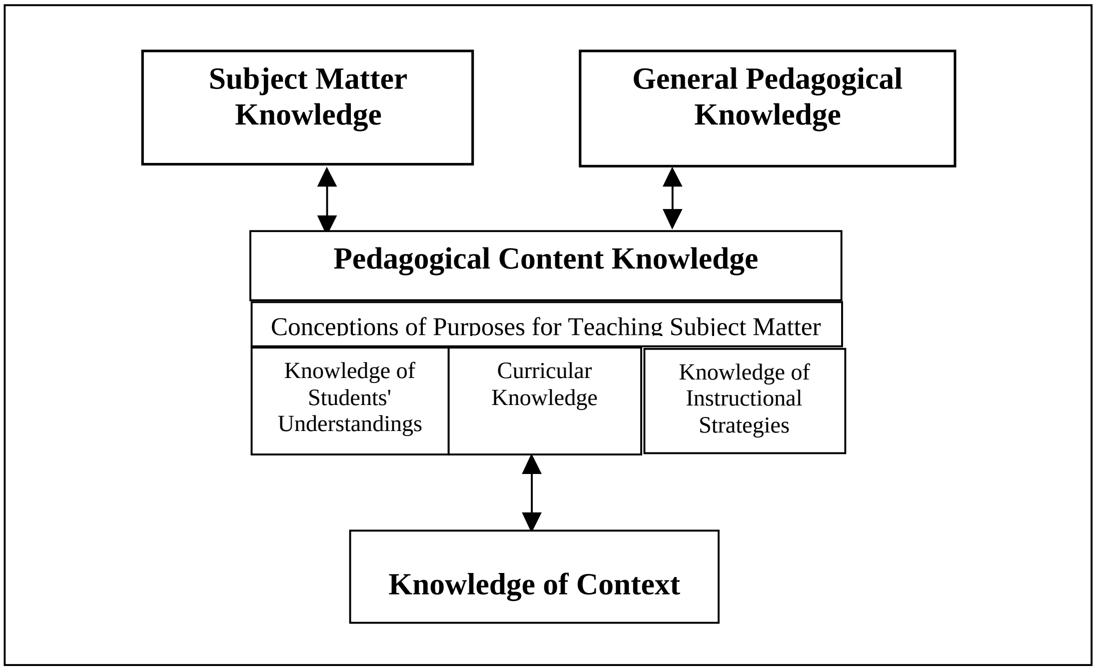

Figure 1.1. Model of teacher knowledge (simplified version) Source: The making of a teacher: teacher knowledge & teacher education. (p. 5), by Grossman, P., 1990. New York: Teachers College Press.

Pedagogical content knowledge, as a construct of teacher knowledge, has been a visible line of research in science education, both in studies of practicing teachers (Hashweh, 1987; Veal, 1997, Smith and Neale, 1989; Smith, 1999, Lederman and Gess-Newsome, 1999, Tobin and McRobbie, 1999) and prospective science teachers in teacher education programs (Zembal-Saul, Starr and Krajcik, 1999; Niess and Scholz, 1999; Mason, 1999). Science education researchers have added components to early models of PCK, originating from the work of Shulman, Grossman and colleagues. Tamir (1988) proposed the knowledge and skills of assessment as another dimension of PCK. Carlsen

(1999) reiterates the importance of the inclusion of "understandings of students misconceptions" as a component of a model of PCK for science teaching (p. 141). Within topic-specific instructional strategies, Carlsen includes "knowledge that science teachers draw upon in choosing and using models, orchestrating substantive classroom discourse, and managing laboratory activities" (p. 141). Magnusson et al. (1999) propose a refined model of PCK for science teaching with the following five components: "(a) orientations toward science teaching, (b) knowledge and beliefs about science curriculum, (c) knowledge and beliefs about student understanding of specific science topics, (d) knowledge and beliefs about assessment in science, and (e) knowledge and beliefs about instructional strategies for teaching science" (p. 97). Refer to Figure 1.2.

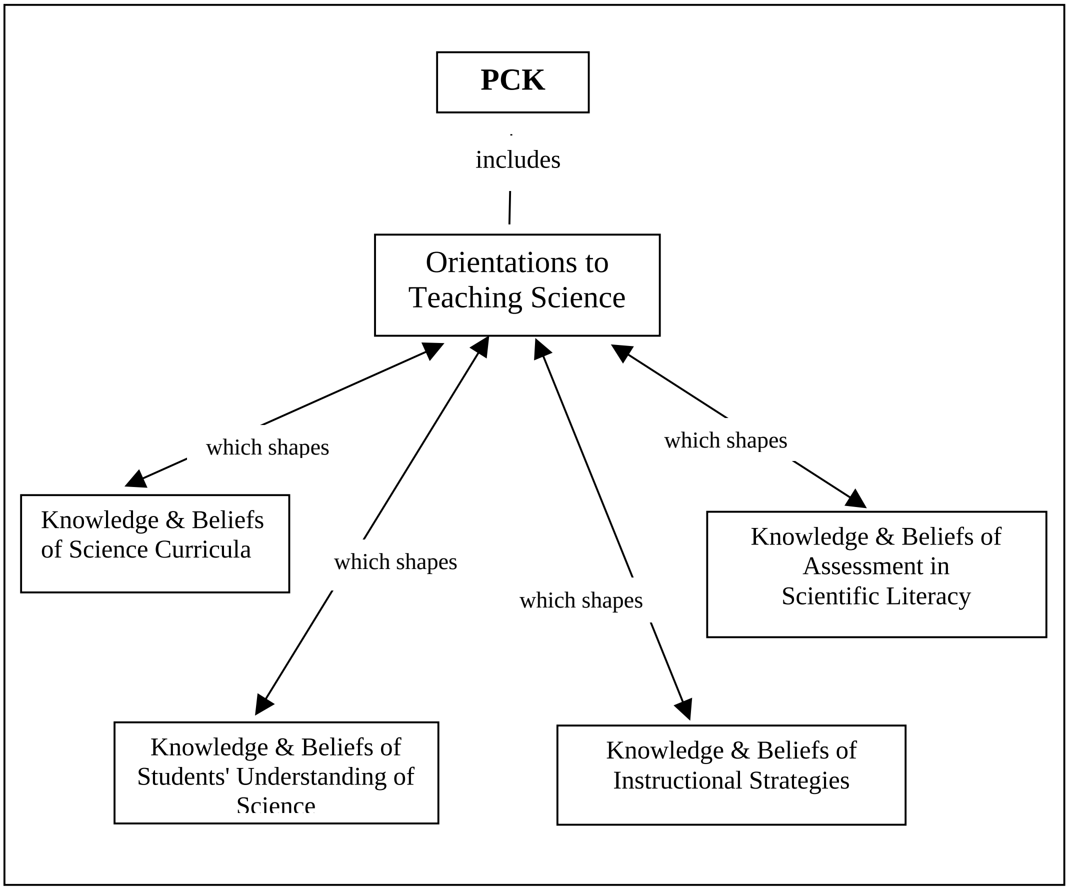

Figure 1.2. PCK model for science teaching (simplified version). Source: Examining pedagogical content knowledge. (p. 99) by Magnusson, S., Krajcik, J., and Borko, H., 1999. In J. Gess-Newsome & N.G. Lederman (Eds.), Examining pedagogical content knowledge: the construct and its implications for science education. Kluwer: Dordrecht.

1.3.1 PCK: Too Big of an Idea?

Although PCK as a construct has been a visible line of research in science education, at the same time, problematic issues remain. Kagan (1990) reviewed the literature on teacher cognition, defined as "pre- or in-service teachers' self-reflections; beliefs and knowledge about teaching, students, and content; and awareness of problem-solving strategies endemic to classroom teaching" (p. 421). Kagan discusses the literature in terms of Katz and Rath's (1985) Goldilocks Principle that some ideas in education are too small and some are too large to be of use. Kagan postulates that teacher cognition may be too large of an idea to be of utility for several reasons. First, Kagan finds the notion of teacher cognition to be ambiguous in the literature. She also found that teacher cognition generally cannot be assessed directly, and the methods used to elicit teacher thoughts are time-consuming. Consequently, most studies lack any generalizability.

Baxter and Lederman (1999) applied many of Kagan's findings in their review of science education literature on assessing and measuring PCK. In reviewing convergent methods of assessing PCK, Baxter and Lederman question if multiple choice test items can capture the context upon which teachers will react. Concept mapping, card sort tasks, and pictorial representations have been used to assess PCK, but the question remains if these methods can be established as literal representations of how knowledge is stored and integrated in teachers' memory. In their review of multi-method evaluation of PCK, Baxter and Lederman discuss the practicality of these studies. Transcribed interviews are labor and time-intensive, and difficult decisions need to be made as to which data sources will yield the most useful information. Baxter and Lederman conclude in their review, "PCK is a highly complex construct that is not easily assessed" (p. 158). Nonetheless, the unique knowledge and beliefs of science teaching captured by PCK makes the construct of vital interest to researchers working to understand how and why teachers implement reform-oriented practices.

1.3.2 A Component of PCK: Orientations

Based on Baxter and Lederman's review, the Goldilocks Principle may apply to the construct of PCK as well, in that it may be too big of an idea to be useful to teacher education researchers. Initially it may be more useful to closely examine one overarching component within the PCK model, that of teaching orientations. Grossman (1990) defines orientations as the "knowledge and beliefs about the purposes for teaching a subject at different grade levels" (p. 8). She describes the central role of orientations in the following way:

> Although beginning teachers may lack the managerial skills necessary to implement their plans successfully, their beliefs about the goals for teaching their subjects become a form of conceptual map for instructional decision making, serving as the basis for judgments about textbooks, classroom objectives, assignments, and evaluation of students (p. 86).

Magnusson et al. (1999) retain this central component in their PCK model for science teaching, applying the term "orientations to teaching science" (p. 99). Magnusson et al. (1999) define orientations as "teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level" (p. 97).In this proposed PCK model, orientations toward teaching science shapes and is shaped by the other four components of their model. In the science education literature, Anderson and Smith (1985) describe teachers' orientations toward science teaching and learning as "general patterns of thought and behavior relating to science teaching and learning" (p. 99).

1.3.3 A Messy Construct: Teaching Orientations

Teaching orientations, as a unique construct, has a limited literature base and may be described as a messy construct. Pajares (1992) uses the term "messy construct" to describe educational research on teachers' beliefs and knowledge. Pajares describes a messy construct as one that lacks clear definitions and common usage of terms among researchers. Scardamalia and Bereiter (1989) use the term "conceptions of teaching" rather than "teaching orientations." No clear definition is given for a "conception of teaching," except as "a view of teaching" (p. 37). Scardamalia and Bereiter state, "No generally agreed classification of views of teaching exists" (p. 37). Based upon a review of the literature, Scardamalia and Bereiter do propose four generalized views of teaching: (a) teaching as cultural transmission; (b) teaching as the training of skills; (c) teaching as the fostering of natural development; and (d) teaching as producing conceptual change.

Within sociology, Enseki and Hancock (1979) discuss the unsystematic use of such terms as "style," "orientation," and "technique." They propose a different categorization system for teaching orientations. They hypothesize a spectrum of teaching orientations - with a “classical orientation” at one extreme and a “modern orientation” at the other (pp. 48-49). In a classical orientation, the faculty act as content experts while in the modern orientation, the teaching role is that of facilitator. Across this spectrum, Enseki and Hancock propose three dimensions to the teaching process: (a) direction refers to the degree that information is organized, (b) control refers to degree of status differentials maintained in the classroom, and (c) participation refers to the degree of desired classroom interaction (p. 47). To illustrate, an individual with a classical orientation would desire low levels of student participation but maintain high levels of direction and control. The Enseki and Hancock study introduces a new classification system for teaching orientations, but lacks empirical evidence to support the proposed model.

In fact, most reports even remotely related to “orientations” lack an empirical basis. For example, Richards, Gipe and Duggy (1992) used student-generated metaphors to examine the teaching orientations held by a group of 23 prospective elementary teachers. The orientations of authoritarian/technocratic and progressive/student-centered were derived from the literature and used to classify the students' metaphors, rather than allowing categories of orientations to emerge from the data. Similarly, in physical education, Curtner-Smith (1997) examined the effects of a teacher education program on pre-service teachers holding either a coaching or a teaching orientation. Again, these orientations are theoretically derived from the physical education literature. Also, it is difficult to generalize from this study due to the small sample size, one individual with a coaching orientation and one individual with a teaching orientation.

Several studies did explicitly compare the teaching orientations held by individuals to the theoretical derived teaching orientations described in that particular field. White (1982) tested the reliability, content validity and construct validity of the Barth-Shermis Social Studies Preference Scale, which identifies three separate theoretical orientations to teaching social studies: (a) social studies taught as citizenship transmission (CT); (b) social studies taught as social science (SS); and (c) social studies taught as reflective inquiry (RI). In a study of 190 secondary-school social studies teachers, White found that 81% of the respondents held aspects of all three orientations and did not distinguish between the theoretical orientations: "Social studies teachers showed themselves to be a most eclectic group of educators, choosing liberally from each tradition to achieve their instructional goals" (p. 18).

In the area of mathematics teaching, Sosniak, Ethington and Varelas (1994) describe similar findings to those described above. Sosniak et al. examined eighth grade teachers' data from the Second International Mathematics Study (SIMS). The original intent of the study was to compare student outcomes between two groups of teachers, those who held “progressive” orientations and those who held “traditional” orientations. A progressive orientation was defined as being “primarily concerned with the transmission of factual and procedural information, while a traditional orientation emphasized “qualitative transformations in the character and outlook of the learner (p. 98). Sosniak et al. were unable to complete the study. Using the SIMS data, they were unable to categorize the teachers into these two theoretically derived orientations. Using the results from the SIMS instruments, they concluded that the teachers participating in the SIMS study held no coherent orientation to mathematics teaching.

1.3.4 Orientations in the Science Education Literature

In reviewing the science education literature for the PCK construct, Magnusson et al. (1999) identify the following nine orientations to science teaching: process, academic rigor, didactic, conceptual change, activity-driven, discovery, project-based science, inquiry and guided inquiry (see Table 1.1.) The table includes each orientation's primary goal for teaching science and gives characteristics of instruction associated with each goal. One key concept to remember is that it is not a particular activity that a teacher utilizes which indicates their orientation to teaching science, but it is how an activity meets a teacher's goals and purposes for teaching science. Magnusson et al. hypothesize the central role that orientations play in decision making related to planning, teaching, and reflecting. However, they offer the following caveat, "Few studies have been conducted . . . that directly assess teachers' orientations to teaching science in order to put that claim to an empirical test" (p. 102). This issue will be explored in more detail in this section.

Table 1.1

The Goals of Different Orientations to Teaching Science

Orientation	**Goal of Teaching Science**	**Characteristic of Instruction**
Process	Help students develop the "science process skills." (e.g., SAPA)	Teacher introduces students to the thinking processes employed by scientists to acquire new knowledge. Students engage in activities to develop thinking process and integrated thinking skills.
Academic Rigor (Lantz and Kass, 1987)	Represent a particular body of knowledge (e.g., chemistry)	Students are challenged with difficult problems and activities. Laboratory work and demonstrations are used to verify science concepts by demonstrating the relationship between particular concepts and phenomena.
Didactic	Transmit the facts of science	The teacher presents information, generally through lecture or discussion, and questions directed to students are to hold them accountable for knowing the facts produced by science.
Conceptual Change (Roth, Anderson and Smith, 1987)	Facilitate the development of scientific knowledge by confronting students with contexts to explain that challenge their naïve conceptions.	Students are pressed for their views about the world and consider the adequacy of alternative explanations. The teacher facilitates discussion and debate necessary to establish valid knowledge claims
Activity-driven (Anderson and Smith, 1987)	Have students be active with materials; "hands-on" experiences.	Students participate in "hands-on" activities used for verification or discovery. The chosen activities may not be conceptually coherent if teachers do not understand the purpose of particular activities and as a consequence omit or inappropriately modify critical aspects of them.
Discovery (Karplus, 1963)	Provide opportunities for students on their own to discover targeted science concepts.	Student-centered. Students explore the natural world following their own interests and discover patterns of how the world works during their explorations.
Project-based Science (Ruopp et al., 1993; Marx et al., 1994)	Involve students in investigating solutions to authentic problems.	Project-based. Teacher and student activity centers around a "driving" question that organizes concepts and principles and drives activities within a topic of study. Through investigation, students develop a series of artifacts (products) that reflect their emerging understandings.
Inquiry (Tamir)	Represent science as inquiry	Investigation-centered. The teacher supports students in defining and investigating problems, drawing conclusions, and assessing the validity of knowledge from their conclusions.
Guided Inquiry (Magnusson and Palinscar, 1995)	Constitute a community of learners whose members share responsibility for understanding the physical world, particularly with respect to using the tools of science.	Learning community-centered. The teacher and students participate in defining and investigating problems, determining patterns, inventing and testing explanations, and evaluating the utility and validity of their data and the adequacy of their conclusions. The teacher scaffolds students' efforts to use the material and intellectual tools of science, toward their independent use of them.

Source: Examining pedagogical content knowledge. (pp. 100-101) by Magnusson, S., Krajcik, J., and Borko, H., 1999. In J. Gess-Newsome & N.G. Lederman (Eds.), Examining pedagogical content knowledge: the construct and its implications for science education. Kluwer: Dordrecht.

In reviewing the literature cited for the nine orientations shown in Table 1.1, I have grouped the orientations into the following general categories: (a) teacher-centered orientations (didactic and academic rigor), and (b) orientations based on reform efforts and associated curriculum projects. The latter category is subdivided into orientations based on the reform efforts of the 1960s (process, activity-driven, and discovery) and orientations based on contemporary reform efforts and curriculum projects (conceptual change, project-based science, inquiry, and guided inquiry).

A didactic orientation is placed within the first category of teacher-centered orientations. Anderson and Smith (1985) state, "We have encountered this [didactic] orientation toward teaching far more often than any other among teachers at all levels" (p. 100). Eaton, Anderson and Smith (1984) observed elementary teachers using a popular elementary science textbook to teach units on light and photosynthesis. Elementary students' pretest and posttest scores were compared and they found that students' misconceptions persisted after didactic instruction. Conclusions were drawn, apparently, from student achievement when a popular science text was used for instruction, and did not explore the teachers' thinking in regard to their purposes and goals for teaching science. Consequently, readers are left unable to deduce whether the teachers actually held a single didactic orientation to teaching science.

An orientation toward academic rigor is also placed within the first category of teacher-centered science teaching orientations. Lantz and Kass (1987) describe this orientation in a study of chemistry teachers' implementation and translation of a new curriculum. Three high school chemistry teachers were interviewed five times over a period of four months. A questionnaire was also used to collect data from 69 high school chemistry teachers. To interpret their findings, Lantz and Kass use the concept of a "functional paradigm" with the following four categories: perceptions of high school chemistry, teaching, students, and school setting. These categories are based on Schwab's four commonplaces of schooling: (a) the subject matter, (b) learners and learning, (c) teachers and the teaching, and (d) the milieu in which education take place (Schwab, 1969). Lantz and Kass define "perception of teaching" as the teacher's view of requirements for effective teaching, as well as the overall aims of teaching. Among the teacher participants, three primary perceptions of teaching emerge. One perception places a high value on pedagogical efficiency, another view emphasized academic rigor, while a third perception emphasizes student motivation. In the science education literature reviewed, Lantz and Kass's study is one of the few that uses teacher interviews to generate categories of orientations held by science teachers. However, their findings suggest that the chemistry teachers in the study held multiple orientations, valuing both academic rigor and pedagogical efficiency.

Process, activity-driven, and discovery orientations are student-centered orientations placed in the subcategory of reform efforts of the 1960s. Within the science education literature on orientations, no empirical studies were found that indicate that science teachers' hold a process orientation. However, Science - A Process Approach (SAPA) was one of three NSF sponsored elementary science programs developed in the 1960s. "The course [SAPA] utilized a highly structured approach to teaching specific processes of science, such as observing, classifying, measuring, and predicting, while it de-emphasized the mastery of specific science facts" (DeBoer, 1991, p. 158).

Magnusson et al. cite Anderson and Smith (1985) as a reference for an activity-driven orientation. In describing this orientation, Anderson and Smith state, "We have observed this orientation primarily among elementary school teachers who are uncomfortable teaching science. These teachers focus primarily on the activities to be carried out in the classroom: textbook reading, demonstrations, experiments, answering questions, and the like" (pp. 99-100). Anderson and Smith cite Smith and Sendelbach (1982) as a reference for an activity-driven orientation. The Smith and Sendelbach study described the practice of one elementary teacher using a single unit in the Science Curriculum Improvement Study (SCIS), and examined the differences between the teacher's intentions and the actual instruction using the SCIS material. DeBoer (1991) describes the activity-oriented SCIS curriculum: "The course focused on both the processes and products of science and made extensive use of the laboratory" (p. 158). Smith and Sendelbach's (1982) study may better be described as a study examining one teacher's use of SCIS, rather than a study exploring a teacher's goals and purposes for teaching science. Other science curriculum projects of the 1960s were structured around the extensive use of student activities, including Time, Space, and Matter, and the Earth Science Curriculum Project (DeBoer, 1991).

Magnusson et al. cite Karplus (1967) as a reference for a discovery orientation. Interestingly, upon closer examination, Karplus (1963) offers a description of the overall design of the SCIS program with advice for implementation. This study is not a description of a discovery orientation held by teachers, but a description of the "orientation" or overview of SCIS curriculum. The Elementary Science Study (ESS) was another curriculum project of the 1960s that used a discovery approach (DeBoer, 1991, p. 158). Teaching science as a set of process skills, hands-on science, and the move from a textbook centered curriculum to a materials-based curriculum were outcomes of the National Science Foundation sponsored curriculum projects in the 1960s (Victor and Kellough, 1997, pp. 7-8). In the absence of empirical studies focusing on teachers' orientations, it is difficult to ascertain whether teachers actually hold these orientations--process, activity-driven, or discovery, or whether these orientations exist in the literature as a result of the descriptions, and evaluation studies of the NSF-sponsored curriculum projects of the 1960s.

Conceptual change, project-based science, inquiry and guided inquiry are student-centered orientations grouped in the subcategory of orientations based on contemporary reform efforts and curriculum projects. Magnusson et al. cite Roth, Anderson and Smith (1987) as a reference for a conceptual change orientation. Roth et al. observed fifth grade teachers teaching lessons on light and photosynthesis over a period of three years. They describe cases in which teachers use different approaches, one group of teachers relied solely on the textbook, one teacher relied solely on activities and used a discovery approach, while a third group of teachers used researcher-designed conceptual change instructional materials. Student achievement was highest in classrooms where the teachers used the conceptual change materials provided by the researchers. Roth et al.'s empirical study describes teaching approaches and their link to student achievement, but the teachers' thinking is not probed to examine their underlying beliefs and purposes for using a particular teaching approach. Again, the orientation of the intervention, conceptual change-based instruction, was the focus of the study.

Project-based science is placed within the third category of orientations. Marx, Blumenfeld, Krajcik, Blunk, Crawford, Kelly and Meyer (1994) describe four middle school teachers as they attempted to enact project-based science. The study describes the teacher's background, their school setting, as well as the teachers' barriers and challenges in enacting project-based science. The four teachers faced some common problems--time constraints, pressures to cover the district's curriculum, and the need to control and maintain order in the classroom. Marx et al. do not use orientations as a theoretical framework and therefore do not examine the teachers' beliefs about the purposes and goals for teaching science, although these beliefs may be inferred from the teachers' perceptions of barriers and challenges.

Tamir (1983) is cited as a reference for an inquiry orientation to teaching science. Tamir compared pre-service and practicing biology teachers' conceptions of inquiry. Data collection consisted of asking participants to write down three associations that came to mind about the concept inquiry, and to write a definition of inquiry. Tamir found that "experienced teachers are more inclined to associate inquiry with scientific research, while the student teachers associate inquiry more with learning and teaching" (p. 661). Tamir discusses the desirability of representing science as inquiry and offers suggestions for helping pre-service teachers acquire the view of science as inquiry. Tamir’s study examines pre-service and practicing teachers conceptions of inquiry, but does not support the idea that teachers do or do not hold inquiry as an orientation to teaching science.

Guided inquiry, as an orientation, may best exemplify the subcategory of orientations associated with contemporary reform and curricula projects. Magnusson and Palinscar (1995) describe guided inquiry in the following way:

> Guided inquiry attempts to blend the emphases of several science education reform efforts of the past. First, it assumes an inquiry-based approach similar to curricula developed in the 1960s, which were focused on discovery learning. . . . Second, guided inquiry emphasizes the development of conceptual understandings of science, an essential feature of the conceptual change approaches first developed in the 1980s and still in development today (p. 44).

Magnusson and Palinscar (1995) do not identify guided inquiry as an orientation held by practicing teachers, rather they describe the use of a guided inquiry heuristic with elementary teachers attempting to implement guided inquiry for the first time. This descriptive implementation report supports the assertion in this dissertation that student-centered orientations reported in the literature are desired orientations to science teaching based on reform efforts, not orientations held by prospective and practicing science teachers.

1.3.5 Gaps in the Literature

In reviewing the science education literature on orientations, several issues emerge. First, the majority of the studies cited as references for specific orientations focus on describing the teacher's practice without exploring teacher thinking, specifically the teacher's purposes and goals for teaching science. Only one of the cited references, Lantz and Kass (1987) uses an inductive approach to generate categories of "perceptions of teaching." In a study with pre-service teachers, Hewson and Hewson (1989) used a card-sorting task to elicit participants' "conceptions of teaching science"(p. 141). While the study was inductive in nature, the researchers chose not to label or categorize the orientations of the teachers' participating in the study. In the majority of the studies reviewed, however, the orientation was theoretically based on desired teaching approaches of past curriculum projects of the 1960s or contemporary reform-based projects.

Second, the orientations defined in the literature may not accurately describe the orientations held by prospective and practicing teachers. Two studies conducted in the spring of 2000 revealed a mismatch between the categories in the literature and the teaching orientations of prospective teachers. Friedrichsen and Dana (2000), in a study of prospective and practicing elementary teachers, asserted that participants did not hold specific orientations to teaching science. The participants held a more generalized orientation to teaching that guided their instructional decision-making process for teaching elementary science. The participants' decision-making was not based on their knowledge and beliefs about the purposes and goals for teaching science to elementary students, but rather on a non-specific, generalized theory of how students learn. Tsur (2000) examined the reflective journals and lesson plans of prospective secondary science teachers enrolled in a science methods course and concurrent practicum. Using the nine categories of science teaching orientations in the literature, individual participants were identified as having between two to five different orientations with one or two major orientations. Tsur (personal communication, June 2000) confirmed a mismatch between the categories in the literature and the orientations held by participants in the study. A similar finding emerged from an earlier study surveying the orientations held by social studies teachers. A majority of the teachers did not hold a single orientation, but held aspects of two or three of the orientations described in the literature (White, 1982). These studies provide evidence that the theoretical categories of orientations toward science teaching may not match those of prospective and practicing teachers.

The PCK model as a construct of teacher knowledge has been useful in science education research. Within this PCK model, orientations have been proposed as an overarching conception that shapes and is shaped by other components of the model. However, in recent years, the number of student-centered categories of science teaching orientations has grown in the absence of empirical studies. If orientations do play an important role in teacher thinking in terms of curricula, instructional strategies, assessment, and knowledge of students' science understandings, then it is important to re-examine the orientation component of the model. Do the orientations of practicing teachers match the theoretical orientations in the science education literature? There is a need for inductive studies that explore the orientations held by practicing science teachers. By revisiting the theoretical orientations in the literature and their relationship to the PCK model, the PCK model can be strengthened and be a more useful tool to researchers.

1.4 The Purpose of the Dissertation Study

The purpose of this study is to empirically examine the nature and sources of science teaching orientations held by practicing teachers. A case study design was used in this research. Merriam (1988) states, "A case study is an examination of a specific phenomenon such as a program, an event, a person, a process, an institution, or a social group" (p. 9). Following this definition, this study is a bounded case study of orientations. This study examines the process of teacher thinking focusing on teachers' goals and purposes for teaching science. Particularistic is one defining characteristic of a case study (Merriam, 1998). To better inform science education researchers and teacher educators, this case study is further limited to highly-regarded teachers who may best offer insight into meeting the guidelines described in reform documents. Within this case study, grounded theory methodology, defined as "developing a theory grounded in data from the field," is utilized (Cresswell, 1998, p. 65). Therefore, the purpose of this study is to explore the science teaching orientations held by highly-regarded biology teachers using an inductive approach, allowing categories to emerge from data collected from the participants.

1.5 Research Questions

This study of science teaching orientations focuses on the following two research questions:

1) What is the nature of the science teaching orientations held by a group of highly-regarded biology teachers?

2) What are the sources of the science teaching orientations held by a group of highly -regarded biology teachers?

The first question is designed to examine the orientations held by highly-regarded science teachers. Participation in the study was limited to exemplary, reform-minded teachers who have been nominated by multiple science educators familiar with each individual's teaching. In this study, a reform-minded teacher is defined as a teacher who is student-centered, incorporates inquiry approaches to learning, and desires to teach for conceptual understanding rather than focusing on coverage of the science textbook.

The second question is designed to explore sources of highly-regarded teachers' orientations to teaching science. The sources of an individual's orientation are defined as descriptions of experiences that individuals believe have contributed to the formation of their science teaching orientations. Sources may include, but are not limited to, teacher education coursework, teaching practice, the classroom setting, mentors, engagement in scientific research, etc. By understanding the source(s) of a teacher's orientation to teaching science, this information may inform the design of secondary teacher education programs and professional development opportunities for practicing teachers.

1.6 Significance of the Study

This study of the nature and sources of practicing biology teachers’ orientations toward teaching science is significant because of its contribution to the scholarly research in science education. In the literature, categories of science teaching orientations have been identified. Upon review of the literature, these categories may be more a product of curriculum reform efforts, past and present, than descriptions of actual orientations held by teachers. The study specifically explores teachers' science teaching orientations with descriptions and categories emerging from the field data. As science education researchers continue to explore the construct of pedagogical content knowledge, the theory generated from this study may inform the refinement of components of the currently proposed PCK model for science teaching.

This study is significant to improving teaching practice for several reasons. First, the interview protocols developed for this study offer practical tools for eliciting individuals' orientations to science teaching. Prospective teachers enter teacher education programs with strong beliefs about teaching and for the most part, these beliefs remain unchanged (Kagan, 1992). In teacher education programs, Kagan recommends that one of the foci of self-reflection should be on individuals' beliefs about teaching. This study also has significance for improving the practice of classroom teachers. Teachers' orientations influence the ways in which they implement new curriculum (Lantz and Kass, 1987). To successfully support teachers' learning, professional development opportunities need to take into account teachers' existing knowledge and beliefs about their role as teachers (Borko and Putnam, 1996). Freeman (1991) argues that one important role of professional development is to help teachers make their implicit beliefs explicit. In doing this, teachers are better able to examine their classroom practice and to consider inconsistencies between their beliefs and practice. As science curriculum coordinators and staff developers work with classroom teachers to implement reform-based curricula, an exploration of individuals' orientations to teaching science should aid the implementation process.

1.7 Limitations of the Study

In any research endeavor, “There are no perfect research designs. There are always trade-offs” (Patton, 1990, p. 162). One limitation of this study is the small number of participants. The number of potential participants was limited by a criterion for participation, that of being identified as an exemplary biology teacher. As a solo researcher working in the field, available time and energy also dictated the number of participants that could be included in the study. In considering this limitation, the positive aspects outweigh the negative. Due to the small number of participants, I was able to spend more time with each individual teacher, gaining a thorough understanding of each participant's science teaching orientation(s).

An inherent limitation in case study research is that the reader may think of the case study as a whole, when in actuality the case study represents just a part (Merriam, 1998). An item on any researcher's wish list is the desire to spend more time in the field. Due to scheduling constraints, most of the classroom observations occurred during the same curriculum unit. My preference would be to observe in participants' classrooms throughout the school year. As the reader proceeds through the study, I would caution that the individual case reports represent a slice of the participant's teaching world. Furthermore, this slice represents my interpretations, although they were created with significant input from the participants in the study.

1.8 Summary and Preview

In this chapter, I have set the stage by situating the context of the study within the theoretical framework of pedagogical content knowledge. In doing so, I have explored some of the issues associated with researching PCK, specifically the issue of the messiness of the construct. To address this issue, I have narrowed the study to examine one overarching component of PCK, that of science teaching orientations. In discussing gaps in the literature on science teaching orientations, I have shown the significance of this study – i.e., an inductive study that specifically focuses on teachers' thinking. As a cautionary note to readers, I have included a discussion of the limitations of the study.

The purpose of Chapter 1 was to give an overview of the study, while Chapter 2 discusses the methodological framework for the study -- a case study design employing grounded theory methods. In Chapter 2, participant selection is discussed, and data collection and analysis techniques are described to make the research process more apparent to the reader. Chapter 3 introduces each of the four participants in the study, describing their teaching contexts, the nature of each participant's science teaching orientation(s), and probable sources that shaped their teaching orientations. The information in Chapter 3 is included only to show the inductive process from individual data to collective interpretations.

Chapter 4 presents a theory of science teaching orientations, grounded in empirical data from the four participants. The theory is presented as a diagram, illustrating the complex interrelationships between nature, sources and means of science teaching orientations. Two sets of assertions are offered relating to the nature of science teaching orientations, while a third assertion addresses probable sources of participants' science teaching orientations. In Chapter 5, the grounded theory of science teaching orientations is situated within models of domains of teacher thinking and specific PCK models for science teaching. Chapter 6 offers implications in three areas: (a) improvement of science teacher practice, (b) future scholarly research on science teaching orientations, and (c) improvements in policy.

Chapter 2

METHODS OF INQUIRY

2.1. Overview

The methods of inquiry that informed the design, data collection and analysis of this qualitative research study will be discussed in the following sections. While an interpretative case study design was used, data collection and analysis was shaped by methods of grounded theory. As the qualitative researcher is the primary instrument for data collection and analysis (Merriam 1998), I've included a discussion of my role as researcher in this study. Purposeful sampling was used to select participants for the study; the criteria and process of selecting the four participants will be discussed. Classroom observations and interviews were the primary data sources, and data collection will be discussed in detail. The data analysis section is divided into two parts: early data analysis that occurred during the data collection phase and later data analysis, including generating substantive-level theory. Last, the design of the research study will be compared to established criteria relating to quality.

2.1. Research Design: An Interpretative Case Study

Yin (1994) states, "A research design is the logic that links the data to be collected (and the conclusions to be drawn) to the initial questions of the study" (p. 18). To explore the research questions relating to the nature and sources of biology teachers' orientations to teaching science, a case study design was selected. Yin (1994) defines a case study in the following way: "A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (p. 13). In Grossman's (1990) PCK model, she proposes that PCK is influenced by three domains: subject matter knowledge, general pedagogical knowledge, and knowledge of the context. Therefore, the PCK model dictates that the phenomenon, science teaching orientations, be studied in context. Grossman represents context on multiple levels, including students, school, district and community. In this study, I situated myself within the context of the classroom observing teacher-student interactions, while soliciting additional information about the school district and surrounding community. Yin's definition emphasizes the selection of case study design when the boundaries between the phenomenon and the context are blurred. The issue of boundaries is one that Loughran, Gunstone, Berry, Milroy and Mulhall (2000) encountered in their research of science teachers' pedagogical content knowledge as they struggled to define the boundary between PCK and the domain of general pedagogical knowledge. The boundaries between the phenomenon and the context become even more problematic in this study, as the research questions focus on one subcomponent within the PCK model, that of science teaching orientations, which influences and is influenced by the other subcomponents.

This research study meets the criteria set forth in Yin's definition of case study as an empirical inquiry investigating a contemporary phenomenon in context. While Yin defines case study as a process, Merriam (1988; 1998) defines case study as an end product. In this study, I conceptualized case study as both a process and an end product. In defining case study as an end product, Merriam (1998) identifies the following characteristics of the written case: particularistic, descriptive and heuristic. Particularistic is defined as focusing “on a particular situation, event, program, or phenomenon” (Merriam, 1998, p. 29). This research study is particularistic, bounded by the phenomenon of science teaching orientations, i.e., participants’ purposes and goals for teaching biology at a particular grade level. Early in the data collection process, the boundaries of the case expanded to include the means or strategies that a teacher employed to help students achieve the goals and purposes of the course. One of the participants, Sharon, made the initial distinction between goals/purposes and means when we were discussing the initial draft of a diagram I had constructed to represent her science teaching orientation. Feiman-Nemser (1990) also included means as part of her definition of an orientation for teacher education programs, stating, “An orientation refers to a set of ideas about the goals of teacher preparation and the means for achieving them” (p. 220). Drawing on Feiman-Nemser’s definition and Sharon’s suggestion, I made a decision to expand the case to include means defined as teacher strategies. This decision enabled me to present a more plausible account of each participant’s science teaching orientation.

Merriam (1998) characterizes case studies as being not only particularistic, but also descriptive and heuristic. “Descriptive means that the end product of a case study is a rich, ‘thick’ description of the phenomenon under study” (p. 29). As a researcher, I made the decision to include a separate chapter that gives a general description of each participant’s background, their teaching context and detailed representations of their science teaching orientations. This decision allowed me to share with the reader a thick, rich description of each participant's science teaching orientation prior to offering a theory of science teaching orientations. If the reader chooses to make generalizations from this study, the task is made easier with the inclusion of rich, thick descriptions of the phenomenon.

Case studies are also heuristic in nature, in that "case studies illuminate the reader's understanding of the phenomenon under study" (p. 30). The theory proposed in this study is intended to serve as a useful heuristic for science teaching orientations and is grounded in the empirical data from the four experienced, biology teachers who participated in the study. While much can be gained from reading the individual descriptions of each participant's science teaching orientation, the grounded theory of the case of science teaching orientations is of greater value to the advancement of PCK as a construct.

Case studies can be further subdivided into different types based on their intended function: descriptive, interpretative or evaluative (Merriam, 1998). This case study is intended to be interpretative in nature. In interpretative case studies, "A case study researcher gathers as much information about the problem as possible with the intent of analyzing, interpreting, or theorizing about the phenomenon" (p. 38). In this interpretative case study, my intentions are twofold. As a researcher, I seek to offer an interpretation or plausible story of each participant's science teaching orientation in the service of the larger goal of developing a substantive-level theory for the case of science teaching orientations.

2.1. Analytic Framework: Grounded Theory

Grounded theory methodology was used as the analytic framework for this study. The primary goal of grounded theory methodology is to generate theory inductively from data (Glaser and Strauss, 1967). Grounded theory was chosen as an appropriate analytic framework because of the weak literature base on science teaching orientations. Categories of science teaching orientations have been proposed in the absence of empirical studies specifically focusing on teaching orientations. Empirical studies are needed that involve teachers as collaborators, and directly focus on teaching thinking. Due to the current weak knowledge base on science teaching orientations, there is a need to generate new theories of science teaching orientations.

Two sociologists, Barney Glaser and Anselm Strauss, originally developed grounded theory. "In contrast to the a priori theoretical orientation in sociology, they [Glaser and Strauss] held that theories should be 'grounded' in data from the field, especially in the actions, interactions, and social processes of people," explains Creswell (1998, p. 56). Glaser and Strauss urged sociologists to put aside the prevailing verification modes of inquiry common in the field at that time. They thought the field of sociology would be better served if researchers focused their energies toward generating new theory. Using the grounded theory techniques of Glaser and Strauss, theory would emerge from the data (Glaser and Strauss, 1967). Later in their careers, these two founding fathers of grounded theory would part ways, setting out on diverging paths to develop their own versions of grounded theory.

I drew on the writings of Glaser and Strauss (1967), Glaser (1978, 1992), Strauss and Corbin (1998), Creswell (1998), and Charmaz (2000) to develop the grounded theory analytic framework for the study. In the discussion of grounded theory methods, it may be helpful to first define theory. Glaser and Strauss (1967) define theory in the following way, “The elements of theory that are generated by comparative analysis are, first, conceptual categories and their conceptual properties; and second, hypotheses or generalized relations among the categories and their properties” (p. 35). A consistent definition is found Strauss and Corbin’s (1998) The Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory: “Theory denotes a set of well-developed categories (e.g., themes, concepts) that are systematically interrelated through statements of relationship to form a theoretical framework that explains some relevant social, psychological, educational, nursing, or other phenomenon” (p. 22). Therefore, in this study, I used this definition of theory to guide my analysis on two levels. First, on the level of the individual participant, I developed categories and properties to describe the nature of their science teaching orientations. Within these representations, relationships were shown between categories. On the next and more important level, I developed categories and their properties that were common to all four participants. By including sources and means with the nature of science teaching orientations, I was able to generate a theoretical framework for science teaching orientations.

Grounded theory methodologists differ in the techniques that they employ to generate grounded theory. Glaser advocates a more general approach based on the constant comparative method, while Strauss and Corbin (1998) offer more prescribed, rigid techniques for developing grounded theory. I used Charmaz's (2000) critique of both Glaser's and Strauss' methods to guide my thinking as I selected techniques that would aid development of theory in this study. Charmaz (2000) identifies basic strategies used in the development of grounded theory:

> The rigor of grounded theory approaches offers qualitative researchers a set of clear guidelines from which to build explanatory frameworks that specify relationships among concepts. Grounded theory methods do not detail data collection techniques; they move each step of the analytic process toward the development, refinement, and interrelation of the concepts. The strategies of grounded theory include (a) simultaneous data collection and analysis of data, (b) a two-step data coding process, (c) comparative methods, (d) memo writing aimed at the construction of conceptual analyses, (e) sampling to refine the researcher's emerging theoretical ideas, and (f) integration of the theoretical framework. (pp. 510-511)

In Sections 2.5 and 2.6, I show how these defining characteristics of grounded theory drove the research design. In the next section, Section 2.4, I discuss my role as researcher in the research process.

2.4 Role of the Researcher

"The construction of any work always bears the mark of the person who created it," stated Riessman (1993, p. v). To assist the reader in making decisions about this research study, I have chosen to include the following subsections describing my background, personal biases and beliefs. Because beliefs about reality and the nature of knowledge influence the research design, I have included subsections that discuss my ontological and epistemological stances. My values and notions of causality also influence the research process, so I close this section with discussions of axiological and causality domains.

2.4.1 Researcher Background

For a significant part of my professional career, I taught middle school life science and high school biology in the midwestern region of the United States. As a middle school teacher, I taught life science to seventh graders for three years. As a high school teacher I taught in an urban school with a student population of approximately 2300 students. During my ten years of secondary science teaching, I taught a variety of biology courses, including Life Science, General Biology, Differentiated Biology (for academically talented students) and Microbiology.

As a science educator, I have a strong interest in teacher education and professional development. I have taught science methods courses to both prospective elementary and secondary science teachers. As a student teacher supervisor, I've worked collaboratively with numerous classroom teachers. During the 1995-96 school year, I worked closely with classroom teachers in a statewide teacher enhancement project. I was also one of the co-leaders of a group of area biology teachers that met on a monthly basis to share teaching ideas. I've given numerous professional development workshops, with the most recent workshops focusing on inquiry in the science classroom.

Based on my teaching background, I felt a strong connection to the participants in the study.

My interest in this research area began while I was working on my comprehensive examinations. I became interested in PCK as a construct of teacher knowledge and specifically, the PCK model for science teaching proposed by Magnusson et al. (1999). I collaborated with Dr. Thomas Dana on a pilot study in the spring of 2000, which explored prospective and practicing elementary teachers' orientations to teaching science. The pilot study confirmed my interest in exploring the science teaching orientation component of the PCK model in greater depth. Through the card-sorting task, participants in the pilot study gave strong evidence that they held a set of conceptions about teaching and learning which acted as a filter for making instructional decisions. However, the participants' purposes and goals for teaching science did not match the categories of orientations in the science education literature. I obtained similar results when I used the card-sorting task with prospective secondary science teachers in the spring of 2001.

As a researcher, one of my biases is that additional research is needed in the area of science teaching orientations. The current literature offers a rather simplistic notion of science teaching orientations. I suspect that contemporary reform-oriented orientations (i.e., conceptual change, inquiry, project-based science, and guided inquiry) are orientations desired by science education researchers, and do not reflect the orientations held by practicing science teachers. One of my strong biases is the need for in-depth, inductive studies that involve co-participation with practicing teachers.

2.4.2 Substantive Sensitivity

As a former high school biology teacher, I was able to quickly establish rapport with the participants in the study. The secondary science classroom setting was a familiar one to me. My content background was similar to most of the participants, and I am familiar with general biology curricula. I felt that I was readily accepted as an insider by each of the participants. My experience as a biology teacher allowed me to generate additional interview questions on the spot that were specific to each participant's curriculum unit. However, this familiarity with the teaching profession had its drawbacks. Glaser (1992) discusses the issue of sensitivity in the field, "The analyst's assumptions, experiences and knowledge are not necessarily bad in and of themselves. They are helpful in developing alertness or sensitivity to what is going on in the observational-interview data, but they are not the subject's perspective" (p. 49). Because the participants felt comfortable with me, they oftentimes fell into a collegial style of conversation, filled with inferences. In order to elicit the participant's perspective, I sometimes had to resort to an apologetic stance when asking interview questions. For instance, I might say, "I did a lot of dissections in my classes, too, but I need to hear in your own words, why you chose to include a cat dissection in your Zoology class." Statements of this kind helped focus the participants on the purpose of our conversations.

2.4.3 Ontology

Baptiste (2001) defines ontology as beliefs relating to the nature of reality. I will share my ontological perspective by responding to the following questions posed by Baptiste, “1) What do I mean when I say something is real? and 2) How does my notion of reality shape the kinds of information I capture, record, interpret and convey?” (p. 5). As I ponder my notions of reality, I draw on the writings of Charmaz (2000). In reference to grounded theory research, Charmaz states, “We can only claim to have interpreted *a* reality, as we understood both our own experience and our subjects’ portrayal of theirs” (p. 523). I believe that what I interpret as real is based upon my perspective and that multiple realities exist. The interpretations and grounded theory presented in this study represent my interpretations of the participants’ reality. I agree with Charmaz when she states, “Thus the grounded theorist constructs an image of *a* reality, not *the* reality—that is, objective, true, and external” (p. 523). I don’t believe there exists a single, objective, true reality.

As a researcher, my evolving notions of reality shape both data collection and data analysis. When I began the study, I viewed the interview transcripts as the only data source. Initially, what I viewed as real data was confined to the recorded words of the participants. Through continued study of qualitative methodologies, I began to view my field notes of classroom observations and my post interview reflections as additional data sources. I came to understand that all data remain reconstructions (Charmaz, 2000, p. 514). In this study, whether it was the participant reconstructing a narrative of her teaching or me reconstructing interpretations based on classroom observations, all data is a reconstruction. Charmaz states, “Thus the research products do not constitute the reality of the respondents’ reality. Rather, each is a rendering, one interpretation among multiple interpretations, of a shared or individual reality” (p. 523).

2.4.4 Epistemology

“Epistemology deals with the nature, sources and processes of knowledge/knowing,” defines Baptiste (2001, p. 5). In this study, I did not seek to find out “the truth” but I sought to generate new knowledge of science teaching orientations. It was not my goal to discover a single, correct answer but to produce a defensible perspective. In considering sources of knowledge, I included the participants’ beliefs, perceptions and intentions, as well as what I could observe with my five senses, such as classroom practice. As I analyzed the data, I included my post-interview analysis notes as a data source. During the data collection process, I was sometimes caught without a tape recorder. This was more apt to happen when I spent an entire day with a participant. Between classes, participants might share a quick story as an illustration of something that was discussed during an earlier interview. Based on my memory, I recorded this information later in the day and used these notes as an additional data source. As I was conducting research, particularly during classroom observations, I did not attempt to be a pure observer. I realized that my mere presence was affecting the teaching process, perhaps making the teaching process more intentional on the part of the participant.

2.4.5 Axiology

Axiology is defined as the domain of values and ethics. Baptiste (2000) identifies three axiological issues relating to qualitative data analysis, "a) the place and roles of values in research; b) the role of research subjects; and c) the appropriate way(s) to use research products" (p. 6). It is my belief that it is not possible for the researcher to keep his/her values from influencing the analysis process. In Section 2.4.1, I have shared information about my background in an attempt to reveal values that I hold. As a science educator, I value teachers who are student-centered and reform-oriented. In regard to the role of research subjects, I have chosen to use the term "participant" rather than research subject. Seidman (1998) advocates the term participant because "the word seems to capture both the sense of active involvement that occurs in an in-depth interview and the sense of equity that we try to build in our interviewing relationships" (p. 8). During the data collection and early data analysis, each participant took an active role in the research project. The diagrams representing each participant's science teaching orientation were co-created with the participants. The extent of involvement for each participant in the data analysis process was determined by the participant's interest in the study. Sharon and Peg expressed the greatest degree of interest in the study and contributed substantially to the initial data analysis, while Mike and Martha tended to confirm my interpretations.

In regard to the third issue, the appropriate ways to use research products, each participant was informed of the nature of the study and possible publication venues. Participants were assured confidentiality. Participants' names and other identifying characteristics have been changed for purposes of reporting the study. Copies of the study will be given to participants who indicated a desire to read the final research product. In generating grounded theory, I have chosen not to generalize beyond the four participants in the study. I have tried to present enough data from each participant to allow readers to generalize beyond the study if they so choose.

2.4.6 Causality

"All research attempts to draw associations between ideas, people and/or events. These associations are called different things - cause, probable cause, mutual shaping, influence, determination, contribution, effects, and so on," states Baptiste (2001, p. 6). In this study, the issue of causality is brought to the forefront. My work in this study is based on the premise that teachers' beliefs play a critical role in shaping how and what they teach (Borko and Putnam, 1996; Pajares, 1992). To inform the design of teacher education programs and professional development, this study also explores the sources of participants' science teaching orientations. In this study, I am not attempting to identify objectivist causes of participants' science teaching orientations; rather, I am drawing on constructivist grounded theory. Charmaz states, "Causality is suggestive, incomplete, and indeterminate in a constructivist grounded theory. Therefore, grounded theory remains open to refinement" (p. 524). Within each case, I present probable influences that may have shaped each participant's science teaching orientation. With each participant, these probable influences were explored in depth and represent our mutually negotiated interpretations. However, there may have been additional sources that were not identified during the research process.

2.5 Data Collection

For clarity reasons, I have separated the discussion of data collection from data analysis. In actuality, true to grounded theory methods, data collection and analysis occurred simultaneously (Charmaz, 2000; Glaser and Strauss, 1967; Strauss and Corbin, 1998). Potential participants for the study were identified through a nomination process and contacted in January of 2001. Theoretical sampling, the nomination process and selection criteria are described below. Actual data collection began in February and continued through the end of May 2001. Multiple data sources were used in this study, with the primary data sources being semi-structured interviews, field notes from classroom observations, and analytic memos. As part of the semi-structured interviews, a card-sorting task was designed and used. Each of the data collection methods is described in greater detail below. As secondary data sources, classroom artifacts generated by the participants were also collected, e.g., unit outlines, laboratory handouts, review worksheets, tests and quizzes.

2.5.1 Sampling

Purposeful sampling was used in this qualitative research study. Merriam states, “Purposeful sampling is based on the assumption that the investigator wants to discover, understand, and gain insight and therefore must select a sample from which the most can be learned" (1998, p. 61). In grounded theory, the term "theoretical sampling" is used and participants are selected on the basis of their ability to contribute to the development of theory (Creswell, 1998). The decision was made to narrow the study to explore the science teaching orientations of highly-regarded biology teachers. The decision to focus on biology teachers was based on my own background. PCK is a specialized knowledge base for teaching which draws upon an individual's knowledge of subject matter (Shulman, 1986). As the sole interviewer in the study, I felt it was important that I have a strong content background in the subject that the participants were teaching. Indeed, during the interview process, it was helpful to draw on my biology teaching background in terms of biology textbooks, curricula and laboratory activities. Rather than study a random sample of biology teachers, the decision was made to focus on biology teachers who were held in high regard by other professional educators. This decision was made because it was felt that more insight for improving practice would be gained by studying highly-regarded teachers. The Search for Excellence project in the United States (Penick and Yager, 1983) and the Exemplary Practice in Mathematics and Science Project (Tobin and Fraser, 1987) followed this same line of reasoning; both of these projects resulted in heuristic case studies of exemplary practice.

After narrowing the study to exploring the science teaching orientations of highly-regarded biology teachers, I used reputational sampling to solicit names of potential participants for the study (Merriam, 1988). I consulted with science education faculty at local universities and colleges. I also contacted the state science consultant, curriculum consultants at several regional educational service units within the state, and officers of the state science teacher organization. Tobin and Fraser (1987) acknowledge, "Of course, exemplary practice comes in many forms and is a subjective term that is interpreted in different ways by different educators" (p. vii). When asking science educators to nominate biology teachers whom they considered to be exemplary, I shared a set of criteria for potential participants in the study (Merriam, 1998).

The first criterion for inclusion in the study was that potential participants were identified as being student-centered, emphasizing conceptual understanding of biology. The National Science Education Standards (NSES) stress that teachers need to shift emphasis from "focusing on student acquisition of information" to "focusing on student understanding and the use of scientific knowledge, ideas, and inquiry processes (National Research Council [NRC], 1996, p. 52). Many more characteristics of reformed-based science teaching could have been identified as criteria in this study. As one of the nominating individuals pointed out, "No teacher meets all the criteria set forth by the National Science Education Standards, which characteristics are you most interested in?" Student-centeredness seemed to be a criterion that nominating individuals were able to relate to exemplary teachers. Tobin and Fraser (1987) used a similar definition of exemplary science and mathematics teachers:

> In this study [Exemplary Science and Mathematics Education Project], the term exemplary practice was not meant to imply that the nominated teachers were 'perfect'. Instead, the teachers were considered effective in a broad sense of providing a learning environment in which students could develop concepts, inquiry skills, and positive attitudes (p. vii).

Realizing that nominating individuals held their own set of conceptions for defining exemplary teachers, I stressed the criteria of student-centeredness and teaching for conceptual understanding.

Potential participants also needed to have extensive teaching experience. Loughran et al. used the same criteria in their research, “It was our view that all teachers would have some level of PCK but that it would be most well developed in very experienced teachers” (2000, p. 8). I requested names of exemplary biology teachers who had at least ten years of biology teaching experience, in hopes of maximizing the potential for studying PCK. As PCK is thought to be subject-specific, another criterion was that biology was the participant’s primary teaching assignment. Potential participants also needed to have a minimum of three years of experience in their present school district. I wanted the participants to be knowledgeable of the school district’s expectations and to have connections to available resources in the school and community.

Another criterion for inclusion in the study was that participants were active in professional development. This criterion was established by drawing on NSES and my personal belief that exemplary teachers are life-long learners actively involved in on-going professional development. As teaching is typically done in a secluded classroom, it is difficult to identify exemplary teachers. The NSES state that there should be more emphases on the teacher as a member of a collegial professional community (NRC, 1996, p. 72). Based on the assumption that exemplary teachers were members of a collegial professional community outside of their school building, I relied on reputational sampling for this study.

After soliciting the names of exemplary biology teachers, I compiled a list of six teachers who were highly-regarded by two or more individuals. I contacted these potential participants and four teachers indicated an interest in learning more about the study. One limitation of this study is the small number of participants. The number of potential participants was limited by both the criteria for participation and by the limitations of a single researcher working in the field. There is also a dimension of convenience sampling in this study as I limited the participants on a geographical basis, to within 250 miles of my home.

2.5.2 Informed Consent

I met individually with each of the four teachers who indicated an interest in participating in the study. I explained the purpose of the study and the required time commitment. All four teachers agreed to participate in the study and signed the Informed Consent Form (see Appendix A for the Informed Consent Form). At the request of the Internal Review Board, each participant's principal needed to give informed consent, as the research was taking place within the school setting. In two schools, I met with the principal and in the other two schools, the participant chose to meet with the principal to complete this paperwork. All four principals whose schools were involved in the study indicated their consent by signing the informed consent form (see Appendix B for the Principal's Informed Consent Form).

2.5.3 Classroom Observations

"The naturalistic researcher should realize that interviews and observations build understanding of a social context in an interactive way. For this reason, the researcher cannot treat these two human sources of data as independent of each other," state Erlandson, Harris, Skipper, and Allen (1993, p. 99). During this study, classroom observations and interviews were interactive data sources. However, for reasons of clarity, I have separated the discussion of these two data sources into separate sections. Interviews are discussed later in Section 2.5.4.

Classroom observations were an important data source for this study. By observing the participants teaching in their own classroom, I was able to gain a better understanding of their teaching practice and the context in which they taught. Erlandson et al. state, "Through observations, the researcher gains a partially independent view of the experience on which the respondent's language has constructed those realities (p. 99). Extensive field notes were taken during the classroom observations and these notes were used as an additional data source.

Most importantly, the classroom observations served as a source of interview questions (Erlandson et al., 1993). As part of the interview process, participants were asked to reflect on various activities observed during the classroom observations. Participants were asked to describe how various teaching activities supported or did not support their goals and purposes for teaching biology at that particular grade level. One limitation of the study was that due to scheduling constraints, the observations generally occurred within the same curriculum unit. Ideally, the observations would be spread out across the school year. “They [qualitative researchers] try to observe the ordinary, and they try to observe it long enough to comprehend what, for this case, ordinary means, ” explains Stake (1995, p. 44). Participants were asked not to make any changes in their teaching because of my observations. Certainly my presence in their classroom had some effect on their teaching, and more extensive classroom observations would have addressed that concern. However, during the second set of observations, I had the sense that I was seeing a typical teaching day. In one case, the participant had completely forgotten that I was observing in her classroom that day, so I knew I was “seeing the ordinary.”

Each of the participants was observed a minimum of two class periods for each biology class they taught. I arrived five to ten minutes prior to the start of the class period and observed for the duration of the class period. I choose to take the role of classroom observer rather than participant. This decision enabled me to keep more detailed field notes. Stake (1995) states, “For all their intrusions into habitats and personal affairs, qualitative researchers are noninterventionists. They try to see what would have happened had they not been there. During fieldwork, they try not to draw attention to themselves or their work” (p. 44). While observing, I sat in the back or to the side of the classroom, staying in the peripheral of the teacher-student interaction. In some cases, the students were told that I was a visitor working on a research project with the teacher. In other cases, the teacher made no mention of my presence in the classroom.

2.5.4 Interviews

Interview transcripts were the primary data source for this study and generally interviews were scheduled immediately following the classroom observations. Glaser (1992) underscores the importance of combining interview data with observational data:

> Observational data is not enough. The researcher should provide interviews along with the observations so that the analyst can get at the meaning of what is observed. Observations do not in and of themselves have the meaning or the perspective in them of the participants (p. 49).

Classroom observations helped me gain an understanding of the school setting and the students, but it was through the interview process that I elicited the participants' understanding and meaning behind the teaching I observed. Strauss and Corbin (1998) emphasize the asking of questions as a primary tool of a researcher using grounded theory methodology. During the interviews, participants were asked to explain their thinking behind their teaching, and to make connections between the observable classroom actions and their overall purposes and goals for teaching biology in that particular course.

The design of the interview structure was informed by Seidman's (1998) three interview series. In the first interview, biographical information was collected (see Appendix C for the 1st Interview Protocol). "The purpose of the second interview is to concentrate on the concrete details of the participants' present experience in the topic area of study," states Seidman (p. 12). The second interview was based on the observed teaching practice, with specific probes being generated during classroom observations (see Appendix D for the 2nd Interview Protocol). The third interview had a twofold purpose. One purpose was a continuation of the second interview, with questions being based on additional classroom observations (see Appendix E for the 3rd Interview Protocol). Seidman refers to the purpose of the third interview as being a “reflection on meaning” (p.12). In addressing this purpose, participants were asked to reflect on an initial diagram I had drawn which represented my interpretation of their science teaching orientation.

Merriam (1998) classifies interviews by the degree of structure present. She presents a continuum from highly structured/standardized to semi-structured to unstructured/informal (p. 73). The interviews that I conducted fell on the continuum between “semi-structured” and “unstructured/informal.” I did prepare a list of questions that served as the basic outline for each interview. However, the questions were flexible and exploratory in nature, based on the observed teaching practice of each participant.

Theoretical sampling drove the second and third rounds of data collection. Charmaz (2000) identifies theoretical sampling as a defining characteristic of grounded theory. Glaser and Strauss (1967) offer the following definition, “Theoretical sampling is the process of data collection for generating theory whereby the analyst jointly collects, codes, and analyzes his data and decides what data to collect next and where to find, in order to develop his theory as it emerges” (p. 45). For each participant, the data was analyzed and coded prior to the next round of data collection. Subsequent interview questions were focused around developing the properties and dimensions of the emerging categories of that individual’s science teaching orientation. As I began to identify categories after the first interview, I generated a list of additional questions to explore the dimensions and properties of these emerging categories.

The constant comparative technique is a major technique used in grounded theory. Charmaz (2000) describes this technique in the following way:

> The constant comparative method means (a) comparing different people (such as their views, situations, actions, accounts, and experiences)/ (b) comparing data from the same individuals with themselves at different points in time, (c) comparing incident with incident, (d) comparing data with category, and (e) comparing a category with other categories (p. 515).

During the interview phase of data collection, I focused on one participant at a time, comparing data taken from each teaching observation, asking how the participant's teaching methods supported or did not support their goals and purposes for teaching biology. In this way, I was "comparing data from the same individuals with themselves at different points in time" (Charmaz, 2000, p. 515). During the third interviews, the interview questions shifted to comparing categories with other categories of their science teaching orientations, and developing relationships between categories.

In grounded theory, data collection continues until theoretical saturation is reached. Strauss and Corbin (1998 define theoretical saturation, "This means until (a) no new or relevant data seem to emerge regarding a category, (b) the category is well developed in terms of its properties and dimensions demonstrating variation, and (c) the relationships among categories are well established and validated" (p. 212). During the second interviews, I started to hear a repetition of core categories and dimensions of core categories. By the end of the third interview, I had a strong sense that core categories for that individual's science teaching orientation were saturated and that little new information or insight would be gained by additional interviewing of that particular individual.

2.5.5 Card-sorting Task

"Although experienced teachers may have a wealth of knowledge about both the content and pedagogy appropriate to science teaching and learning, much of this knowledge is tacit and therefore difficult for individual teachers to recognize and express," states Loughran et al. (2000, p. 5). This was also true for the participants in this study, although individuals varied in the degree to which they could articulate their goals and purposes for teaching biology. Of the four participants, Sharon was the most articulate in expressing her science teaching orientation. With a minimal amount of probing, Sharon was able to explicitly state her goals and purposes for teaching biology. Mike was at the opposite end of this continuum. Even with repeated probing, it was difficult for him to articulate his goals and purposes for teaching biology.

To help elicit participants' goals and purposes for teaching biology, a card-sorting task was designed. Hewson and Hewson (1989) designed a task-based interview to elicit science teachers' "conceptions of teaching science." They define this construct as: "the set of ideas, understandings, and interpretations of experience concerning the teacher and teaching, the nature and content of science and the learners and learning which the teacher uses in making decisions about teaching, both in planning and execution" (p. 195). Participants in this study were given brief scenarios and asked to describe whether or not science teaching was occurring in each situation. Based on Hewson and Hewson's idea of a task-based interview, I designed a set of scenario cards for eliciting participants' science teaching orientations. Each card described an instructional strategy, planning technique, laboratory activity, or assessment strategy commonly used in high school biology teaching. Participants were asked to sort the cards into two piles, one pile that represented how they teach and the other pile representing scenarios that would not occur in their classrooms. At the end of this initial sorting process, participants were asked to explain the cards that they sorted into the stack that did not represent their teaching. Then using only the cards in the stack that did represent how they taught, participants were asked to do a second sorting. This stack of cards was sorted into a continuum from "most like me" to "least like me." Participants generally grouped the scenario cards into 5-8 stacks along a continuum. Participants were asked to describe how each stack of cards supported their purposes and goals for teaching biology. It was not the placement of particular cards that was revealing, but it was the reasons given by the participant that helped elicit their goals and purposes for teaching biology. (See Appendix F for the Card-sorting Interview Protocol and the Scenario Cards.) The card-sorting task was usually completed as part of the second interview.

2.5.6 Data Collection Procedure and Schedule

Data collection occurred during the spring of 2001, beginning in February and ending in May, with the close of the school year. In general, I attempted to complete data collection with one participant prior to beginning to work with another participant. However, this wasn't always possible. I needed to be flexible in scheduling observations and interviews, working around the busy schedules of the participants. In general, the interviews followed the classroom observations, with both occurring on the same day. In some cases, however, the interviews were conducted several days after the classroom observation. I tried to follow the sequence of the numbered interview protocols, but that wasn't always possible. In one case, the biographical interview occurred later in the data collection phase. Spring sports, student teachers, science fair competitions, Advanced Placement test reviews, and the building of a new house dictated the schedule for data collection. The data collection schedule is shown in Table 2.1.

Table 2.1

Data Collection Schedule

Contacts	Sharon	Mike	Peg	Martha
1st	2-14-01 • Explained study • 1st interview (1.5 hrs) Total of 2 hrs.	3-13-01 • Explained study during lunch at JSHS Total of 1 hrs.	3-12-01 • Explained study at JSHS • Began 1st interview Total of .75 hrs.	4-27-01 • Began the 1st interview Total of .5 hrs.
2nd	3-23-01 • Observed Adv. Biology class • Card-Sorting Task (.5 hr) • 2nd Interview (1 hr) Total 2.5 hrs.	3-21-01 • Observed 3 classes Life Science (2 periods) and AP Bio • Card-Sorting Task and 2nd Interview (1.3 hrs) Total of 4 hrs.	5-16-01 • Observed 5 class periods • Finished 1st interview, 2nd interview and Card-Sorting Task (3 hours) Total of 8 hrs.	5-3-01 • Observed Zoology class Total of 1 hr.
3rd	3-29-01 • Observed Adv. Biology. -3rd interview (1 hour) Total 2 hours	4-6-01 • Observed Life Science (1 period) and AP Biology (1 period.) • 1st and 3rd Interviews (1.25 hrs) Total of 2.5 hrs.	5-17-01 • Observed 5 class periods. • Completed2nd interview and 3rd interviews (3 hrs) Total of 8 hrs.	5-9-01 • Observed Bio 2 and Zoology classes Total of 2 hrs.
4th				5-22-01 • Observed Bio 2 and Zoo class Total of 3 hrs
5th				5-25-01 • 2nd Interview Total of 1 hr.
6th				5-31-01 • 3rd Interview • Completed 1st interview • Card-Sort Task Total of 1.5 hrs.

2.6 Data Analysis

In this section, I describe the specific data analysis techniques used in the study. Because data analysis began during the data collection phase, I have divided the following discussion into two sections. The first section describing data analysis procedures that occurred during data collection, and the second section describes subsequent analysis procedures that occurred post data collection.

2.6.1 Data Analysis: Concurrent with Data Collection

My data collection and analysis processes closely followed Creswell's (1998) description of a grounded theory study, a "zigzag process- out to the field to gather information, analyze the data, back to the field to gather more information, analyze the data, and so forth" (p. 57). The early phases of data analysis occurred during data collection. After each classroom observation and interview, I would analyze the data before returning to the participant's school for the next round of classroom observations and interviews. During this phase of early data analysis, I used the following techniques: post interview analysis notes, initial reading of transcripts and field notes, the creation of initial diagrams representing a participant's science teaching orientation, and the use of member checks. Each of these techniques is described in greater detail in the subsections that follow.

2.6.1.1 Post Interview Analysis Notes: Analytic Memos

Upon leaving the participant's school after a day of data collection, I recorded my reflections as initial analytic notes or memos. Strauss and Corbin (1998) define memos as notes that contain the products of analysis or directions for the analyst. "They [memos] are meant to be analytical and conceptual rather than descriptive," state Strauss and Corbin (p. 217). Sometimes the memos were handwritten in my car before I left the school parking lot. As data collection progressed, I tended to audiotape my analytic memos as I drove home from the participant's school. I later transcribed the audio taped memos. These early memos contained the first record of emerging categories. After my first interview and classroom observation with Mike, I reflected on Mike's goals for teaching 8th grade Life Science, "A lot of the things that he does, he likes to demonstrate and point it out to the kids and ask questions and get them to ask questions and think about it" (Mike, post interview analysis, 3/21/01, p. 2). The central category of "wondering and appreciating the complexity of life" was later developed, with one dimension of this category being the promotion of curiosity. In the same memo, I reflected on Mike's means for reaching his goals, "…it's part of his job to tell stories so that kids will remember" (pp. 2-3). Later, storytelling was identified as one of Mike's primary means of helping students become familiar with key biological concepts. In reflecting on Mike's purposes and goals for involving his AP students in science fair competitions, I recorded these thoughts, "… so he's thinking there [AP Biology] that to wonder about something and then to have some tools to be able to answer the questions is important to him" (p. 3). Later, two central categories were developed for Mike's teaching orientation for the AP biology course. The central categories became 1) to wonder and appreciate the complexity of life, and 2) to develop skills and tools to explore questions. The post interview memos were a record of my initial analysis immediately following a round of data collection.

2.6.1.2 Open and Axial Coding of Transcripts and Field Notes

Charmaz (2000) identifies a two-step coding process as a defining characteristic of grounded theory. In this section, I describe the coding processes that occurred as I developed a representation of each individual's science teaching orientation. I transcribed each of the interviews prior to the next interview. Due to schedule constraints and the need to schedule interviews on consecutive days, Peg was the exception to this rule. Peg's observations and interviews took place during an intense two-day period, and it was not possible to transcribe the lengthy interview tapes overnight. In Peg's case, I analyzed my handwritten field notes and listened to portions of the taped interviews, in order to generate interview questions for the next day. With the other three participants, I was able to schedule the interviews a week or more apart. This spacing of data collection allowed me to transcribe the audio taped interviews prior to the next interview. Before returning to the study site, I would read through my field notes from classroom observations, my analytic memos and the transcripts from the last interview.

As I read the data collected from a participant, I began to analyze the data through the process of open coding. Glaser (1992) describes open coding in the following way:

> Open coding is the initial step of theoretical analysis that pertains to the initial discovery of categories and properties. The mandate of open coding is that the

> analyst starts with conceptual nothing—no concepts. Open coding comes to an end when it yields a core category (p. 39).

As I read through the data, I summarized short sections with descriptive codes. Coding can be done on several levels: line-by-line analysis, sentence/paragraph analysis and whole document analysis (Strauss and Corbin, 1998). In general, my unit of analysis consisted of several sentences within a transcript. The codes were handwritten in the margins of the transcripts and field notes. As I progressed through the data, I used a constant comparative method of analysis. I followed Glaser and Strauss's (1967) defining rule for the constant comparative method—"while coding an incident for a category, compare it with the previous incidents in the same and different groups coded in the same category" (p. 106). In reviewing the open coding for Mike's data for his Life Science course, the following core categories began to emerge: develop a sense of wonder, develop an appreciation for the complexity of life, challenge students to be successful, develop skills and learn key concepts. A constructivist approach to grounded theory recognizes that categories do not magically emerge from the data but emerge from "the researcher's interactions within the field and questions about the data" (Charmaz, 2000, p. 522).

After open coding, the next step was to begin axial coding. "The purpose of axial coding is to begin the process of reassembling data that were fractured during open coding," state Strauss and Corbin (1998, p. 124). In axial coding, dimensions and properties are developed for each core category (Strauss and Corbin, 1998). In some cases, I found that open and axial coding occurred simultaneously (Glaser, 1992). I began to develop the dimensions of core categories and generated a list of interview questions for the next round of data collection. For example, I began to explore the dimensions of one of Mike's central goals of preparing students for college. What did Mike mean when he said that he wanted to prepare his AP students to be successful in college? What classroom activities support Mike's goal of preparing students for college? Is Mike preparing his students to be successful college students or does he have a more specific goal of wanting his students to pursue a college major in a science discipline? From this initial data analysis, I would generate a list of interview prompts to include in the next interview. The interview prompts were intended to explore dimensions of core categories. For example, here is a partial list of interview prompts that I generated to develop questions for Mike's second interview:

1. Why does Mike involve his AP students in science competitions?
2. Why does Mike restrict participation in science fairs to his AP course?
3. Why did Mike have the AP students grade each other's practice exam questions?
4. How much emphasis is placed on getting a high score on the AP exam?
5. What role does the textbook play in the curriculum for the AP course?
6. Are the students expected to obtain information from the textbook or do they rely on Mike's class discussions?
7. What was Mike's purpose in giving the position paper assignment in the AP class? Does he use this assignment in the Life Science class? (Mike, pre-interview notes, 4/05/01)

These interview questions were used to elicit additional information about the dimensions of core categories. Using the constant comparative technique, I compared data taken from the same individual at different points in time. I also compared one teaching incident with the next and compared new data with the emerging categories (Charmaz, 2000). Using the constant comparative method, I used this additional data to further develop the properties and dimensions of each core category.

2.6.1.3 Initial Representations, Member Checks and Selective Coding

Prior to each participant's final interview in the spring, I reviewed all the data I had collected for that individual. I reviewed the core categories designated during the open coding process and, through axial coding, continued to refine the dimensions and properties of each category. As part of the constant comparative method, I continued to write memos as a means of recording my analysis decisions (Glaser and Strauss, 1967). I constructed a simple diagram that represented my initial understanding of the nature of each participant's science teaching orientation. The first diagrams were fairly simple representations, using lists with sub-points that represented dimensions and properties of that core category. These diagrams served as visual analytic memos (Strauss and Corbin, 1998). Table 2.2 represents the initial diagram for Sharon's science teaching orientation for the Environmental Biology course. I created a separate diagram for each biology course taught by the participant.

Table 2.2

Sharon's Science Teaching Orientation: Version 1

Core Categories	**Environmental Awareness/Values**	**School Science Needs to Be:**	**Immersion Experiences**
Dimensions and Properties	• increase observational skills→ understand it →care for it • foster sound decision-making on environmental issues • respect for life • advocate for the environment • scientific literacy	• Interesting • Fun, evoke a good feeling • Practical, have real life connections --> action component • Real, local, research projects	• Field trips • Need to internalize • Promotes positive attitudes (in school or in classroom?)

In the third interview, as a form of member checking, I shared my initial diagrams with each participant and we discussed the representations. In all four cases, the participants agreed with the core categories. Discussions tended to focus on further developing properties and dimensions of core categories and on the clarification of relationships between core categories. In grounded theory, the process of constructing relationships between categories is referred to as selective coding. During selective coding, categories are integrated and refined for the purpose of developing theory (Strauss and Corbin, 1998). Working collaboratively with the participant, I began to construct relational statements from the data. Strauss and Corbin (1998) state, "By 'constructed' we mean that the analyst reduces data from many cases into concepts and sets of relational statements that can be used to explain, in a general sense, what is going on" (p 145). Diagrams are often used during the selective coding process (Creswell, 1998, Strauss and Corbin, 1998). After the third interview, I modified the science teaching orientation diagrams based on the participant's input. Figure 2.1 shows the next version of the representation of Sharon's science teaching orientation. Compare the representation shown in Figure 2.1 to the representation shown in Table 2.2. In the later representation, relationships between categories are developed.

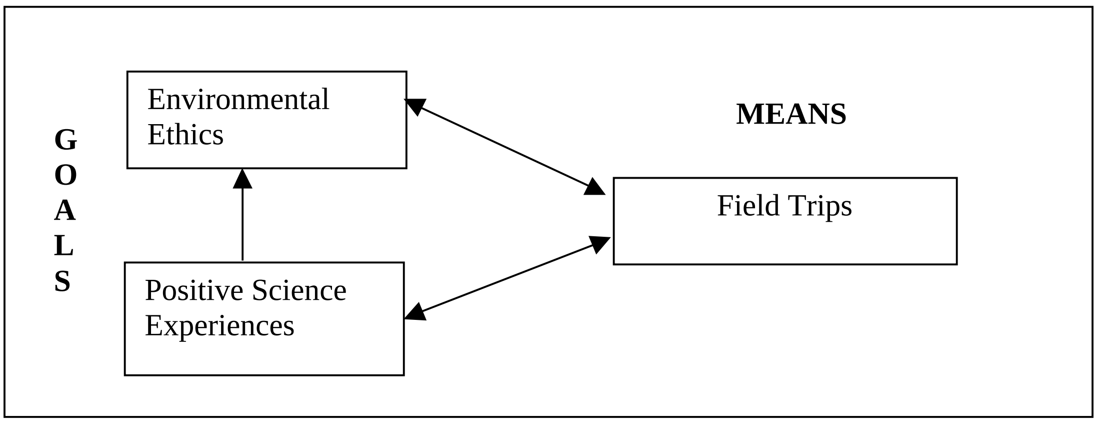

Figure 2.1. Sharon's science teaching orientation diagram, version 2.

In our discussion of the diagram representing her science teaching orientation, Sharon offered two suggestions as part of the selective coding process. Sharon suggested that the "Field Trip" category be identified as her means of achieving her other two goals. The second suggestion that Sharon offered was to represent the two goal categories and the means category as a triangle with multi-directional arrows. Sharon uses field trips to meet her goals of developing environmental ethics and creating positive science experiences for her students. In addition, when students have positive science experiences, Sharon's goal of developing environmental ethics is supported.

2.6.2 Data Analysis: Post Data Collection

Data collection from the field was completed on May 31, 2001, as the school year ended, with data analysis continuing through the summer and fall semester of 2001. The following subsections describe the techniques that I used in this later stage of data analysis. During this stage, the data was reviewed and a third draft of the science teaching orientation diagrams was generated. To support the representations of science teaching orientations, I made the decision to write a narrative describing each participant's science teaching orientation(s). The final and most important step of data analysis focused on looking across the four individual participants. Section 2.7 describes the process of generating a theory of science teaching orientations.

2.6.2.1 Generation of the Third Version of Diagrams

Using a constant comparative method, I continued to refine each individual's representation of his or her science teaching orientation(s). I reviewed interview transcripts, classroom observation notes, and memos, including earlier versions of science teaching orientation diagrams. I continued to do selective coding, incorporating the participants' feedback. With Dr. Dana's input, a decision was made to differentiate between central and peripheral core categories within an individual's science teaching orientation. The central categories represent the participant's major goals and purposes for teaching biology. The peripheral categories are expressed as part of the participant's science teaching orientation, but play a lesser role in the teacher's decision-making. The third draft of Sharon's science teaching orientation is shown in Figure 2.2.

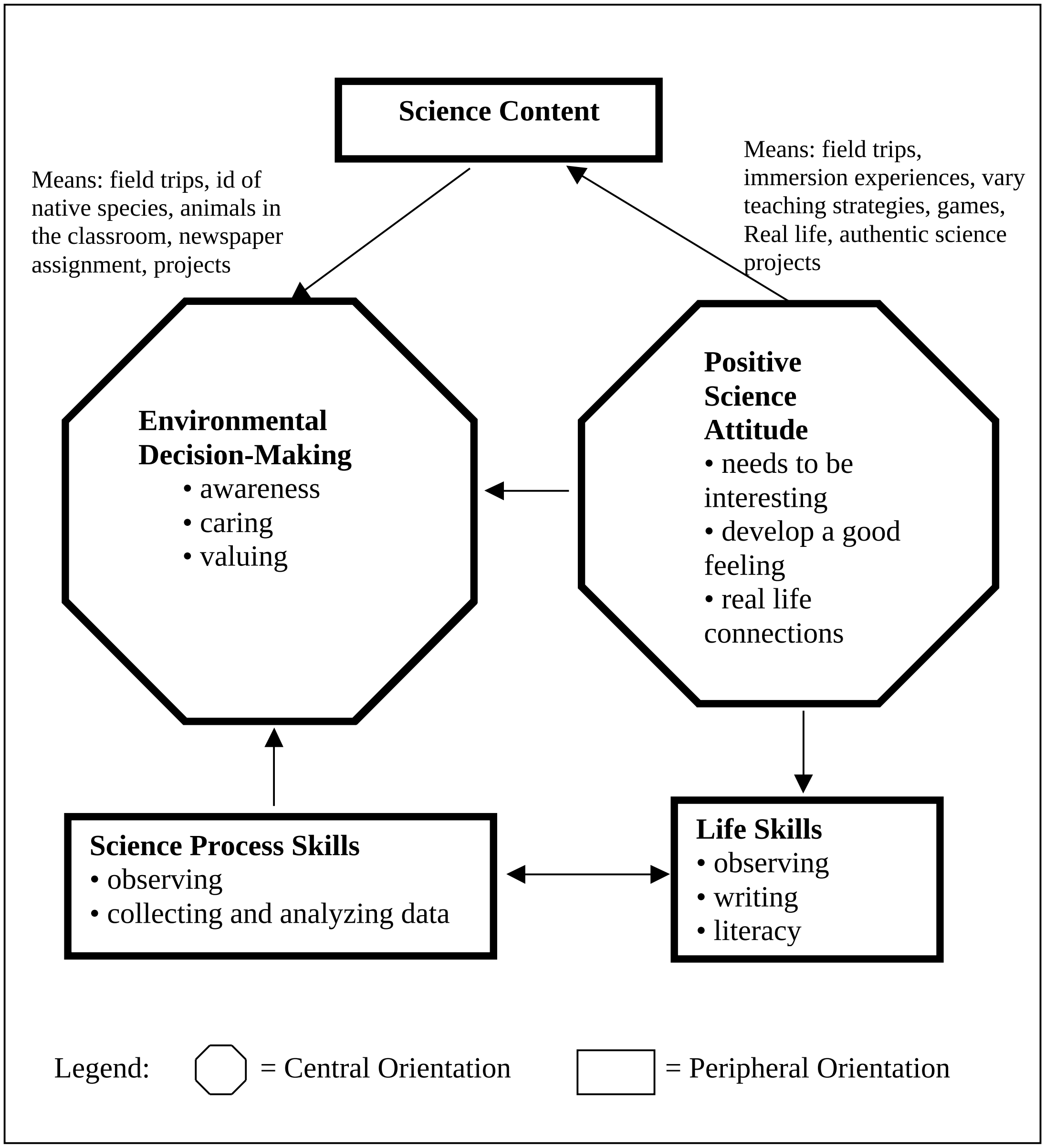

Figure 2.2. Sharon's science teaching orientation diagram, version 3.

In Figure 2.2, the representation of Sharon's science teaching orientation has evolved from lists with subpoints (See Table 2.2) to a diagram differentiating between central and peripheral goals, and showing relationships between goals. In grounded theory, diagrams have multiple functions of both storing information and providing a written record of analytic thought. In addition, diagrams force the analysis to work with concepts, moving beyond the raw data (Strauss and Corbin, 1998). For example, in Figure 2.2, "observing" is subsumed into the concept "science process skills." Diagrams are an important tool in selective coding, allowing for visual representation of the relationships between categories. For example, in Figure 2.2, one of Sharon's central goals is to promote positive science attitudes in her students. When students have positive attitudes toward science, Sharon is better able to meet her other goals of developing environmental decision-making and learning science content.

2.6.2.2 Writing Individual Narratives

The analysis of each individual's data continued into the process of writing (Mitchell and Charmaz, 1996). After the third revision of the diagrams, I began to write individual narratives. The narratives included information about the teacher's educational background, a description of the school context and teaching assignment, as well as the nature and sources of their teaching orientation(s). Diagrams were used to represent the nature of the participant's teaching orientation. The diagrams underwent additional revision during this writing process. While writing Peg's narrative, I wrote the following memo, "I shifted lab skills to a peripheral component in Peg's s.t. orientation for the College Prep Biology. It seemed to play a more secondary role—especially based on my observations and Peg's interview data. As I re-read the transcripts, check this" (Analytic memo, 10/5/01). Through a constant comparative method, I continued to compare data to categories, and categories to each other (Glaser and Strauss, 1967). Prior to describing the sources influencing an individual's teaching orientation, I began the process of analyzing across the four participants. Again, through a constant comparative method, I began to develop initial categories of sources as part of the development of a substantive-level theory of science teaching orientations. In this case, the constant comparative method focused on comparing individuals' sources with each other.

2.7 Continued Data Analysis: Substantive-level Theory Development

Glaser (1978) states, "Grounded theory assumes that part of the method, itself, is the writing of theory. The way data is coded, ideas are memoed, and memos are sorted are all partly focused on designing and facilitating the writing of the theory" (p.7). Although close attention to individuals' science teaching orientations helped to build theory, the individual narratives alone are not theory. Glaser (1992) would describe the individual narratives as full, conceptual descriptions. The next step was to develop a grounded theory of science teaching orientations across the four participants. This theory may best be classified as a substantive-level theory, which Creswell (1994) defines as a middle-range theory, "restricted to a particular setting, group, time, population or problem (e.g., math anxiety)" (p. 83).

Using a constant comparative method, I looked across the four participants to generate categories representative of all four individuals. In writing the individual narratives, I had started to look at the sources of science teaching orientations. At this stage, I employed a different version of theoretical sampling. Strauss and Corbin (1998) state, “Another form of [theoretical] sampling is to return to the data themselves, reorganizing them according to theoretically relevant concepts” (p. 209). Rather than returning to the participants, I returned to the collected data to look for confirming and disconfirming examples as I generated categories for sources of teaching orientations During this open coding phase, I initially viewed sources as being biographical in nature. In a memo I wrote, “I’m defining sources as external sources, is this the only way to look at sources?” (Analytic memo, 9/20/01). Later, in the integration of the categories, the category of sources was expanded beyond its original conception.

In the next step, I developed categories for the nature of the science teaching orientations across the four participants. The individual diagrams (see Chapter 3), thoroughly grounded in the data, served as analytic memos. Using the diagrams as analytic memos, I compared categories with categories. From this constant comparative method, I developed three categories pertaining to the nature of science teaching orientations across the four participants. As I developed these new categories, I continued to write analytic memos. I wrote, “I don’t know if pedagogical efficiency is part of Sharon’s orientation or not. Maybe it’s time constraints and pedagogical efficiency” (Analytic memo, 9/24/01). Using theoretical sampling, I returned to Sharon’s data to look for confirming and disconfirming data. In the following memo, I begin to explore relationships between categories. “Influence of the learners – do the students drive only the means or are they part of internal sources?” (Analytic memo, 9/16/01). At this stage, the analysis process quickly moved to the integration of the theoretical framework.

Strauss and Corbin (1998) use the term “selective coding” to describe the process of integrating the theoretical framework. I chose to represent the emerging substantive-level theory in two forms. First, I developed a set of assertions that related to each of the research questions. The assertions describe the categories and properties of the categories generated during theory building. As described in Section 2.3, theory consists of two elements: 1) conceptual categories and their properties, and 2) hypotheses or generalized relations between categories and their properties (Glaser and Strauss, 1967). I chose to use a diagram to represent the relationships between categories. Using a constant comparative method, I explored relationships between categories. I continued to theoretically sample the data to test these relationships. The diagram format also allows for future modification of the theory as additional research is done in this area. The diagram serves as a visual representation of the theory, allowing me to represent the density and complexity of the theory (Strauss and Corbin, 1998). My final version of the diagram of the substantive-level theory of science teaching orientations is shown in Chapter 4.

2.8 Criteria for Evaluating the Research Study

In this section, I discuss criteria for evaluating the research methods used in the study, as well as criteria for evaluating the resulting theory. The discussion is divided into two sections. In Section 2.8.1, I offer criteria for evaluating qualitative research in general, drawing on the work of Erlandson, Harris, Skipper, and Allen (1993). In Section 2.8.1, the discussion focuses on the product of this research study, a grounded theory of science teaching orientations. In this section, I draw on the writing of Glaser and Strauss (1967) and Charmaz (2000). These criteria are offered as guidelines in assisting the reader in evaluating the methods and products of the research study.

2.8.1 Criteria for Evaluating Qualitative Research

To establish trustworthiness in a qualitative research study, researchers need to address issues of credibility, transferability, dependability, and confirmability (Erlandson et al., 1993). Credibility refers to the "degree of confidence in the 'truth' that the findings of a particular inquiry have for the subjects with which - and the context within which - the inquiry was carried out" (Lincoln and Guba, 1985, p. 290). From a constructivist viewpoint, an objective truth does not exist, so I draw on Erlandson et al.'s (1993) definition of credibility. Credibility is the compatible relationship between the constructed realities in the participants' minds and the realities attributed to them by the researcher. In the design of this study, I addressed the issue of credibility in several ways, including member checks, triangulation, referential adequacy materials, and peer debriefing (Erlandson et al., 1993).

A significant portion of the third interview was dedicated to member checking. "Because the realities that will be included are those that have individually and collectively been constructed by persons within the context of the study, it is imperative that both data and interpretations obtained be verified by those persons," state Erlandson et al. (1993, p. 31). In the third interview, I shared my interpretations of the data with each participant. The interpretations were in the form of diagrams that represented each participant's science teaching orientation(s). Participants were asked to react to the diagrams. In all cases, the participants agreed with the major categories and properties representing their science teaching orientations. I also collected referential adequacy materials to give a holistic view of the classroom context (Erlandson et al, 1993). These materials consisted of class schedules, unit outlines, lab hand-outs, worksheets, tests and other curricular materials. Peer de-briefing is another strategy for addressing the issue of credibility. Erlandson et al. state:

> Occasionally the researcher should step out of the context being studied to review perceptions, insights, and analyses with professionals outside the context who have enough general understanding of the nature of the study to debrief the researcher and provide feedback that will refine and, frequently redirect the inquiry process. (p. 31)

During data collection and analysis, I scheduled meetings with my thesis advisor, Dr. Thomas Dana. During these meetings, I shared my analytic memos in the form of diagrams. During these meetings, I received critical feedback, oftentimes re-directing my data collection process to explore new categories or relationships between categories.

Transferability refers to the extent to which a study can be applied in other contexts or with other respondents (Lincoln and Guba, 1985). Erlandson et al. (1993) state, "The naturalistic researcher maintains, however, that no true generalization is really possible; all observations are defined by the specific contexts in which they occur" (p. 32). The burden of transferability is left to the reader. To facilitate judgments about transferability, Erlandson et al. recommend that researchers employ the following strategies: thick descriptions and purposive sampling. In Chapter 3, I have included detailed descriptions of each participant's background, teaching context, and the nature and probable sources of their individual science teaching orientations. This chapter was included to give the reader sufficient information to make judgments relating to transferability. Purposive sampling is the second strategy recommended to facilitate transferability. Erlandson et al (1993) describe purposive sampling:

> In contrast to the random sampling that is usually done in a traditional study to gain a representative picture through aggregated qualities, naturalistic research seeks to maximize the range of specific information that can be obtained from and about that context (Erlandson et al., 1993, p. 33).

In grounded theory studies, purposive sampling is referred to as theoretical sampling. As described in Section 2.5.1, participants were selected on the basis of their ability to contribute to the development of theory (Creswell, 1998). Refer to Section 2.5.1 for the criteria used in selecting participants.

Dependability refers to repeating the study with the same participants or similar participants, and arriving at similar interpretations (Lincoln and Guba, 1985). However, the naturalistic researcher strives for trackable variance that can be attributed to various sources, such as reality shifts in the participants. Qualitative researchers strive for consistency and explainable variation. In qualitative research, dependability is addressed in a dependability audit (Erlandson et al., 1993). I have left an audit trial to facilitate a dependability audit. Interview transcriptions, field notes and detailed analytic memos were kept as a record, making it possible to conduct an external audit for dependability.

Confirmability refers to the degree to which the findings represent the data and not the biases of the researcher (Lincoln and Guba, 1985). "The naturalistic researcher, however, realizes that objectivity is an illusion and that no methodology can be totally separated from those who have created and selected it," states Erlandson et al., (1993, p.

34). They suggest, "An adequate trails should be left to enable the auditor to determine if the conclusions, interpretations, and recommendations can be traced to their sources and if they are supported by the inquiry" (Erlandson, 1993, p. 35). Materials for the audit trial include raw interview data; field notes, analytic memos; and open, axial and selective coding records. In grounded theory research, this issue is addressed through the use of constant comparative methods, with the researcher constantly returning to the data to compare the data to the emerging theory.

2.8.2 Criteria for Evaluating Grounded Theory

The last section, Section 2.8.1, discusses issues of trustworthiness relating to qualitative research studies in general. In this subsection, I address criteria for evaluating grounded theory studies, drawing on the work of Glaser and Strauss (1967), Glaser (1978, 1992), and Charmaz (2000). Fit, work, relevance and modifiability are identified as criteria for evaluating grounded theory. Glaser and Strauss (1967) discuss the criteria of fitness, “It may seem an obvious requirement that a grounded theory, particularly a substantive theory, must correspond closely to the data if it is to be applied in daily situations” (p. 238). Charmaz (2000) elaborates, “Theoretical categories must be developed from analysis of the collected data and must fit them, these categories must explain the data they subsume” (p. 511). As this study generated a substantive-level theory, the fitness criterion was easily met. Through constant comparative methods, the data was compared to the emerging theoretical framework. In Chapter 3, detailed descriptions of each participant’s science teaching orientation(s) are provided. The inclusion of this material allows the reader to evaluate the fit between the data and the substantive-level theory generated in this study.

Glaser (1978) defines a theory as working in the following way, “By work, we meant that a theory should be able to explain what happened, predict what will happen and interpret what is happening in an area of substantive or formal inquiry” (p. 4). Again, through the constant comparative method, the data are constantly checked against the emerging theory. As a final step in developing the substantive-level theory, I re-checked each participant’s science teaching orientation diagram against the proposed substantive-level theory. The proposed substantive-level theory also has predictive power in regard to the influence of various sources of an individual’s science teaching orientation, as well as the nature of science teaching orientations. The proposed substantive-level theory also predicts the relationship of means to the nature and sources of science teaching orientations. On another level, the substantive-level theory also works within the larger models of domains of teacher knowledge. This idea is further elaborated in Chapter 5.

“The relevance of a grounded theory derives from its offering analytic explanations of actual problems and basic processes in the research setting,” states Charmaz (2000, p. 511). Glaser (1978) notes that relevance is not automatically achieved in theory development. Relevance can be missed when researchers draw on theories from other fields, rather than concentrating on allowing the theory to emerge from the data. At the beginning of the study, I sensitized myself to the existing categories of science teaching orientations. However, I rejected the notion of forcing the data to fit into existing categories, but rather I generated new categories as they emerged from the data.

The substantive-level theory is sufficiently flexible to allow for modifications. Three general characteristics of the nature of participants' science teaching orientations are proposed in Chapter 4. This aspect of the substantive-level theory is not closed-ended but allows for additional characteristics to be added as the theory is further developed. The sources of science teaching orientations are also presented in a format, past and present sources, that allows for elaboration. The relationships between the nature, sources and means of science teaching orientations are proposed, but the theoretical framework allows for additional relationships to be defined.

2.9 Summary and Preview

In this chapter, I have attempted to make my research process more apparent to readers of this study. I have shared my research decisions and rationale as the study progressed from conception of the research questions, through research design, data collection and analysis to the development of substantive-level theory. I have also included a discussion of my personal beliefs and biases that may have influenced decisions made during the research process. While grounding the substantive-level theory in the data, I have connected the research process to scholarship in grounded theory methods. In discussing issues of established quality criteria, I have identified general qualitative research criteria and criteria specific to grounded theory.

In the next chapter, I introduce each of the participants, providing information about school contexts, the nature of individual science teaching orientations and probable sources of their teaching orientations. The reader is cautioned that the information provided in Chapter 3 should not be viewed as the substantive-level theory. Chapter 3 illustrates the inductive process used in data analysis. The substantive-level theory of science teaching orientations is presented in Chapter 4.

Chapter 3

Context, Nature and Sources:

Introduction to the Participants

3.1 Introduction

Stake (1995) emphasizes the importance of context in qualitative research, "Qualitative researchers treat the uniqueness of individual cases and contexts as important to understanding. Particularization is an important aim, coming to know the particularity of the case" (p. 39). In this study, I have defined the construct of science teaching orientations as the overall case. Each participant in the study is an instance or particularity of the larger case. To help readers better understand the case of science teaching orientations, I have chosen to share the particularity of each individual teacher in the study. Readers should not view the information in this chapter as the substantive-level theory generated in this dissertation study. The information in this chapter is provided to show the initial stages of the inductive process used to generate the substantive-level theory.

This chapter is included so that the reader may glean characteristics of each participant in the study. In the following sections, I show how I used individual data sources to characterize the nature and sources of each participant's science teaching orientation. In the overall study, it is not the individual participants that are important. In this chapter, I am sharing part of the inductive process that I used to construct the substantive-level theory presented in Chapter 4. For each individual, I have provided the context, representations of the nature of their science teaching orientations, and probable sources. This information is provided only to give the reader a sense of the different contexts, the individual representations of the nature of science teaching orientations and probable sources.

The nature of an individual's science teaching orientation is represented with a diagram. With the participants' input, I constructed a separate diagram for each biology course taught by the participant. The participants' teaching orientations should not be viewed as static. Participants gave evidence that their teaching orientations had evolved over time. However, the development of science teaching orientations across time is beyond the scope of this study. The interpretations represent a snapshot in time of the participants' science teaching orientations. Each participant's section ends with a discussion of probable sources (i.e., influences) on the formation of their science teaching orientations.

All research is based on interpretation (Stake, 1995). In this chapter, I offer my interpretations of the data collected from each participant. In part, the interpretations are co-constructions between the participants and myself. I constructed the initial representation of each participant's science teaching orientation based on interview data and field notes. A major portion of each participant's third interview focused on examining the representations. Each participant agreed with the major categories in the representation of their science teaching orientations. During the interviews, some minor revisions and elaborations were made to the diagrams. The representations evolved from the original simple list format to more elaborate diagrams, including central and peripheral components (see Figures 3.1-3.7). The central goals are defined as the participant’s primary goals and purposes for that course, and are represented by octagonal shapes. Peripheral goals and purposes play a lesser role in teacher decision-making, but are still part of the participant’s teaching orientation. Peripheral components of an individual’s science teaching orientation are represented in the diagrams with rectangles. At Sharon’s suggestion, the concept of means was included in the diagrams. Means are defined as instructional and assessment strategies used by the teacher to help students achieve the goals and purposes of the course. After the data collection phase ended, the diagrams underwent additional revisions as I continued to analyze the data. In general, these revisions consisted of adding peripheral components and elaborating the means used by each participant.

The substantive-level theory of science teaching orientations is presented in Chapter 4. The diagrams shown in this chapter served as analytic memos for generating theory across the four participants. The substantive-level theory regarding the nature of science teaching orientations is found in Chapter 4.3. The sources component of the substantive-level theory is presented in Chapter 4.4. The information in this chapter is included only to show the particularity of each individual participant.

3.2 Sharon

Based on sampling criteria, Sharon was recommended for this study by a science education professor and a graduate student who had supervised pre-service secondary science practicum students placed with her. Sharon was identified as a biology teacher with a strong environmental focus. Sharon routinely takes her students on field trips and involves them in outdoor projects, such as habitat restoration, building bluebird boxes and stream monitoring. Initially, Sharon was hesitant to participate in the study because of her busy schedule. As the study progressed, Sharon stated that she enjoyed participating in the research study and had gained insight into her own teaching. In working with Sharon, I found her to be a thoughtful, reflective practitioner. Of the four participants, Sharon was the most articulate in expressing her goals/purposes and means of teaching biology, and was able to readily identify the sources of her science teaching orientation. In the following sub-sections, I share more of the particularities of Sharon as a biology teacher. The first sub-section explores Sharon's background and describes her school context. The remaining sub-sections describe the nature of her science teaching orientation and probable sources.

3.2.1 The Context of Sharon's Teaching

Sharon teaches in a school district comprised of many, small rural communities. She teaches in the secondary building which houses approximately 1100 students in grades 7–12. Sharon characterized the school district as having a majority of families who were not well educated or wealthy. According to the Pennsylvania Department of Education's School Profiles for 1999-00, approximately 30% of the students in Sharon's building were identified as being from low-income families. Of the seniors graduating in 1999, approximately 60% indicated their intent to attend a postsecondary degree-granting institution, compared to the state average of 69.6% (Pennsylvania Department of Education [PDE], 2000). Many of the students in Sharon's classes will not go to college but will instead find jobs in the area (1st Interview, 3/14/01). Sharon thinks her students are fortunate to live in this geographical area. "I'm working with a population of students that are lucky enough to have enormous wealth in natural resources, and they don't necessarily have parents that think about saving these natural resources in the long run," said Sharon (1st Interview, 3/14/01).

Sharon has 16 years of science teaching experience, and has been teaching in her present school district for five years. Prior to this assignment, Sharon taught biology for ten years in another state. In her first teaching position, Sharon began to organize her biology curriculum with an environmental focus. Sharon's current teaching assignment consists of one section of Biology II, a one semester elective course, and multiple sections of Environmental Science. Sharon's initial assignment in this district was to teach junior high physical science courses, although she quickly began incorporating environmental units, such as water chemistry, into these courses. In her second year of teaching in the district, she was assigned to teach an elective course, Biology II. Sharon gave the Biology II course an environmental focus by including an extensive ecology unit. In her fourth year of teaching, Sharon was able to offer elective courses in Environmental Biology.

In exploring Sharon's background, she describes her family as being "nature lovers." As a child, Sharon spent a lot of time outdoors and often helped her mother who worked at a nature center (2nd Interview, 3/23/01). As an undergraduate, Sharon earned a degree in Natural History**.** At that time, she was not interested in becoming a classroom teacher. After graduation, Sharon worked as a naturalist for several years. Tired of temporary positions, Sharon decided to become a classroom teacher and returned to college for certification in secondary biology teaching. Sharon's science teaching orientation has a central component of "developing environmental decision-making."

At first glance, this orientation might be considered an outcome of her current teaching assignment, primarily that of Environmental Science courses. By reviewing Sharon's teaching background and the history of her current teaching position, one sees that Sharon's central goal of environmental decision-making pre-dates her current teaching position.

3.2.2 A Representation of Sharon's Science Teaching Orientation

Sharon's science teaching orientation for the Environmental Science course is represented in Figure 3.1. Sharon's student teacher was primarily responsible for selecting topics in the Biology II course, therefore, we made a decision to focus on Sharon's goals/purposes and means in her Environmental Biology course. Sharon holds two primary goals for her Environmental Science students. Developing environmental decision-making is one of her primary goals. The category has three dimensions that are sequential. Sharon first wants her students to develop an awareness of the plants and animals in their environment. After students become aware of other inhabitants of their environment, she wants the students to develop a caring attitude towards these organisms. As a final dimension, Sharon wants her students to value their natural resources and make sound environmentally-based decisions in regard to their natural resources. To help students meet this goal, Sharon uses a variety of means, including: extensive use of field trips, identification of native species, animals in the classroom, reading of newspaper articles about environmental issues, and the engagement in environmental projects, such as building bluebird boxes.

Sharon's goals and purposes for her students are based on the premise that students find school to be boring. Based on this premise, Sharon's other central goal is to have her students develop a positive attitude toward science. Dimensions of this category include making science interesting, having her students develop a good feeling about science and having her students see real life connections between science and their lives. Sharon employs a variety of means to help her students develop positive attitudes toward science. Sharon likes to involve her students in full day canoe trips, which serve as immersion experiences in environmental studies. Sharon uses a variety of teaching strategies to keep the students interested and to entertain them. Sharon feels that students will develop a positive attitude towards science if they are engaged in real life, authentic science projects, such as wetlands studies.

There are also peripheral components to Sharon's science teaching orientation; developing an understanding of science content is one peripheral goal. Sharon feels that if students first have a positive attitude toward science they will be open to learning science content. As students develop an awareness of the organisms around them and begin to care for these organisms, they will increase their science content knowledge. The development of life skills is another peripheral component of Sharon's science teaching orientation. Sharon feels that it's important for students to be able to observe and to express their thoughts orally and in writing. Another peripheral goal is the development of science process skills, particularly observation skills, as well as data collection and analysis skills. Sharon relies on field trips as a primary means of helping her students achieve the goals of the course Time constraints in the daily schedule conflict with Sharon's preferred means. She was able to arrange double lab periods for some of her classes, but continues to feel the constraints of the school's traditional 42-minute class period schedule.

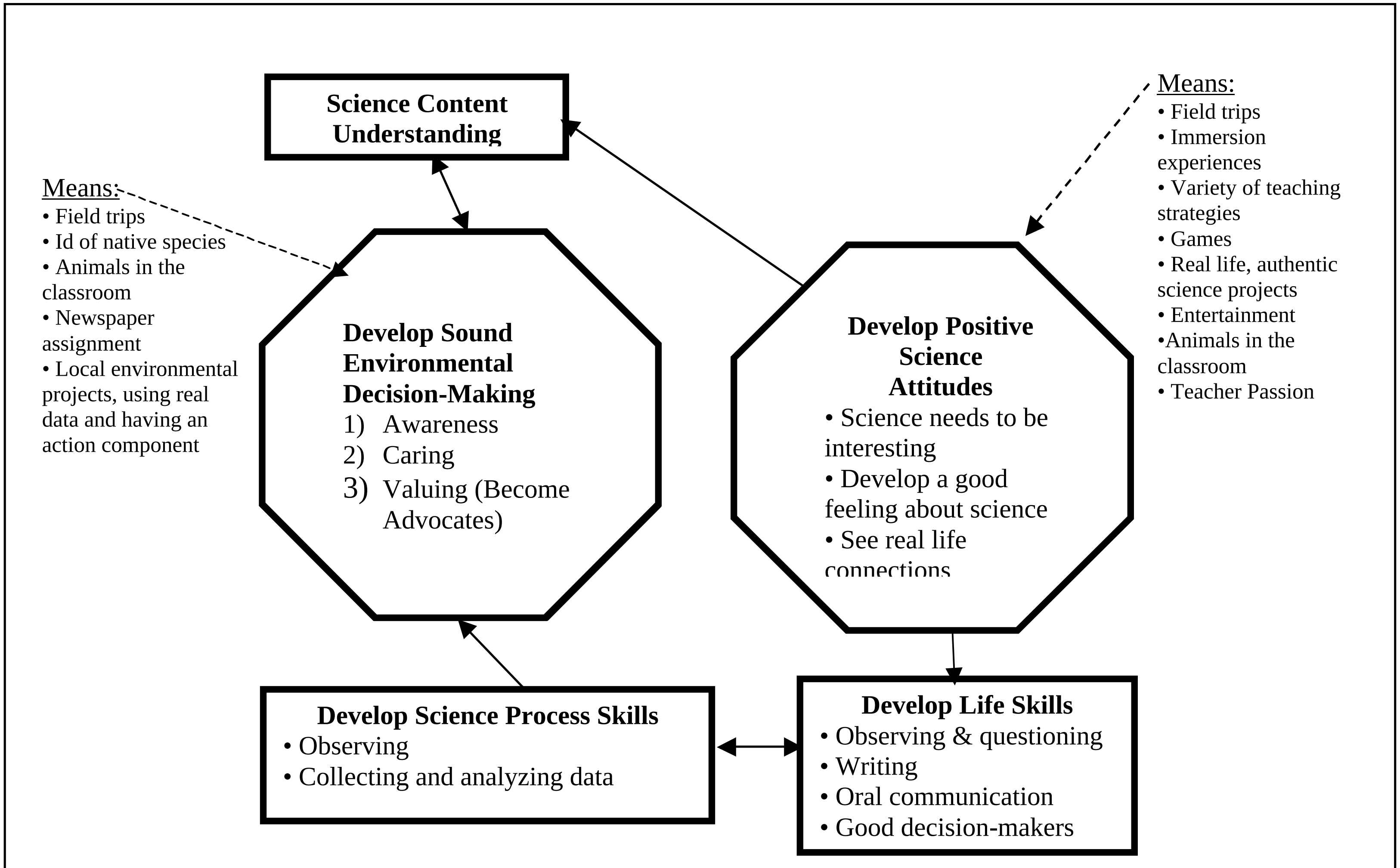

Figure 3.1. Representation of Sharon's science teaching orientation

3.2.3 Probable Sources of Sharon's Science Teaching Orientation

In the initial interview and subsequent follow-up interviews, I collected biographical information from each participant. As each participant's goals and purposes, as well as means, were articulated, I asked participants to reflect on the sources of their science teaching orientation. In Sharon's case, it was relatively easy to elicit this information. After graduation from college, Sharon worked in a variety of informal science settings, including the National Parks Service and a private environmental consortium. These work experiences gave Sharon experience working with school-age children in an outdoor setting. Sharon discusses her work as a field instructor for a private consortium:

> Teachers brought their kids to me for three days and I took them out on the ocean and I took them to the marsh and I only did outside work and that shaped how I teach enormously because I have no problem taking kids outside and doing things with kids outside. And I believe that all kids have to go, be outside. (1st Interview, 3/14/01)

Later in the interview, Sharon states that she typically does not have students memorize vocabulary terms, but she does require the students to learn the names of local birds, fish, amphibians, and reptiles. Sharon feels that if students know the names of organisms that they are more aware of what lives in their environment. Sharon attributed this philosophy to her work with a private marine consortium (1st Interview, 3/14/01). Sharon's purposes and goals for teaching biology, as well as her means, were directly shaped by her previous work experience as a naturalist.

Sharon's selection of professional development opportunities is closely aligned with her science teaching orientation. Sharon has participated in workshops such as

Project Wild, Project Aquatic and Project Wet. Sharon also enrolls in science content courses, stating, "I've always taken any course that dealt with the environment" (1st Interview, 3/14/01). Sharon identified colleagues as another source of professional development. In her previous teaching job, Sharon collaborated extensively with a colleague who taught in the next classroom. Sharon felt that her teaching philosophy was shaped by her work with this colleague. In her first teaching position, Sharon was also involved with a group of 12 teachers who did water monitoring and conducted workshops. Currently, Sharon collaborates with a private foundation to organize and facilitate extended fieldtrips. She occasionally collaborates with science faculty from nearby universities. Sharon values her collaborations with scientists because it helps her grow as a professional and it allows her students to become involved in authentic science projects, such as invertebrate and wetland studies.

Sharon's focus on students is another source of her science teaching orientation. Sharon designed and implemented the Environmental Science course because she felt strongly that students needed another science course option other than chemistry or physics. In discussing her teaching orientation, Sharon stated, "I think school is boring, and kids are bored, and bored kids get in trouble" (1st Interview, 3/14/01). Based on this premise, she wants students to have a positive experience in school and in her classes. Sharon stated, "And this is a long day for them [the students] and to come be yakked at all day is a crime and it makes me mad. They don't deserve that" (1st Interview, 3/14/01). Sharon started to incorporate outdoor problems into her physical science classes. "I used outdoor problems, because I knew that was what would interest them" (1st Interview, 3/14/01). Sharon uses projects and field trips because she doesn't think students learn by listening to lectures. She feels that students have to be actively involved in order to learn. Sharon also feels that the natural environment is her students' greatest wealth. Not all of her students will go on to college, but they may inherit land from their parents. Because of this, Sharon wants to foster sound environmental decision-making, in the hope that her students will be stewards of the land. Sharon's Environmental Science course is popular with the students. "The kids love the class and they're like can't you do Environmental Science II?" (1st Interview, 3/14/01). Sharon receives positive feedback from her students, which may re-enforce her science teaching orientation.

Time constraints shape the means that Sharon uses to help her students achieve the goals and purposes of the course. Immersion-type field trips are Sharon's preferred instructional means. The regular class schedule does not allow her to take the students on long field trips. Sharon was able to negotiate double class periods in her afternoon classes to help accommodate short field trips. On occasion, Sharon is able to re-arrange her daily schedule to take a group of students on a half-day field trip. Sharon talked about her idealized class schedule. She would like to be able to re-arrange her teaching schedule to take each class on a monthly full day field trip. With this format, Sharon could organize curriculum units around field trips. The beginning of each unit would focus on preparation for the field trip and data collection methods, with post-field trip activities focusing on data analysis.

Engaging students in environmental action projects is another of Sharon's preferred means. Class schedule constraints, as well as limited personal time, have influenced the number of action projects Sharon uses with her students:

> I used to be heavy into action before I had children, and that's why I don't do it as much, because of the time constraint and the amount of time it involves in setting up action projects. . . . [In the past,] we've built osprey platforms, we've planted marsh grass, we've done beach clean-ups. I've always built bluebird boxes. (2nd Interview, 3/23/01)

Because of class schedule constraints and a limited amount of personal time, Sharon has reduced the number of action projects that she uses. She continues to have students build bluebird boxes because they are able to fit this into the normal class schedule.

3.3 Mike

Mike was recommended for the study by a science education professor who had worked with Mike and his students at science fair competitions. Initially, Mike was hesitant to become involved with the study. Mike felt there were other teachers who fit the criteria of "exemplary" better than he did. Mike was selected, in part, because he had recently received a state teaching award. Mike is also active in professional development, both as a participant and as a workshop leader. Mike is a storyteller by nature, both in the classroom and during interview sessions. Mike found it difficult to articulate his goals and purposes for teaching biology. It was easier for Mike to discuss the means he used in his teaching; therefore by discussing Mike's means, he was able to articulate his goals and purposes for teaching biology. Mike was a busy teacher, as were all the participants. Along with his classroom teaching assignment, Mike juggled the demands of administrative duties, coaching, and parenting a large family. The following sub-sections describe the context of Mike's teaching, discuss representations of Mike's science teaching orientations and offer probable sources of Mike's teaching orientations.

3.3.1 The Context of Mike's Teaching

Mike teaches in a school district in a small town, which he identified as a bedroom community of a nearby city. Mike teaches in the junior/senior high school building with a student population of approximately 550 students. Mike characterizes the school as representing the make-up of the town, with two major groups of people, "the haves and the have nots" (2nd Interview, 4/06/01). According to the Pennsylvania Department of Education's School Profiles for 1999-00, approximately 18% of the students in Mike's building were identified as being from low-income families. Of the seniors graduating in 1999, approximately 72% indicated their intent to attend a postsecondary degree-granting institution, compared to the state average of 69.6 % (PDE, 2000).

Mike has taught science for approximately 15 years. During the study, Mike taught four sections of Life Science for 8th graders and one section of Advanced Placement (AP) Biology. Mike considered himself to be a biology educator, having taught General Biology, Honors Biology, Human Anatomy and Physiology, as well as Environmental Science. Mike had also taught courses in physical science, earth science and geography.

Mike did not begin his career as a science teacher. In college, Mike had wanted to become a lawyer so he could "run for office and change the world" (3rd Interview, 4/6/01). The Vietnam War interrupted Mike's college education. After serving in the military, Mike completed an undergraduate degree in Secondary Education Social Studies. Due to a scarcity of teaching openings at that time, Mike took a job in retail business. While Mike was in business, he realized that all he really wanted to do was teach. After ten years working in the business field, Mike decided to return to college. Mike asked a friend's advice about what subject he should teach, and the friend suggested science. Mike had enjoyed his science classes as a senior in college, and based on the friend's advice, he chose to pursue a biology and general science certification. After obtaining a teaching degree, Mike earned a master's degree in biology. While working on his master's degree, Mike was a research assistant in the biology department. Shortly afterwards, Mike began teaching secondary science.

3.3.2 Representations of Mike's Science Teaching Orientations

In Mike's current teaching assignment, he was teaching Life Science for 8th graders and AP Biology. As data was being collected, Mike and I compared and contrasted his teaching orientations for these two courses. Separate representations of Mike's science teaching orientation were created for each course. Refer to Figures 3.2 and 3.3 for diagrams of Mike's science teaching orientations. In Life Science, Mike has a single, central goal for his eighth grade students. Mike wants his students to wonder about and appreciate the complexity of life. "With my eighth graders, I just want them to wonder about stuff, " Mike stated (Card Sort, 3/21/01). After the first interview and classroom observation, I recorded the following analytic memo: "Mike mostly wants kids to be curious and to think and wonder about things, there is not necessarily an action component for this grade level" (Analytic Memo, 3/21/2001). Promoting students' curiosity is an important dimension of this central goal. Mike wants the students to ask questions about the world around them. He wants the students to be engaged in discovery. Mike wants the students to think that biology is "cool" because life is so intricate and complex. As an example, Mike discusses the incredible process of photosynthesis and explains that this process is going on in every green leaf.

In his AP course, Mike has the same central goal of wanting his students to wonder about and appreciate the complexity of life. However, Mike has an additional central goal for his AP students; he wants his students to develop the skills and tools to explore their questions. Mike requires each of his AP students to do an independent science research project. Oftentimes, the students enter these projects in science fair competitions. Mike feels this experience helps his students develop research skills that can be used to answer some of their own questions. Another dimension of this central goal is to have students develop the ability to "think beyond the box." Mike uses this phrase frequently, referring to his desire to have students be critical thinkers. Mike assigns college-level position papers, requiring the students to take a stand on bioethical issues.

Mike's science teaching orientations consist of peripheral components, too. In both courses, Mike wants students to understand basic biological concepts. In the interviews, Mike did not emphasize the importance of content knowledge. Mike feels that if his students are curious, then content knowledge will follow. In his Life Science course, Mike uses stories to teach key biological concepts. He prefers to start with something familiar to the students, and then proceed by breaking the new information into manageable chunks. Mike teaches photosynthesis by telling the story of the sweet little carbon dioxide molecule and her encounter with the nefarious character, RuBP (Card Sort, 3/21/01). In AP Biology, Mike uses textbook readings and class discussions as a means to teach the content.

Mike's orientations for the two courses differ in significant ways. In the AP Biology course, the goal of developing skills and tools is a central component of Mike's science teaching orientation. In the Life Science course, Mike shifts this goal to a more peripheral component of his orientation. When Mike describes dimensions of his goal to help students develop tools and life skills, the skills are more general in nature. Although Mike includes skills such as classification and observation, he doesn't consider these skills to be science-specific. Challenging the students to be successful is one important means that Mike uses to help students develop tools and life skills. Mike likes to give challenging lab practicals because it shows the students they can be successful. For the AP students, Mike has an additional peripheral goal, that of helping prepare the students for college. Mike uses the following means to help students prepare for college: practice AP examinations, lengthy textbook reading assignments, class discussions and essay writing.

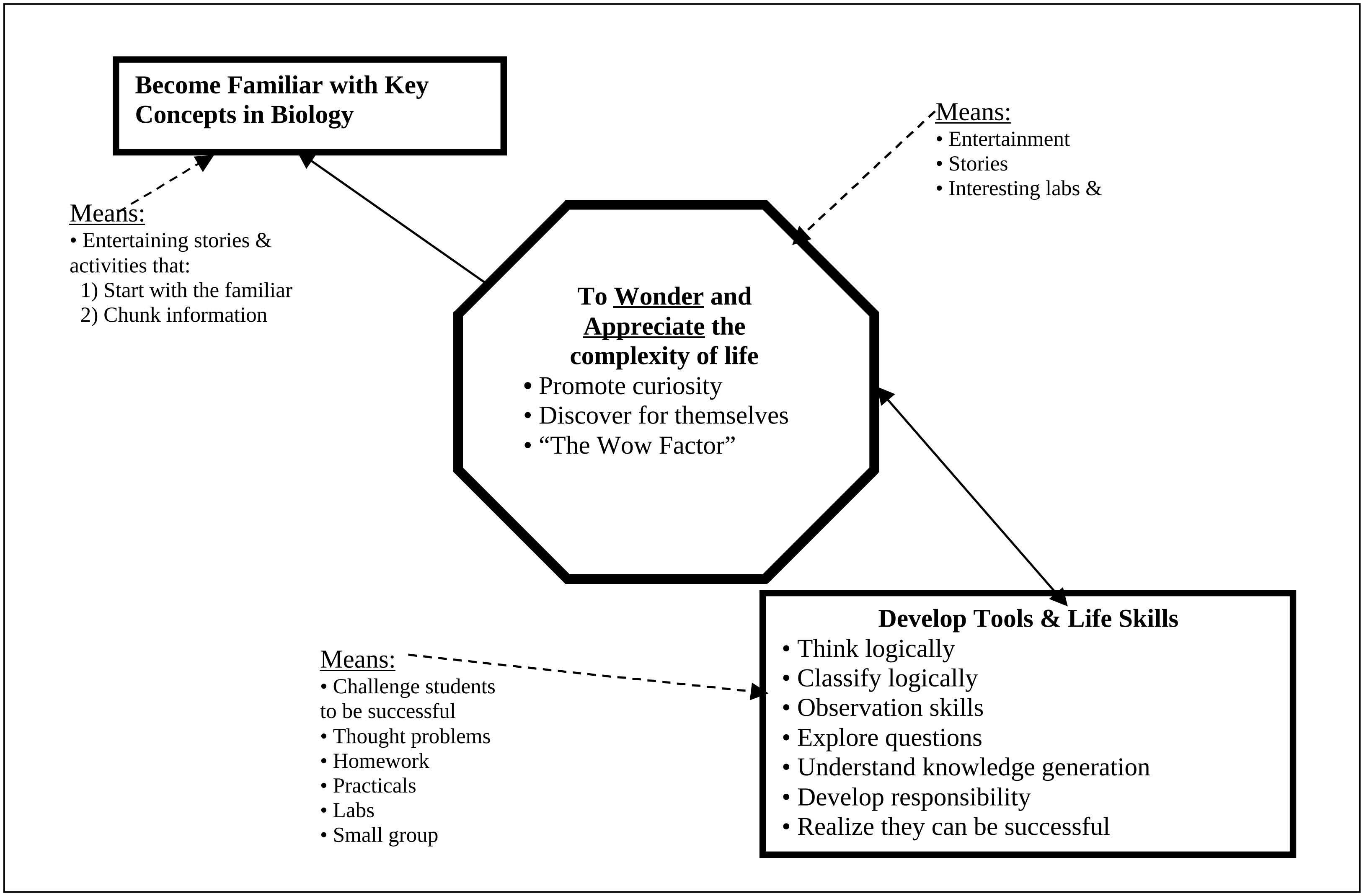

Figure 3.2. Representation of Mike's science teaching orientation for Life Science

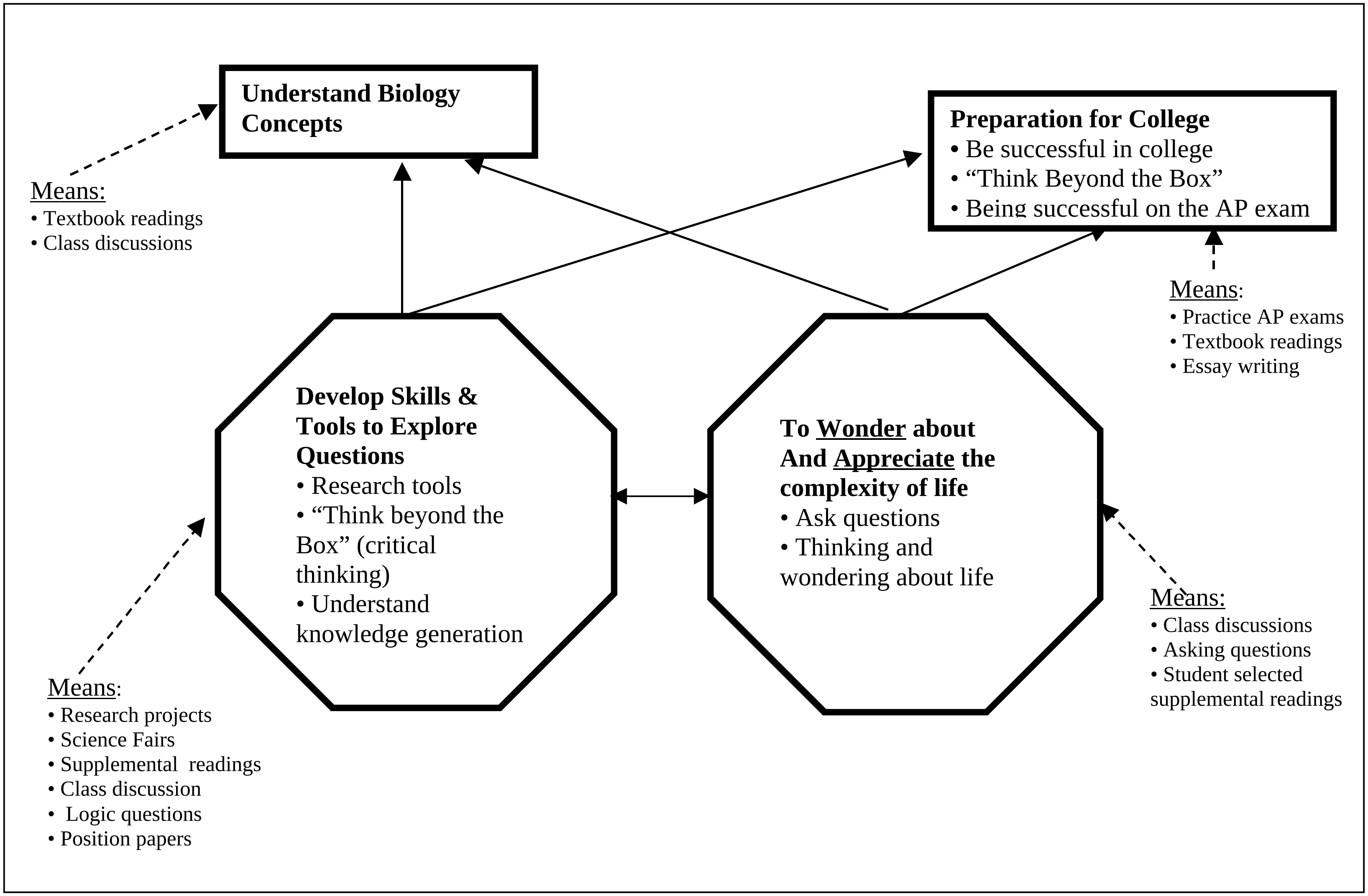

Figure 3.3. Representation of Mike's science teaching orientation for AP biology

3.3.3 Probably Sources of Mike's Science Teaching Orientation

It was difficult for Mike to articulate probable sources of his science teaching orientation, so we began by discussing Mike's background. Mike had worked as a manager in a retail business for ten years. Mike discussed what he valued in a good employee and how he thought employees should be treated. In discussing the school district's mandatory homework policy, Mike draws on his business background:

> Most of the kids, I don't think it's [homework] as valuable because of all the other projects and things we're doing, except for to teach you that you have a job to do . . . this is just something, and it's going to be like that out in the real world. In the real world, you have tasks that are due, and they're due to be done in a certain way, and due at a certain time, and if I can teach you that, that's a job skill that's important in the future. (3rd Interview, 4/6/01)

So, Mike views homework more as a way to develop job skills than as a way to re-enforce science concepts. Mike drew another connection between his past work experience and components of his science teaching orientation for the AP Biology course. As part of Mike's master's program in biology, he worked as a research assistant for 1 1/2 years. I asked Mike how this research experience influenced his teaching. "It's the reason why the AP kids do research projects" (3rd Interview, 4/6/01). In this case, Mike was able to quickly identify the source of one of his goals in the AP Biology course.

As we explored additional influences shaping Mike's teaching orientations, Mike described his former science methods professor. Mike's professor encouraged his students to challenge themselves throughout their teaching career by being active in professional development. Each summer, Mike participates in teacher workshops.

> It's my job to stay ahead of the students' needs and so, again, if I don't go some place in the summer time to study something, I would feel that I let Dr. ____ down, and I just simply cannot do that. (3rd Interview, 4/6/2001)

Partially because of his duties as science department chair, Mike chooses to participate in summer workshops on a wide range of topics. Primarily, though, Mike selects workshops on the basis of what interests him at that time. Mike is a curious individual, and his choice of professional development activities appears to be driven by his curiosity. Mike is also involved in providing professional development. Each year, Mike conducts a full day workshop for secondary biology teachers, with the topics varying from year to year, depending on his current interests.

Mike differs from the other participants in that he didn't major in science as an undergraduate. After a career in business, Mike decided to pursue his dream of being a teacher. Based on the advice of a friend, Mike decided to be a teacher of science. Mike was more focused on teaching kids than the subject he would teach. Mike agreed with his friend's advice, thinking it would be easier to engage students in science than in other subjects (Analytic memo, 3/21/01). Mike's focus on the students was a re-occurring theme in our interviews.

The students' feedback influences and shapes Mike's science teaching orientation. In Mike's Life Science course, he often uses storytelling as a means of teaching the science content. "I believe they'll listen to a story way faster than they'll listen to me say that there is ribulose biphosphate and . . ." (Card Sort, 3/21/01). As a parent and a teacher, Mike is knowledgeable of the students' culture, referring to the influence of MTV, video games and Pokemon. As a teacher, Mike feels he has to be entertaining to compete for the eighth graders' attention. Labs and demos are additional means that

Mike uses to compete for the students' attention. However, Mike is selective about labs, using only those labs and demos that he thinks will fascinate his students. I asked Mike how he decides if he wants to keep an activity from one year to the next.

> M: Oh, well, you pick that up from the kids.
> I: And what is it about the kids?
> M: Their general enthusiasm level and the fact that they've learned something . . . and they thought it was really cool, you know." (Card Sort, 3/21/01)

Some of Mike's favorite labs involve exploding egg membranes and transformation of glowing jellyfish genes in microbes. When asked to elaborate on the aspect of "really cool," Mike connected back to his central goal for the Life Science students, wanting the students to wonder about and appreciate the complexity of life. In the AP course, Mike often receives feedback from the students after they have graduated. Mike's students often complain about doing research projects while they are in the AP course. Later, however, they often come back to visit Mike relating that the research project was valuable to them (3rd Interview, 4/6/01). Student feedback is an important source that shapes and influences Mike's science teaching orientations.

Perceived time constraints also play a part in shaping Mike's science teaching orientation. During the card sort, Mike related one of the card scenarios to his own experience using a BSCS DNA activity. In the activity, the students build DNA models from colored paper clips. Mike rejected this model-building activity because he felt it was "so time intensive . . . when it's all over, the kids don't really have any greater understanding of DNA than they did before they played with paper clips" (Card Sort, 3/21/01). We also discussed having animals in the classroom during the card sort. Mike likes to have animals in the classroom because the students can observe and wonder about the animals. He doesn't think it's worth his time to organize having the students be responsible for the animals' care. In AP Biology, Mike is especially sensitive to time issues. "I'm probably a unit behind right now and we're on Chapter 28 . . . which is a lot of chapters to go through in, you know, in this short of time" (Card Sort, 3/21/2001). Mike requires the AP students to design and carry out an independent research project, but the project work is done before and after school. Mike says that he does not have time for students to work on their research project during the AP class period. Mike's peripheral goal of preparing his AP students for the AP exam conflicts with Mike's central goal of developing skills and tools to explore their questions.

3.4 Peg

A science educator who had worked with Peg in science fair competitions recommended her for the study. Although she was very busy with science fair competitions, Peg expressed an interest in the study and agreed to participate. During the initial meeting, Peg warned me that she considered herself a traditional teacher. Peg was selected for the study partially because of her excellent reputation working with students in science fair competitions. Because of Peg's busy schedule, the data collection occurred during an intensive three day time period in May. Each day, I observed Peg teach all of her classes and conducted interviews during her planning period and after school. During the data collection process, Peg gave freely of her time. Peg is an introspective person who enjoyed reflecting on her teaching practice.

3.4.1 The Context of Peg's Teaching

Peg teaches in a high school located in a community of approximately 15,000. There are 1400 students enrolled in grades 9-12. Peg describes her students as primarily from middle class families (Field Notes, 5/16/01). According to the Pennsylvania Department of Education's School Profiles for 1999-00, 12% of the students in Peg's building were identified as being from low-income families. Of the seniors graduating in 1999, approximately 60% indicated their intent to attend a postsecondary degree-granting institution, compared to the state average of 69.6% (PDE, 2000).

Peg has been teaching in her present school district for over twenty years. Peg has also taught in several other school districts. Peg differs from the other participants in that she has been a high school teacher throughout her career. As an undergraduate, Peg did not initially plan to become a teacher. To fulfill the community service requirement in one of her courses, Peg volunteered at her former high school. Based on that two-week experience, Peg decided to add a secondary teaching endorsement. Peg majored in botany and was involved with research projects with her professors. As she was nearing graduation, Peg was encouraged to pursue a doctorate. Peg was engaged to be married at that time and did not consider a doctoral program. Peg taught abroad for a few years and upon returning to the United States, she earned a master's degree in education.

Peg's current teaching assignment includes three sections of College Prep Biology, one section of Physical Science, and an Independent Research course. In the past, Peg has also taught environmental science. In the College Prep Biology course, a tenth grade course, Peg uses the green version of the Biological Sciences Curriculum Study (BSCS) textbook. In the Independent Research course, each student designs and carries out a college-level research project for science fair competitions. When Peg began teaching in her current school district, the high school students were not involved in science fairs. After three years in the school district, Peg received permission to do a small science fair with her ninth grade students in an advanced physical science class. The science fair gradually expanded and now Peg is able to offer a separate Independent Research class with a separate classroom set aside for research. Peg's Independent Research students have a history of award-winning projects, top awards at the International Science Fair.

3.4.2 Representations of Peg's Science Teaching Orientations

The representations of Peg's science teaching orientations for College Prep. Biology and Independent Research are shown in Figures 3.4 and 3.5. On the final day of the data collection, I shared my tentative representations with Peg. Of the four participants, Peg was the most involved in the process of examining the diagrams and engaging in revision. Peg enjoyed the self-study aspect of her participation in the research project.

In the College Prep Biology course, Peg holds three central goals for her students. Peg wants the students to "have a solid understanding of biology concepts, become useful, productive, and informed citizens, and be prepared for college." As I continued to analyze the data, I made several revisions to Peg's representations for this course. Peg originally grouped "becoming a useful, productive, and informed citizen" with "preparation for college." As I looked at dimensions of this category, a division into two separate goals seemed to better represent the data. Peg also grouped "lab skills" with the goal of having a solid understanding of biology concepts. As the concept of central and peripheral components later emerged in the analysis process, I re-examined the data and shifted “lab skills” to a peripheral position (Analytic Memo, 10/5/01).

Peg feels that it is her job to give the students a solid background in biology. When asked about teaching strategies that she uses to help the students, Peg replied, “I teach mostly by question and answer, and lecture” (3rd Interview, 5/17/01). Peg also uses labs, demonstrations and videos as a means of illustrating the science content. Peg believes that students have to learn the material themselves. “They’ve got to sit there and learn it. I can’t learn it for them” (Interview 2B, 5/16/01). Peg’s primary means of teaching the science content is through assigned textbook readings.

Another of Peg’s central goals is to have the students become useful, productive and informed citizens. Developing personal responsibility is one dimension of this goal. As a means of fostering responsibility, Peg does not accept late assignments. Neatness and proper grammar are included in Peg’s grading criteria. Students are responsible for reading the text and preparing for tests. The development of critical thinking skills is another dimension of Peg’s central goal of developing useful, productive and informed citizens. I asked Peg to define critical thinking. “To me, making them use the knowledge that they have, maybe not even just biological knowledge, but all kinds of knowledge, to look at something from the real world and try and understand it,” replied Peg (Interview 2A, 5/16/01). Peg wants students to be able to connect topics, to apply knowledge in new contexts, and to be critical consumers of information in the popular press. Peg gives the students critical thinking exercises and includes critical thinking items on her tests. The critical thinking questions test the students’ understanding at an application level.

Peg's third central goal is to prepare her students for college. "I want them to be as prepared as I can get them for college Bio 101 because this may be the last biology they have" (Interview 2A, 5/16/01). Peg includes the development of study skills as one dimension of this goal. [With some classes] I may spend some time with study skills. And show them things to do and tell them how I study" (Interview 2B, 5/16/01). Peg thinks that being able to read a science textbook is an important skill to be successful in college. "I think I need to teach them to be able to take a textbook that they're going to get in college and read a chapter and have a clue about what's important here" (Interview 2B, 5/16/01). To help students achieve her goal, Peg assigns textbook readings and homework assignments. The students are responsible for learning the material from the assigned readings.

Peg has one peripheral goal of having her students develop lab skills. Peg described such skills as recording observations, using a microscope, designing a dichotomous key and graphing as being important. Peg uses labs and lab notebooks as a means to achieving this peripheral goal. Peg does not like discovery activities, but prefers to use labs that clearly illustrate the biological concept being studied (Interview 3A, 5/17/01). Therefore, the peripheral goal of developing lab skills supports Peg's central goal of developing a solid background in biology.

Peg designed the Independent Research course to provide an opportunity for gifted students to engage in college-level science and to eventually excel in college science courses (Interview, 5/17/01). Peg has one central goal in her science teaching orientation for this course. She describes this goal as "doing science at the college level." Peg identifies the following dimensions of this goal. She wants students to use the scientific method and develop specialized science skills. Peg also wants students to understand that scientific knowledge is generated through a building process. As a means to accomplishing this central goal, each student designs and carries out an independent research project. In this course, one of Peg's primary roles is to help each student find a testable question that interests him or her. Students read 50-60 scientific journal articles on their selected topic and communicate with scientists, via e-mail, as they develop their research projects.

In the Independent Research course, one of Peg's peripheral goals is for the students to consider pursuing careers in science or in science-related fields. Peg has a strong interest in encouraging female students to pursue science careers (Interview 2A, 5/16/01). Peg has developed an especially close rapport with her Independent Science students and keeps in contact with former students, many of who are pursuing undergraduate degrees in science. Developing lab confidence is another dimension of this goal. Peg feels that if students are confident in their lab skills they are more likely to consider pursuing a career in science. Science fair competitions are the primary means that Peg uses to have her students consider science careers. Science fair competitions are also used as a means to help students achieve Peg's other peripheral goal, that of developing a belief in personal success. Peg identifies recognition and self-satisfaction as dimensions of this goal. Awards in science fair competitions and publication of articles in scientific journals are some of the forms of recognition that the students receive. Peg also feels strongly that students gain a sense of self-satisfaction through the process of completing an extensive research project. Throughout the research process, Peg sees herself as both a facilitator and a cheerleader for the students, helping and encouraging them.

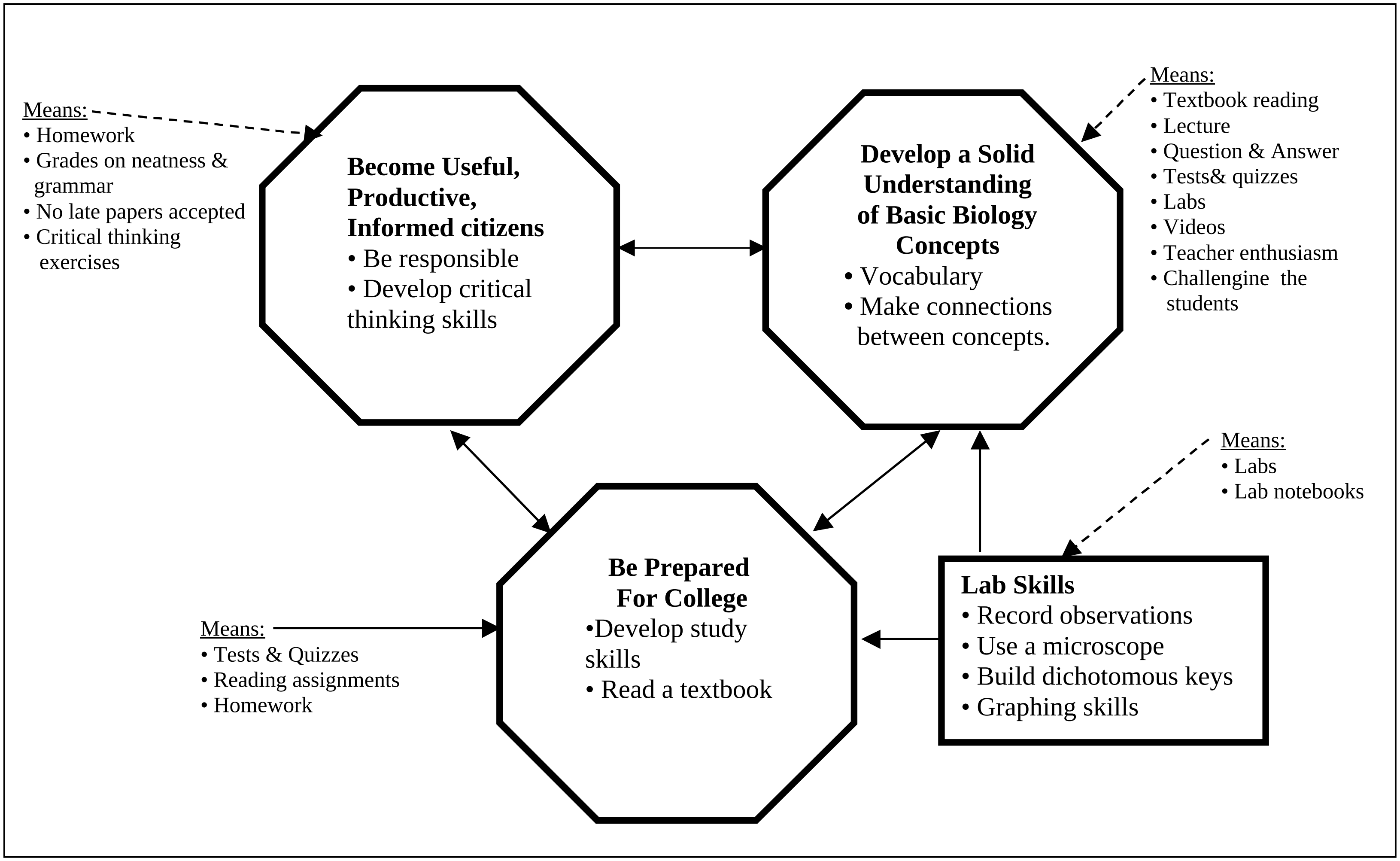

Figure 3. 4 Representation of Peg's science teaching orientation for college prep biology

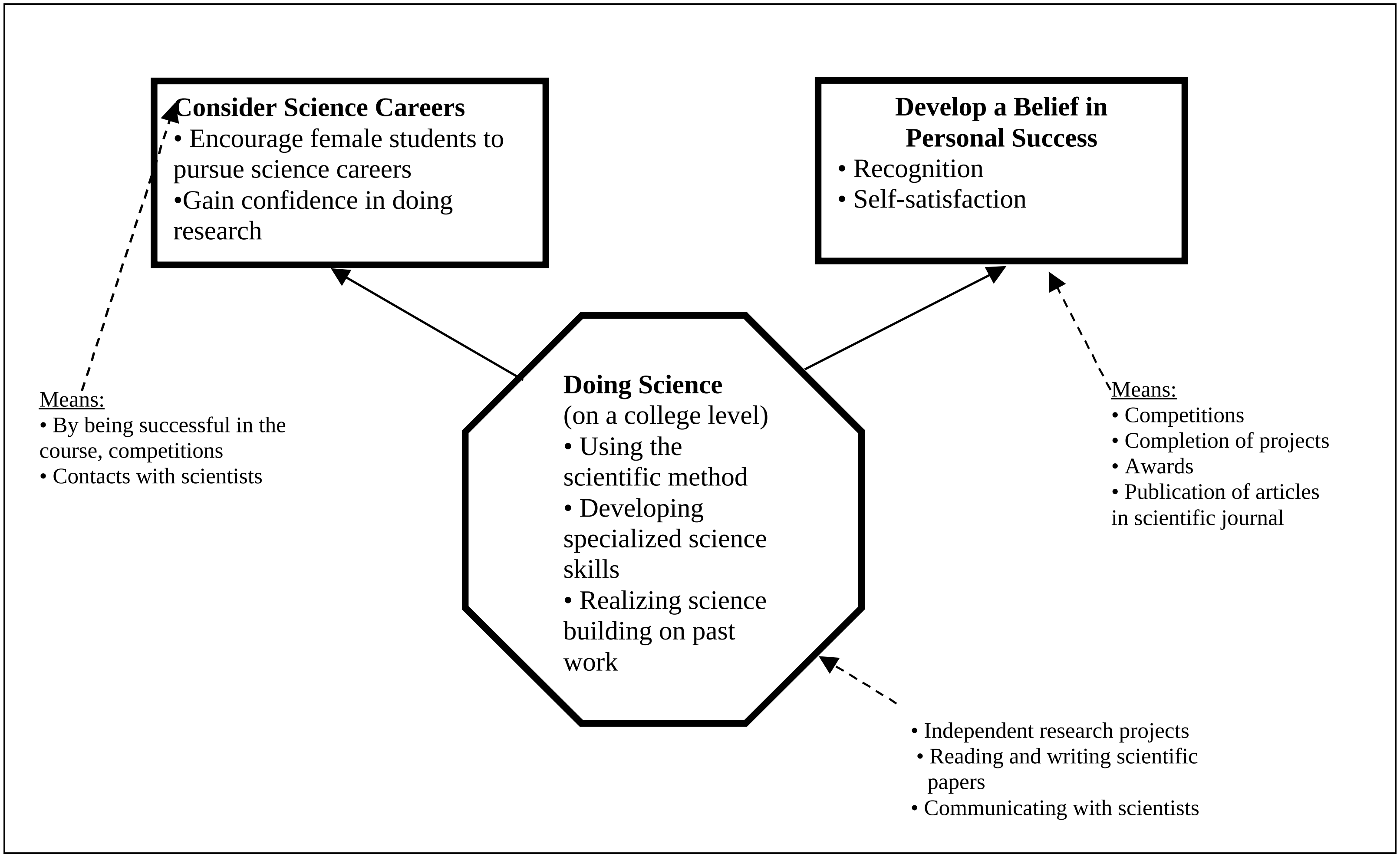

Figure 3. 5 A Representation of Peg's science teaching orientation for the independent research course

3.4.3 Probable Sources of Peg's Science Teaching Orientations

Peg is unique among the participants in that she did not have a career outside of the teaching field. In the absence of other work experience, Peg appears to draw heavily on her own her experiences as a learner. Peg was influenced by her high school science teachers. Peg admired her high school biology teacher, noting that he had authored the textbook used in her biology class. Peg's biology teacher supplemented his lectures with innovative technologies for that time, an overhead projector and a filmstrip projector (1st Interview, 3/12/01). Peg thinks that lectures are an effective means of teaching. In her College Prep Biology classes, Peg uses lectures as a means of helping her students achieve the goal of developing a solid understanding of basic biology concepts. As a student, Peg was required to do a science fair project in grades 7-12. She remembers being appalled by a winning science fair project in which the student conducted an actual experiment. Peg recalls that her projects were not experimental in nature, but consisted of literature reviews. It was only later, as a teacher, that she figured out that students needed to collect data as a critical aspect of their science fair projects. Peg attributes her high school experience in science fairs as the source of her teaching orientation for the Independent Research course (1st Interview, 3/12/01).

One of Peg's peripheral goals in the College Prep Biology course is to prepare her students to be successful in college biology courses. To guide her teaching, Peg draws on her own experiences as a college student. In college science courses, Peg needed to be able to read and comprehend textbooks to be successful (Interview 2B, 5/16/01). Peg stated, "They (the students) have got to get all that stuff themselves at a rate that they can then use to help them understand what the prof. is talking about during lectures"

(Interview 2A, 5/16/01). In a later interview, Peg discusses her teaching means and elaborates on preparing the students for college:

> And I do try to accommodate other learning styles as much as I can, but I think when they get to college, they're not going to have a whole lot of, at least, I didn't, a whole lot of difference, or addressing of learning styles. They are going to get a lecture . . . they are going to have some lab hours to put in. They are going to take exams, and that's about it." (Interview 2B, 5/16/01)

Peg assigns textbook readings and uses tests and quizzes as a means of holding the students accountable for learning the material in the readings. In the card sorting task, Peg rejected several scenarios describing hands-on activities. Peg explained her reasoning:

> I don't think kids at this age, even the smart ones, necessarily always get what it looks like ideally they should get from it (hands-on, discovery activities). I know I wouldn't have learned that well that way. I mean I probably teach the way I learn." (Interview 2B, 5/16/01)

In preparing students to be successful in college, Peg draws heavily on her experiences as a learner in high school and in college.

I asked Peg to describe her professional development activities. Peg has attended National Science Teachers Conventions, although she is more active in the state science teachers' organization. Like Mike, Peg views her involvement in the state organization as more of a workshop provider than as a recipient of professional development. Unlike the other participants, Peg does not typically attend teacher workshops in the summer (Field notes, 5/16/01). As a source of professional development, Peg prefers to attend professional science research meetings, in such diverse areas as ornithology and cotton research. At the research meetings, Peg gets ideas for research projects for her Independent Science students (Interview, 3/12/01). During the interviews, Peg frequently mentioned her network of research scientists across the country. I asked Peg if her professional colleagues were scientists rather than other secondary teachers. Peg agreed that this was probably true and that she sees this network of scientists as a source of ideas, help and inspiration (1st interview, 3/12/01).

Writing is another source of professional development for Peg. Peg is the author of three books on science fair projects and independent research projects. Peg is also co-authoring a paper with a university professor, describing the modification of his research technique for use at the secondary level. Peg also collaborates with former students, co-authoring research articles for publication in scientific journals. Rather than attend summer workshops for teachers, Peg uses her summers for writing which enhances her professional growth.

I asked Peg to share her views on how students learn. Peg, herself, learns best by reading books. "Learning is something they do. . . [With some classes] I may spend some time with study skills. And show them things to do and tell them how I study" (Interview 2B, 5/16/01). To explain her ideas about teaching and learning, Peg shared with me an analogy that she gives to her students:

> It doesn't really matter how good of a pitcher I am, it depends on your skill and attentiveness to be able to hit the ball. You may be an excellent hitter and I may be a great pitcher, but if you have your eyes closed, you won't hit the ball. I might be a lousy pitcher, but if you are a good hitter, you will still get a hit off me. (Field Notes, 5/17/01)

Peg feels strongly that learning the course material is a process that the students must do themselves. As a teacher, Peg's role is to set deadlines for the students to learn the material. She sets deadlines in the forms of quizzes and tests (Interview 2A, 5/16/01). Peg might be classified as being oriented toward academic rigor, but she is not challenging students because science is hard. Peg believes that students need to be challenged in order for them to be successful in school. I asked Peg if she would teach mathematics in a similar way and she replied yes (Field Notes, 5/17/01).

Throughout the interviews, Peg talked about using her time at school in an efficient manner. During the card sort, Peg appeared to sort the cards based on the perceived efficiency of different teaching strategies. Peg noted that there has to be a balance between time, energy, expense and use of class time. Peg feels that hands-on projects are too time-consuming in the College Prep Biology classes. "It's very time consuming and maybe you can do that in college, I don't think I have the time to even get through the basics that I do get through . . . But I don't think I could even get through what I get through if I'm going to have them learn everything by discovering it themselves, hands-on" (Card Sort, 5/16/01). I asked Peg to elaborate on the teaching strategies or means that she does use with her ninth and tenth grade students. "I use probably about as many demonstrations as I do labs. Anything that I can do quickly, as a one person thing, rather than spending a whole lab period on it, " said Peg (Interview 3A, 5/17/01). In selecting labs for her classes, Peg only uses labs that clearly illustrate the target concept:

> Having labs not work is fine, it's something that they need to learn about, but we don't have time. They don't have time to then go back and make it work right, so they go away with a lab thinking well, that doesn't work. (3rd Interview, 5/17/01)

As a teacher, Peg is quite concerned that students might get misinformation from a lab. Peg eliminates any labs in the curriculum which leave the students confused or uncertain, because there is not time to go back and re-do labs. Peg values the Independent Research class because students are engaging in doing science, which she defines as the scientific method. “They never get to do that in [the College Prep Biology] class because we don’t have that much time,” stated Peg (Interview 2A, 5/16/01). Peg clearly holds two separate teaching orientations for the College Prep Biology students and the Independent Research students.

Other participants also discussed the issue of time constraints and the need to use instructional time in an efficient manner. Lanz and Kass (1987) have referred to this concept as “pedagogical efficiency.” In Peg’s interviews, she discusses another dimension of the time issue. Through her many years of teaching, Peg has learned to be efficient with her own preparation time for classes. “I don’t have time in my day to do essays at all anymore and I don’t,” explained Peg (Interview 2A, 516/01). Peg has designed a testing format that includes multiple choice short answer questions. The students have to follow the logic in each choice and select the one best answer. Peg feels that her testing method encourages the students to read the questions carefully and to be critical thinkers, while also allowing Peg to save time during the grading process (Field notes, 5/17/01). Grading lab notebooks can be a time-consuming task. Peg has the students record their lab results and answers to lab questions in a bound lab notebook. However, Peg does not grade the lab notebooks. Once in each marking period, Peg gives a multiple choice exam over the lab investigations. The students use their lab notebooks to answer the exam questions. If the students have kept careful observations and answered the lab questions, the exam is fairly easy (Field Notes, 5/17/01). With this strategy, Peg has found a way to reduce the amount of time she spends grading, while still holding the students responsible for keeping good lab notes. Time management appears to be a strong source of Peg’s science teaching orientations. I asked Peg to explain why she requires science fair projects in the Independent Research course and the Physical Science course, but not in the College Prep Biology course. One of the reasons is that the other teachers who teach sections of College Prep Biology are not interested in requiring science fair projects. But more importantly, Peg feels she does not have the time or energy to manage an additional 60 science fair projects (3rd Interview, 5/17/01).

3.5 Martha

Martha is the fourth and final participant in this study. Multiple individuals recommended Martha for this study. Martha's department chair, science educators from two colleges and a graduate student, who had supervised university students in her classroom, identified Martha as an exemplary, student-centered biology teacher. Martha was cautious in agreeing to participate in the study. She had a difficult teaching schedule and was committed to working with students after school on projects and AP reviews. Because of Martha's prior commitments, data collection occurred during the final month of Martha's school year. The data collection process with Martha was characterized by a greater number of school visits, with each visit being relatively short in duration, often a single class period. Classroom observations and interviews were conducted on different days. Time was a scarce commodity for Martha and interviews often needed to fit into single planning periods. The time lag between classroom observations and interviews did not seem to affect Martha's ability to reflect on her teaching. Martha was able to succinctly and clearly articulate her goals and purposes, as well as means, for teaching biology. It was more difficult for Martha to reflect on probable sources of her science teaching orientations.

Martha characterized herself as a very organized individual. During the interviews, she frequently referred to notebooks containing her unit plans and daily lesson plans. Martha includes learning objectives on each unit handout. Martha stated, "I'm definitely an objective-driven teacher. I teach to the objectives and I test to the objectives" (Field Notes, 5/09/01). The next sub-section offers a more detailed exploration of Martha's background and her school context. Sub-sections describing the representation of Martha's science teaching orientations and probable sources of her science teaching orientations complete this section.

3.5.1 The Context of Martha's Teaching

Martha teaches in a school district located in a community with a population of approximately 78,000. With 2500 students enrolled in grades 9-12, Martha considers her school to be large. Martha describes her students as motivated and for the most part, cooperative. Martha stated that most of her students are from wealthy families (3rd Interview, 5/30/01). According to the Pennsylvania Department of Education's School Profiles for 1999-00, less than 10% of the students in Martha's building were identified as being from low-income families. Of the seniors graduating in 1999, approximately 80% indicated their intent to attend a postsecondary degree-granting institution, compared to the state average of 69.6% (PDE, 2000).

Martha has been teaching high school science for 13 years, all at the same high school. Martha's educational background includes an undergraduate and master's degree in biochemistry. Martha worked as a research assistant in a biochemistry lab for five years before becoming a secondary teacher. Martha is certified to teach both chemistry and biology. During the study, Martha taught sections of Chemistry, Advanced Zoology, and Biology II. The Advanced Zoology course is a one semester, elective course designed for college-bound students. The Biology II course is a required science course designed for college-bound students who aren't interested in pursuing science careers. Martha has previously taught secondary-level courses in general biology, botany, cell biology and genetics.

3.5.2 Representations of Martha's Science Teaching Orientations

During the study, I observed Martha teaching sections of Biology II and Advanced Zoology. The representations of Martha's science teaching orientation for each of these courses are shown in Figures 3.5 and 3.6. Martha was able to clearly articulate her goals and purposes for each of these courses. Martha has two central goals for her students, which are consistent for both courses. The goals relate to developing and maintaining positive science attitudes and developing conceptual understanding of biology content. The dimensions of each of these goals are shown in Figure 3.5. Martha's orientation differs between the two courses in regard to the sequencing of her central goals. In the Biology II course, Martha ranks her central goal of "developing positive attitudes toward science" as her primary goal. "Developing an interest in science" and realizing that "they can be successful biology students" are two dimensions of this goal. I asked Martha what she wanted her Biology II students to take away from the course. Martha said, "I want them to think that [the class] wasn't so bad because in Biology II, it's not advanced and a lot of them don't like science," (1st Interview, 4/27/01). The concept of student ownership is another dimension of Martha's central goal of developing positive attitudes toward biology. Martha wants students to be actively involved and committed to their learning of science.

Martha uses a variety of means to help her students develop a positive attitude toward science. Showing students the relevancy of biology in their lives is an important means that Martha uses in her teaching. "I like, in Biology II, especially, taking everything I teach and relating it to them personally," explained Martha (1st Interview, 4/27/01). I observed Martha giving a lecture on digestion in the Advanced Zoology class. She asked the students to compare how they feel after eating a low fat meal at a Chinese restaurant to how they feel after eating hamburgers and fries at a fast food restaurant. She asked students why they feel hungry again in two hours after eating a low fat meal. She related these physical feelings to the various digestive processes at work (Field Notes, 5/3/01).

Martha makes extensive use of labs in her science courses, designing all of her own labs. Martha recently changed the format of her labs, organizing each lab around a central question. She tries to select questions that will be of interest to the students. For example, Martha designed a Biology II lab around the following question, "What is the effect of raw versus 7 minute cooked hamburger on the bacterial population in ground hamburger?" (Field Notes, 5/9/01). In a Biology II class, I observed Martha's students extracting DNA from wheat. I asked Martha to explain her reason for including this lab in the course. Martha replied, "I think the reason it was important to do the DNA extraction was for them to see how easy it is to extract DNA, and that this is not some mysterious, ethereal, unseeable, untouchable concept" (2nd Interview, 5/25/01). Martha uses labs to show her students that they can be successful in biology classes. Martha requires that all her students record their labs in bound notebooks. Martha explained her reason for using lab notebooks in the following way, "I like having it in a bound notebook, so that there's a building sense of ownership and pride in their work, and a sense of accomplishment at the end of the year" (2nd Interview, 5/25/01). Another way that Martha fosters student ownership in their work is to give students some opportunities for choice. When possible, Martha lets each lab group select a variable that they would like to test within the whole class lab.

Martha believes that if students have a positive attitude toward biology, they will learn science content, which is Martha's other central goal/purpose for her students. Based on how Martha described the dimensions of this category, I have chosen to re-name this central goal as "developing conceptual understanding of biology content." (Note: This label should not be interpreted as a conceptual change approach to learning science.) When Martha refers to learning the biology content material, she wants the students to be able to apply biological concepts in new contexts. She particularly wants her students to be able to understand biology-related issues that they read about in the newspaper or see on television. She also wants students to be able to draw connections between different biology topics and concepts. For example, Martha wants the students to understand the relationship between structure and function, whether the topic is organic molecules or vertebrate anatomy. In the Advanced Zoology course, Martha has the same two central goals, but she reverses the order of their importance. Martha feels that the students, by enrolling in this elective course, already have positive attitudes toward science. Learning the biology content material becomes Martha's primary central goal for the Advanced Zoology students. However, Martha also believes that maintaining a positive science attitude needs to remain a central goal for this group of students.

To help the students develop conceptual understanding of the science content, Martha relies primarily on the use of lectures and labs. During her lectures, Martha strives to make the content understandable to the students. Martha presents her lectures in an organized outline format. Terminology is emphasized in both courses (Field notes, 5/3/01). Martha's means vary depending on the biology course. In the Biology II course, Martha uses review and practice strategies, such as vocabulary review sheets to help the students master the terminology. In the Advanced Zoology course, Martha motivates the students by offering more in-depth content coverage, making the class appropriately challenging for the students who elect to take the course. However, Martha disagrees with teachers who make science classes difficult because they think science is a difficult subject. Martha explained, "I really like taking hard stuff and making it so that anyone can learn it" (3rd Interview, 5/30/01). To motivate her students, Martha assesses her students' conceptual understanding on an application level. In an Advanced Zoology test, Martha compiled a story about ostriches and provided the students with a list of animal behavior concepts. The students were asked to identify examples of ostrich behavior from the story which illustrated concepts learned in the chapter (2nd Interview, 5/25/01). In sharing this test example, Martha was enthusiastic and excited about the test she had written. In both courses, Martha uses her own enthusiasm and passion for the subject to motivate her students to achieve the goals and purposes of the class.

Martha identified a peripheral goal for each of her two biology courses. In the Biology II course, Martha wants to help her students be successful in school and in life.

Martha uses group projects as one of her means for helping students work toward achieving this goal. I asked Martha to explain why she incorporated time-intensive group projects into her Biology II course:

> M: To develop the skills that aren't science skills.
> I: Is that part of your job?
> M: I think so, because they are still children.
> I: Right.
> M: I see my job preparing them to be successful in life, not just biology.
> (2nd Interview, 5/25/01)

Martha uses the term "lab skills" to describe one dimension of this peripheral goal. I asked Martha if lab skills were important because some of the Biology II students might be taking lab classes in college. "Well, no, I think these lab skills are important for whether you are going into lab or not. . . Being organized, following instruction, being able to know when it's time to draw a conclusion" replied Martha (3rd Interview, 5/30/01). So Martha thinks this set of skills, which she calls "lab skills" are not unique to science, but are important life skills. Martha uses labs and lab notebooks, as well as group work and group presentations to helping her students achieve the goal of being successful in school and in life.

Martha has a similar peripheral goal for her Advanced Zoology students, but the goal in more narrow in focus. Martha wants her students to be successful in college-level science courses. There are two major dimensions to this goal of being successful in college-level science courses. The first dimension of this goal is for the students to develop lab skills and confidence in their ability in doing science labs. I asked Martha to discuss why she valued lab confidence:

> M: Because they're going to go to college and they are going to be in a lab room with forty other kids and one TA . . .You know, I want them to know that they

> don't have to be afraid, that they can read the lab, know what the procedure is and go in and do it.
> I: Is this relating to your goal that you talked about wanting them to be successful?
> M: Right, in college?
> I: In college.
> M: Yes, yes. (2nd interview, 5/25/01, p. 22)

Whenever Martha discussed the development of lab skills for her Advanced Zoology students, she always linked lab skills to the development of lab confidence. She did not relate labs and lab skills to the work of practicing scientists. This notion may have been implicit in Martha's thinking, but she did not express this idea as part of her rationale for developing lab skills. Martha clearly values lab confidence and views it as an essential element in being successful in college science labs.

In Advanced Zoology, another dimension of Martha's peripheral goal is for the students to develop general study skills that will serve them well in college. Martha thinks it is important for the Advanced Zoology students to learn to read a science textbook in order to be successful in college science courses.   The development of group skills is another dimension of Martha's peripheral goal. Martha describes how she teaches the Vertebrate Unit in the Advanced Zoology class, "I break the class into six groups. They pick their groups, each group studies one class of vertebrates in detail and dissects the animal and then does a show and tell presentation" (2nd Interview, 5/25/02). This instructional strategy clearly supports Martha's central goals of learning science content and maintaining positive attitudes but it also supports Martha's peripheral goal of being successful in college science classes.   Within each group, the students research their topic, plan and carry out their dissection and make a presentation to the class.

Martha sees these skills as being important to the students' future success in college science classes.

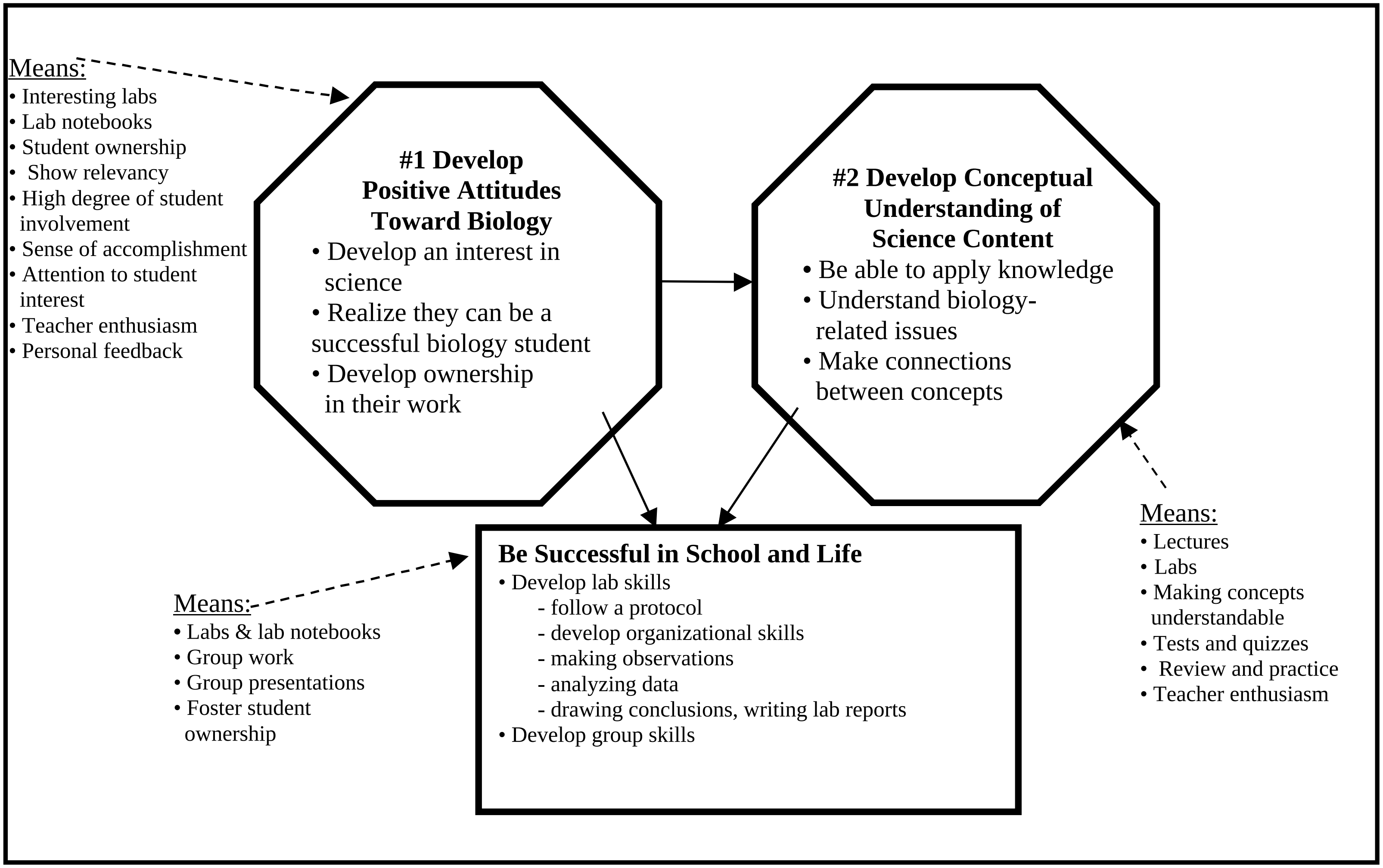

Figure 3.6 Representation of Martha's science teaching orientation for Biology II

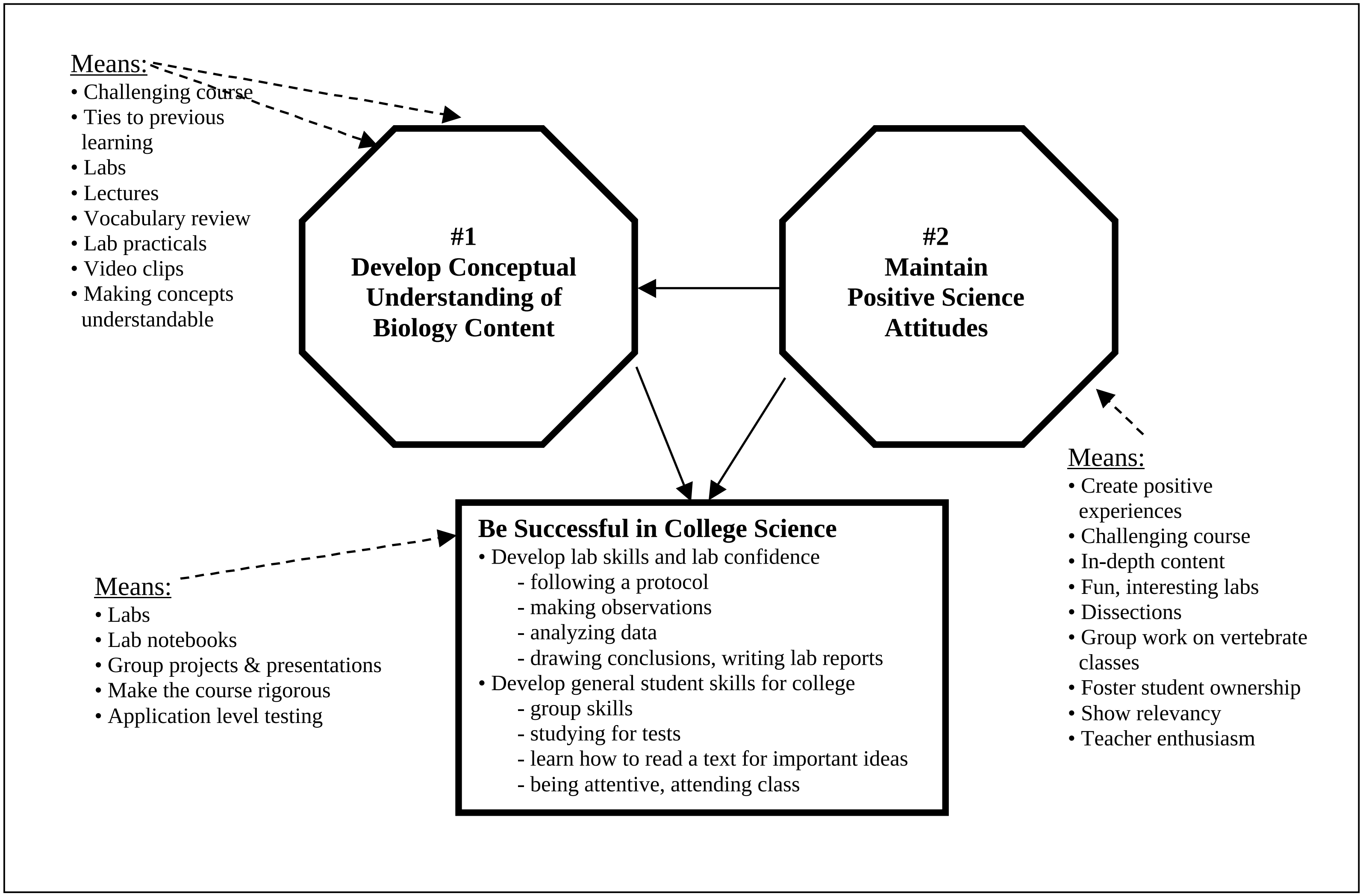

Figure 3.7 Representation of Martha’s science teaching orientation for Advanced Zoology

3.5.3 Probable Sources of Martha's Science Teaching Orientations

Martha chose teaching as a second career. After earning her master's degree in biochemistry, Martha worked as a research assistant in a biochemistry lab. Initially, it was difficult for Martha to identify experiences in her background that had shaped her teaching orientation. Martha makes extensive use of labs in her science classes. She is proud of the fact that as a teacher, she writes all of her own labs. Martha did attribute her ability to design labs to her previous work as a researcher. I asked Martha if she thought her emphasis on lab work was a result of her experience in research. "Maybe it is my research background, maybe it's that when I was a student it's the part I liked best," reflected Martha (2nd Interview, 5/25/30). In her science classes, Martha emphasizes following lab protocols and keeping careful records in a bound lab book, both of these skills being important in scientific research. Of the four participants, Martha had the most extensive background in science research. Martha used labs as a means more extensively than the other participants in the study.

Martha is a teacher who challenges herself, not only in the writing of her own labs, but also by continually revising the curricula. I asked Martha about her formal professional development activities. She does not attend professional conferences, but does participate in the district's professional development activities. During the study, Martha was the sole teacher of both the Advanced Zoology and the Biology II courses. She was working alone to revise the Biology II curriculum. However, Martha does collaborate extensively with other chemistry teachers in her department who are teaching the same chemistry course. Martha does participate in summer workshops for teachers, but she is very selective about her choice of workshops. Martha described her favorite summer workshop, held each summer at a local college. I asked Martha why she had attended this workshop for the last ten years. She replied, "Practical labs, and not only do they teach me how to do the practical labs, they let me write the practical labs, develop them completely on my own, and they gave me everything for free. So when I want to do the lab, I call them on the phone, say I would like to do this lab and they bring everything to my door, drop it off, and then pick it back up again" (2nd Interview, 5/25/01). Martha also selects a few other workshops to attend in the summer. Besides practical labs, Martha looks for workshops that offer science content (3rd Interview, 5/30/01). Martha's desire to continue to increase her content knowledge and her desire for practical labs appear to be related to Martha's goals and purposes for teaching biology, as well as her means.

As Martha discussed her teaching, she frequently referred to her students' needs and interests. Martha made strong connections to her students as a source that shapes and influences her science teaching orientation. During the card sort, Martha rejected a scenario describing a series of lectures on the Krebs Cycle of photosynthesis. Martha explained her rejection in the following way, "Its just a minute point that most of them would find it boring and irrelevant and I would find it irrelevant to a tenth grader" (Card Sort, 5/30/01). Martha feels strongly that her Biology II students need to see the relevancy of the material to their lives, before they can achieve her goals of developing positive science attitudes and a deep understanding of the content. In Advanced Zoology, Martha frequently illustrates a biological concept with a short video clip. The students have given Martha positive feedback about the video clips. She explained, "The pieces I pick out are so good; the kids love them. They make a point that I never can about a particular aspect in an animal. . . It's fun, it's just pure fun and interesting" (2nd Interview, 5/25/01). Throughout the interviews, Martha shared various means she used to keep her classes fun and interesting, including picture cards for review and creative test questions.

Labs are in important means that Martha uses to help her students achieve her goals and purposes. Not only do labs help develop and maintain positive science attitudes and illustrate science content, labs also develop life skills and lab confidence. The students' feedback drives the revision of Martha's labs. In the past, Martha listed the lab objectives at the beginning of each lab, but she found that students didn't respond enthusiastically to that format. She re-organized her lab around a central question and found that the student became more actively engaged as a result of the new lab format. Martha discusses the lab revision process, "Sometimes my ideas for labs, well, actually, quite frequently, come from students. We'll do a lab and they'll ask a question and I'll think 'Oh, that's a good question' and then the next year, that's the lab!" (2nd Interview, 5/25/01). When Martha talks about the lab notebooks, she relates the function of the notebooks to facilitating the learning process, not to the work of scientists. The notebooks give the students a sense of accomplishment, as well as giving Martha a place to provide individual encouragement. The notebooks help the students work to achieve Martha's goals of developing positive science attitudes and developing life skills, such as observing, recording and drawing conclusions.

Throughout the interviews, Martha made references to time constraints and the need to use planning periods and class time in an efficient manner. I asked Martha why she preferred to write her own labs, even though it was a time consuming process. Martha replied,

> They [the labs] do exactly what I want. I have the supplies. I know that I have everything I need, so that instead of having to run around and buy the stuff, I purposefully designed it so that I can use what I have." (1st Interview, 4/27-01)

So by writing in her own labs, Martha actually saves lab preparation time. Martha is even more sensitive to the efficient use of class time. During the card sort, Martha rejected several scenarios describing hands-on activities. I asked Martha to differentiate between a lab and a hands-on activity. Martha said, "A hands-on activity [pause] seems less [pause] direct to me, more like playing. I don't know, maybe I've seen too many hand-on activities that are time inefficient "(Card sort, 5/30/01). As an example, Martha described a hands-on activity genetics activity in which students make marshmallow creatures. Martha stated that she would never use this activity in her classes. "I think it's a stupid waste of time. That's my personal opinion, cause the kids spend so much time building that little critter and the concepts are so easy, that it doesn't take three lab periods to get the concept of gene distribution . . . I don't think it's worth the time it takes," Martha explained (Card sort, 5/30/01). Martha elaborated on this point by discussing a former university practicum student. Martha said, "She [the practicum student] wanted to come in with fun activities and I said, but you have to weigh the activity and decide if it's worth the time and if the concept is simple, we don't need a fun activity. They will get it the first time you say it" (Card sort, 5/30/01). Martha likes to incorporate group presentations into her classes, but limits group presentations to one per marking period. She explained, "Student presentations are time costly, and your goals have to be more than the science content or you're never going to do them" (2nd Interview, 5/25/01).

3.6 Summary and Preview

In this chapter, I have shared some of the particulars of each participant in the study, including their teaching context, the nature of their science teaching orientations and probable sources. This information was given to show the inductive process that was used in the initial stages of data interpretation. However, the reader is reminded of the diminished importance of the individual in generating grounded theory. In the next chapter, I present a substantive-level theory of science teaching orientations as it applies across the four participants introduced in this chapter. Chapter 4.2 presents a diagram indicating the components and interrelationships between components of the substantive-level theory. The substantive-level theory is further explained in a set of assertions. Chapter 4.3 offers a set of assertions relating to the nature of science teaching orientations, and Chapter 4.4 offers a set of assertations relating to the sources of science teaching orientations.

Chapter 4

SCIENCE TEACHING ORIENTATIONS:

A SUBSTANTIVE-LEVEL THEORY

4.1 Introduction and Overview

In this chapter, a substantive-level theory of science teaching orientations is presented. Glaser and Strauss (1967) define substantive-level theory as a middle range theory developed from a substantive, or empirical, area of inquiry (pp. 32-33). Cresswell (1994) gives a more narrow definition of substantive theory, stating, "Substantive theories are restricted to a particular setting, group, time, population or problem" (p. 83). In this study, I propose a substantive-level theory generated from the data and analytic memos shared in Chapter 3. Therefore, the substantive-level theory applies to this particular group of highly-regarded secondary biology teachers. The reader may choose to generalize the substantive-level theory beyond these four participants. Erlandson (1993) places the burden of transferability on the reader of qualitative studies. However, to assist the reader in this process, I have supplied "thick descriptions" of each participant in Chapter 3.

The discussion of the substantive-level theory is divided into three sections. In Section 4.2, the substantive-level theory is presented in a diagram format, allowing for representation of both the components of the theory and the complex interrelationships between components. The remainder of Chapter 4 consists of assertions that comprise the substantive-level theory. In Section 4.3, two sets of assertions are offered relating to the research question: What is the nature of the science teaching orientations held by a group of high-regarded biology teachers? In Section 4.4, a set of assertions are given relating to the second research question: What are the sources of the science teaching orientations held by a group of high-regarded biology teachers?

4.2 A Substantive-level Theory of Science Teaching Orientations

Using the data from across the four participants, I propose a substantive-level theory of science teaching orientations. The theory is presented as a diagram in Figure 4.1. This form of representation was chosen to illustrate the complex interrelationships between the nature, sources and associated means of science teaching orientations. The diagram is situated upon two axes. The horizontal axis represents the degree to which components of the theory are visible in classroom teaching observations and explicit in the teacher's thinking. The vertical axis represents time, showing the position of past and present experiences that shape the nature of science teaching orientations.

In this dissertation study, the nature of the participants' science teaching orientations is interpreted as consisting of three major types of goals: (a) affective domain goals, (b) general school goals, and (c) science content goals. The nature of the participants' science teaching orientations should not be viewed as static, but the interpretations represent the participants' science teaching orientations at the time of the study. The probable sources of these goals can be sub-divided into past biographical experiences and current experiences from the school context. Prior work experiences were found to be an important influence on the nature of an individual's science teaching orientation. In the absence of prior work experiences, the teacher tended to draw on past experiences as a science learner. Past professional development activities act as a feedback loop, and this relationship is denoted with a double arrow. Participants selected professional development activities based on their existing science teaching orientations. In turn, experiences in these professional development workshops tended to re-enforce the participants' science teaching orientations.

The current school context influences the nature of science teaching orientations and is shown in the lower portion of the diagram. In the context of the school, the learners in the teachers' classes have the greatest influence in shaping the participants' teaching orientations. The future goals of the students, whether they are college-bound or not, influence the teachers' actual goals for their biology courses. Within the current school context, time constraints also strongly influenced the participants' goals and means. The school administration, other biology teachers in the department, parents of the students, and AP test scores appear to play a minor role in shaping the participants' teaching orientation.

In the diagram, means are included as an important component of an individual's science teaching orientation. Means are identified as the teacher's enacted curriculum, and instructional and assessment strategies used by the teacher to help students meet the goals and purposes of the course. The relationship between the nature of the teaching orientation and means is represented with a double arrow. Certainly, means are the natural outcome of a teacher's goals and purposes for a course. For example, in the Independent Research course, Peg's central goal is for the students to engage in science, what she refers to as the "doing of science." Peg uses independent science fair projects as her means of helping students engage in the "doing of science." However, this chosen means is an extremely time consuming and energy-intensive strategy. Peg does not have additional means of engaging students in scientific inquiry. Peg's limited repertoire of means, that of engaging students in independent research projects, actually influences the nature of Peg's goals for the College Prep Biology course. She makes a conscious decision to exclude scientific research as a goal for the College Prep Biology students. On a daily basis, the students greatly shape and influence the means or instructional strategies used by the teachers. Participants identified textbooks and teacher workshops as additional sources of instructional strategies. However, trial-and-error was the major process that the participants used in developing a set of instructional strategies. The students' daily feedback was a major component in this trial-and-error process.

The participants in the study held complex science teaching orientations. Teaching orientations, as a construct, is influenced by a multitude of factors. Past work experiences and the present school context are major influences. Means, as a set of instructional and assessment strategies, as well as curricula, help students achieve the purposes and goals of the course, but a limited set of means can also restrict the teacher's purposes and goals for a course. In this study, the greatest influence of the nature of the individual's science teaching orientation and its associated means appears to be the specific school context, with the greatest influence being the students.

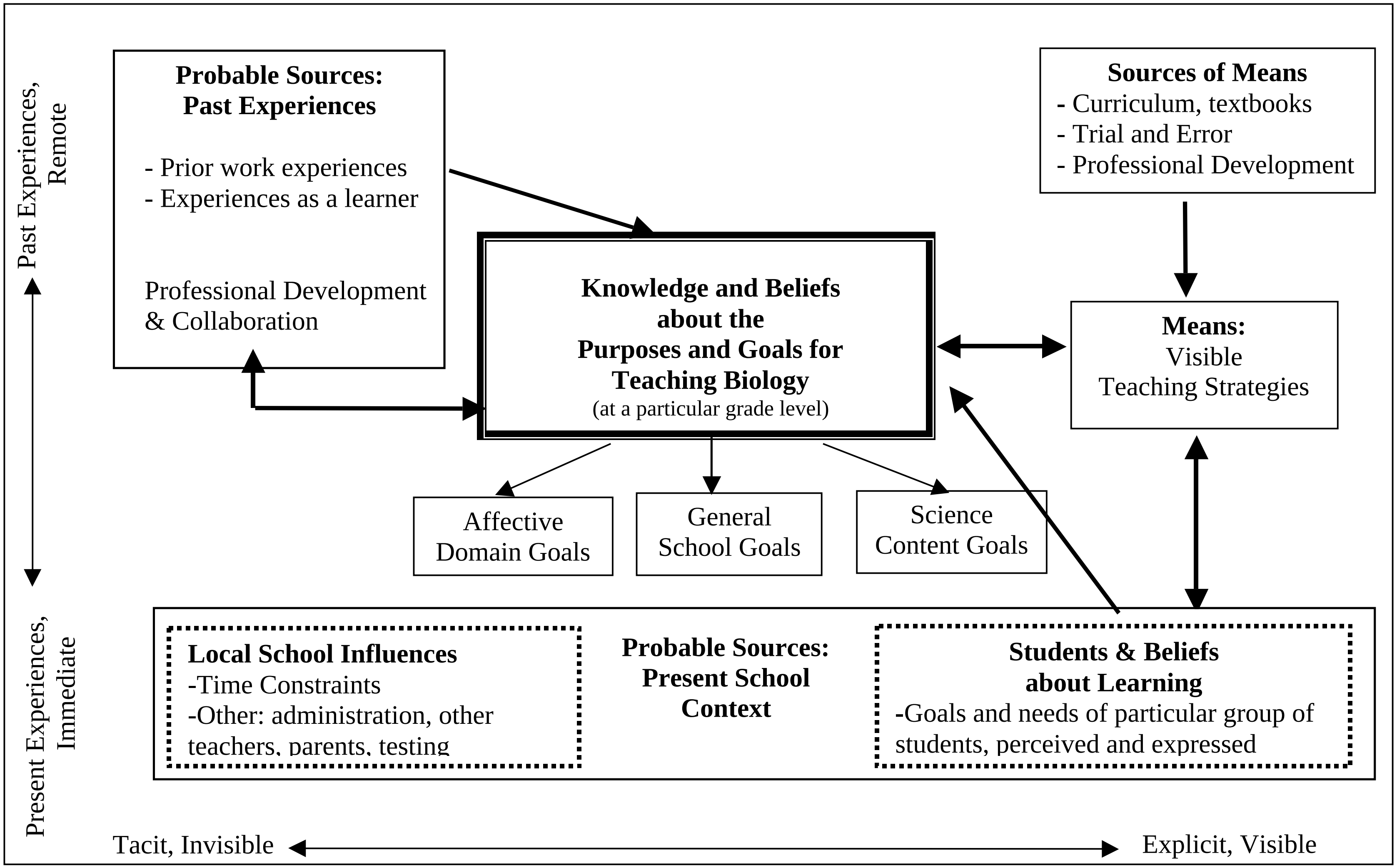

Figure 4.1. Substantive-level theory of science teaching orientations

4.3 The Nature of Science Teaching Orientations

The substantive-level theory of science teaching orientations is further elaborated through a set of assertions (See Table 4.1). The first assertion, in Section 4.3.1, relates to the construct of science teaching orientations on a general level. This assertion is divided into three subpoints, with the first two subpoints focusing on the representation of science teaching orientations, while the third subpoint emphasizes the specificity of a science teaching orientation to a course and/or grade level. The second assertion (Section 4.3.2) focuses on specific components represented across the four participants' science teaching orientations. This assertion calls attention to the more general rather than science-specific nature of participants' science teaching orientations, including teaching goals in the affective domain, goals relating to the development of life skills and college preparation, as well as goals relating to the mastering of science content. Each of these assertions is discussed in greater detail in the following sections of this chapter.

Table 4.1

Assertions Relating to Nature of Science Teaching Orientations

Research Question: What is the nature of the science teaching orientations held by a group of highly regarded biology teachers?	
Section	**Assertions**
4.3.1	**Assertion #1: There is a need for a more elaborate representation of science teaching orientations.**
4.3.1.1	• Representations of central and peripheral components
4.3.1.2	• Inclusion of means
4.3.1.3	• Specificity to grade and/or course
4.3.2	**Assertion #2: Participants held more general teaching orientations rather than science-specific orientations.**
4.3.2.1	• Affective domain goals
4.3.2.2	• General school goals: life skills and college preparation
4.3.2.3	• Science content goals are present, not always central goals

4.3.1 Assertion #1: Need for More Elaborate Representation of the Construct

During this research study, three methodological issues emerged which relate to the construct itself. First, participants hold complex science teaching orientations. Consequently, representations that account for this complexity are needed. I chose to represent teaching orientations with central and peripheral components (Section 4.3.1.1). Second, the inclusion of the participants' means provides a more complete picture of an individual's science teaching orientation. Therefore, means were included in the representations (Section 4.3.1.2). Third, participants hold science teaching orientations that are specific to courses and/or grade levels (Section 4.3.1.2). Each of these three subpoints builds the assertion that a more elaborate representation of individuals' science teaching orientations is needed.

4.3.1.1 Representation of Central and Peripheral Components

In this study, participants' science teaching orientations were interpreted as being complex, with participants holding aspects of multiple orientations. (Refer to participant diagrams in Chapter 3.) This interpretation differs from the science education literature in which an individual science teacher's orientation is represented as a single, homogenous entity (Magnusson et al., 1999). An individual's science teaching orientation may be better represented as having multiple components, some of these components playing central roles while other components having peripheral roles. Central components consist of goals that dominate the teacher's thinking and appear to drive the individual's decision-making process in regard to teaching. These goals, identified as central components of an individual's teaching orientation, were highly visible in classroom observations and dominated interview discussions.

The number of central components varied across the four participants, ranging from a single central component to an orientation consisting of three central components. Some of the central components held by the participants matched those described in the literature. For example, Magnusson et al. (1999) identify didactic as one type of teaching orientation held by science teachers. See Table 1.1. In returning to this theory base, Peg's science teaching orientation for her College Prep Biology classes might be labeled as didactic in which the goal of teaching is to transmit the facts of science. However, this didactic label glosses over the complexity of her purposes/goals and means for teaching biology in the College Prep Biology course. Of equal importance to Peg is her goal of helping the students develop into useful, productive, and informed citizens. In another example, Martha might also be labeled as holding a didactic orientation to teaching science. Once again, the use of this label completely masks her equally important goal of developing and maintaining positive science attitudes. By designing engaging instructional activities that are relevant to students' lives, Martha hopes to foster and maintain positive attitudes toward science. Martha rejects instructional strategies and activities that she feels will bore and or discourage her students. Using a single label of a didactic orientation misrepresents Martha's concurrent central goals for teaching biology. While some of the participant's central goals could be matched to categories identified in the literature, additional central goals emerged that are not part of the current science teaching orientation literature. As described in Martha's teaching orientation, the central goal of developing and maintaining positive science attitudes is not currently part of the science teaching orientation literature. Sharon's goal of developing environmental decision-making and Mike's goal of developing a sense of wonder and appreciation for the complexity of life are additional central goals that emerged from the data in this study.

The representation of the complexity of an individual's science teaching orientation is further enhanced through the identification of peripheral components. All of the participants in the study described a secondary set of goals and purposes for teaching biology. Even though this set of goals plays a lesser role in instructional decision-making, they are certainly part of the teacher's thinking and are visible in the classroom. For example, one of Sharon's peripheral goals is the development of life skills. In designing assignments for her students, Sharon purposefully incorporates basic reading and writing skills. As a weekly assignment, Sharon has her students read environmental articles in the local newspaper. Sharon doesn't feel that this is a critical assignment, but includes the assignment regularly because it supports her secondary goals of developing literacy. Another example relates to one of the peripheral components of Mike's science teaching orientation: to prepare his AP students for college. To help his students meet this goal, Mike assigns additional readings and requires his students to write "college-style" opinion papers. In these two examples, the peripheral components are more closely related to general goals of schooling. In other examples, some of the peripheral components identified in this study are science specific. In Mike's 8th grade Life Science course, mastering science content is a peripheral goal to his central goal of developing a sense of wonder and appreciation for the complexity of life. Mastering science content was also a peripheral goal of Sharon's teaching orientation. As was true of the central components, some of the peripheral components described in this study have been previously described in the literature. Peg's peripheral goal of developing lab skills in her College Prep Biology course might be labeled as a process orientation. Mike's peripheral goal of learning science content might be labeled as a didactic orientation. Other peripheral aspects of orientations are not represented in the science education literature and, at this point, I've chosen to represent these components with inductively derived codes, incorporating phrases used by the participants. "Being successful in college and life" and "considering science careers" are two examples of codes derived from phrases used by the participants to describe their peripheral goals.

In summary, the participants' science teaching orientations are better represented as being comprised of central and peripheral components. Some of the components identified in the study have been described in the literature, while other components are unique and are represented by phrases used by the participants. This claim agrees with the assertions made in an earlier study of the science teaching orientations held by a group of prospective elementary teachers (Friedrichsen and Dana, 2000) and prospective secondary teachers (Tsur, 2000). Furthermore, the representation of central and peripheral components of a teaching orientation has explanatory value in other teaching orientation studies. White (1982), in a validation study of the Barth-Shermis Social Studies Preference Scale, reported an overlap in the orientations held by social studies teachers. Sosniak, Ethington and Varelas (1994) report similar findings in a study of mathematics teachers. Sosniak et al. were unable to identify a group of potential participants who held "a clear and consistent curricular point of view which emphasizes either a 'progressive' or 'traditional' orientation" (p. 98). (These two studies are discussed in greater detail in Chapter 1.3.1.) Employing a qualitative lens and representing participants' orientations with central and peripheral components might offer new insights in these studies.

4.3.1.2 Inclusion of Means

In exploring individuals' science teaching orientations, it is important to focus on the means that a teacher uses to achieve his/her teaching goals. In this study, the term "means" is defined as the teacher's purposefully selected and visible use of curricula, as well as instructional and assessment strategies, for supporting students in achieving the purposes and goals of the course. These means, being explicit in their nature, are visible during classroom observations, and are easily described during interviews. It is for this particular reason that means need to be included as a component of teaching orientations. The means that a teacher uses offers the researcher critical probes for understanding the teacher's goals and purposes.

The current framework of science teaching orientations is constructed within a stance that excludes the meanings attached to behaviors by those enacting the behaviors. Means are merely identified as "characteristics of instruction" (Magnusson et al, 1999). Such a view is useful to some because it allows an observer to identify the instructional strategies used by the teacher, and then attach an orientation label to the teacher. The majority of the studies cited by Magnusson et al. did not explore the teacher's thinking about goals and purposes for teaching science, or decision making about instructional strategies. The studies were based on "objective" classroom observations and the researchers assigned the orientation labels, without input or verification from the teachers.

I propose re-examining the role of means in teaching orientations from an interpretive stance. By including means as a critical piece in understanding teaching orientations, the research process is enhanced. First, means are a visible aspect of the teaching process. In interviews, a researcher can use means as an avenue for eliciting teachers' underlying goals and purposes. In this way, goals and purposes are identified by the teacher, rather than solely inferred by the researcher. During the elicitation process, the researcher and the participant work together to interpret and represent the participant's goals and purposes for teaching science. Secondly, by providing the reader with the teacher's means, a more holistic, complex representation of the individual's teaching orientation is provided. For example, knowledge of Sharon's use of field trips is critical to understanding her science teaching orientation. Sharon's extensive use of field trips helps her students achieve her two central goals: developing environmental decision-making, and developing positive science attitudes. Other teachers might use in-class activities to meet these same goals, but Sharon relies on the use of field trips to engage students. In Mike's 8th grade Life Science course, his central goal is to help his students develop a sense of wonder and appreciation for the complexity of life. This goal might be attained through the use of field trips or through reading scientific accounts of the wonders of life. However, Mike uses entertainment, in the form of stories and "cool" labs, to help students meet this goal. The reader gains more insight into Mike's science teaching orientation when means are included with goals. In Peg's Independent Science course, her central goal of "doing science" can best be understood by describing Peg's means. In this course, the students design and carry out college-level scientific research projects. The students write journal-quality research papers and compete in science competitions on an international level. Clearly, by sharing Peg's means, the reader gains a better understanding of the code of "doing science."

In past research, means have been used to label individuals' science teaching orientations, without input from the individuals under study. From an interpretive stance, means provide a way to elicit from the teacher his/her purposes and goals. In addition, including teachers' means, as part of the representation of their science teaching orientation, gives the reader additional information to better understand the complex nature of teaching orientations.

4.3.1.3 Course and/or Grade Level Specificity

Individual participants' science teaching orientations differed based on the particular grade level and course they were teaching. Magnusson et al. (1999) note this distinction in their definition of orientations as "teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level" (p. 97). The powerful effect of this condition was brought to the forefront in this study. Mike, Martha and Peg operated from different science teaching orientations depending of the course they were teaching. (Sharon was only teaching sections of a single course, Environmental Biology, during this study.) In general, the components of the participants' science teaching orientations shifted in status depending on the perceived needs of a particular group of students. In Martha's case, the shift occurred in the sequencing of the central components of her science teaching orientation. For example, in her Biology II course, Martha's foremost central goal was to have these students' develop positive attitudes toward science, and teaching science content was her second central goal. However, in Martha's Advanced Zoology course, the sequence of her primary goals was reversed. Learning science content was her foremost central goal for the students in the Advanced Zoology course, with maintaining positive science attitudes shifting in sequence to her second central goal. In Mike's case, a peripheral component was raised in status to a central component. In 8th grade Life Science, Mike's goal of developing tools and life skills was peripheral component of his teaching orientation. In his AP Biology course, Mike shifts this peripheral component to a central position. When comparing Peg's science teaching orientation in College Prep Biology and the Independent Research course, the greatest differences are seen. In Peg's case, new components emerge in both her peripheral and central orientations. Peg's central components of her science teaching orientation for College Prep Biology include: being a useful, productive, informed citizen, and developing a solid understanding of basic biology concepts. In the Independent Research course, Peg perceives entirely different needs for these students. Peg's primary goal in Independent Research is to have the students engage in scientific research, a goal completely absent from her orientation for the College Prep Biology course. New peripheral components emerge as well. Peg wants the Independent Research students to develop a belief in personal success and to consider pursuing careers in science. Peg's science teaching orientations exemplify the assertion that teachers' hold different science teaching orientations for different groups of students.

4.3.2 Assertion #2: Participants Hold More General Teaching Orientations

Assertion #2 focuses specifically on the nature of the components of the science teaching orientations held by the participants. In looking across the four participants' teaching orientations, some commonalities are seen. Overall, the participants hold more general, rather than science-specific teaching orientations. Affective domain goals hold a prominent place in the science teaching orientations of the participants; this aspect of the nature of the participants' science teaching orientations is discussed in greater detail in Section 4.3.2.1. Section 4.3.2.2 continues to support the assertion of a more generalized teaching orientation. Teachers in the study had goals for their students to develop general life skills and to prepare for college. The third subpoint, discussed in Section 4.3.2.3, is that all participants' science teaching orientations included the goal of learning science content, although this goal was never held as a sole central component of a participant's science teaching orientation. In some cases, this goal was assigned a lesser status, that of a peripheral component.

4.3.2.1 Affective Domain Goals Hold a Prominent Position

Krathwohl, Bloom and Masia (1964) identify three domains of instructional objectives: cognitive, psychomotor and affective. They define the affective domain as having "objectives which emphasize a feeling tone, an emotion, or a degree of acceptance or rejection. Affective objectives vary from simple attention to selected phenomena to complex but internally consistent qualities of character and conscience"(p.7). Using this definition, it can be said that three of the four participants hold affective domain goals as central components of their science teaching orientations. In Sharon's science teaching orientation, both of her central goals are in the affective domain (see Figure 3.1). Sharon's central goal of environmental decision-making includes dimensions of learning to care for the environment and learning to value one's natural resources. Sharon's other central goal is for her students to develop positive science attitudes. As one dimension of this goal, Sharon wants the students to have a "good feeling" for her Environmental Science course. At the beginning of the school year, Sharon takes her students on canoe trips because it helps her foster a positive attitude toward science and the Environmental Science course. Sharon invests a great deal of time and energy, through the means of field trips, to support her goal of developing positive science attitudes.

Martha's science teaching orientation has a central goal relating to positive science attitudes. In her Biology II course, her primary central goal is to develop positive science attitudes, while maintaining positive science attitudes is a central goal in the Advanced Zoology course. Martha invests time writing her own labs, in part, because she thinks students like labs. By engaging students in interesting, relevant labs, the students will have a positive attitude toward science. Mike's central goal of wondering and appreciating the complexity of life is also in the affective domain. In Mike's Life Science class, this is his sole central goal for the eighth grade students. The goal of wondering and appreciating the complexity of life remains as a central component in Mike's science teaching orientation for the AP Biology course. Mike uses entertaining stories and highly engaging labs as a means of helping his students achieve this goal. For the Independent Research course, Peg has a peripheral goal of having the students develop a belief in personal success. The Independent Research course is a time-consuming course. Peg often spends three to four additional hours after school helping students prepare for competitions. Peg stated that her goal is not about winning competitions. Peg uses the completion of science fair projects and competitions as a means of helping her students develop confidence in their personal ability to succeed beyond high school. In this study, affective domain goals hold a prominent place in science teaching orientations of the participants.

4.3.2.2 General School Goals: Life Skills and College Preparation

Each of the participants has goals that might be best described as general goals of schooling. The participants, themselves, use the terms “life skills” and “preparing for college” when they talk about this particular set of goals. In some cases, these general school goals are peripheral components of the participants’ science teaching orientations, but in other cases, the general school goals are central components. The general school goals do not relate specifically to the teaching of science. In the category described as “developing life skills,” participants discussed developing responsibility, critical thinking skills, oral and written communication skills, and a belief in personal success. In preparing for college, participants discussed the need for test-taking skills, being able to read a science text, and critical thinking skills. Participants were asked to consider the scenario of teaching a course in another discipline, such as mathematics. The participants stated that they would continue to have this same set of goals for their students, i.e., developing life skills and preparation for college. Mike reflected on his social studies background and teaching geography. After interviewing Mike I wrote the following analytic memo, "Mike's goals are not specific to science. The way he taught history was very similar to the way he teaches biology" (Mike, Analytic Memo, 3/21/2001). Mike valued exploring questions and being able to think logically, regardless of the subject he was teaching. Martha summarizes the need to have general school goals when she gave her rationale for including group projects in her courses:

> I: Why do you include one [student presentation] in each marking period? How does that support your goals for the students?
> M: Personal interest. . . Developing the skills that aren't science skills.
> I: Is that part of your job?
> M: I think it is . . . Because they are still children. I still see my job preparing them to be successful in life, not just in biology. (Martha, 2nd Interview, 4/25/01)

Other participants in the study expressed a similar viewpoint; although they are science teachers, they are primarily teachers of children and the science is secondary.

The participants did differentiate between life skill goals and college preparation goals. In the study, the teachers tended to have life skill goals for younger students in required courses or for non-college bound students in electives. In the Environmental Biology course, many of Sharon's students are not college-bound. Developing life skills is a peripheral component of Sharon's teaching orientation for this course. She discusses developing skills in observation, asking questions, written and oral communication, and becoming good decision-makers. In the context of the Environmental Science course, Sharon does not discuss goals related to preparing her students for college. In Mike's Life Science course, he discusses life skills goals as well. Mike wants his eighth grade students to learn to think logically, to explore questions and develop a sense of responsibility. Peg's teaching orientation for her College Prep Biology tenth grade students includes both college preparation goals and life skill goals of "becoming useful, productive, informed citizens."

Participants who taught college-bound students, particularly in upper level elective courses, have goals of preparing the students to be successful in college. Mike's science teaching orientation for the AP Biology course has a peripheral component of preparing students for college. Mike thinks students will be successful in college if they are able to "think outside the box." In the Advanced Zoology elective course, Martha fosters the development of lab skills and lab confidence because she feels they are important to being successful in college science courses. Martha also stresses the development of general study skills as another dimension of helping her students be successful in college. Peg prepares her Independent Research students for college science courses by helping them develop specialized lab skills and confidence in their ability to do scientific research.

When participants discussed general school goals, they often times listed science process skills, such as making observations, classifying, organizing and analyzing data, and drawing conclusions. The participants tended to talk about these skills as general life skills, not as science-specific process skills. For examples, refer to the representation of Mike's science teaching orientations (Figures 3.3 and 3.4) and Sharon's representation of her science teaching orientation (Figure 3.1). In other examples, the participants discussed the development of science-specific laboratory skills, but developing laboratory skills was viewed as a way to develop laboratory confidence. Laboratory confidence was viewed as an important element of preparing students to be successful in college science courses. For example, see representations of Martha's teaching orientations (Figures 3.6 and 3.7) and Peg's teaching orientations (Figure 3.4 and 3.5). Even though participants taught science process skills, they viewed the development of these skills not as a end itself, but as a means to helping students develop general life skills and confidence to be successful in college science courses.

4.3.2.3 Science Content Goals are Present, Not Always Central

In the PCK literature, an academic rigor orientation toward teaching science has the central goal of "representing a particular body of knowledge" and is characterized by "challenging the students with difficult problems and activities" (Magnusson, et al., 1999, pp. 100-101). A didactic orientation has the goal of "transmitting the facts of science" and is characterized by the use of lecture or discussion (pp. 100-101). Participants in this study did not hold orientations that could be interpreted as purely didactic or academic rigor. The participants' orientations were more complex, including goals in the affective domain and general schooling goals. The teachers did have goals related to science content. Participants varied in their description of their science content goals. Martha expressed her science content goal in the following way, "I want them [the students] to take away a deeper understanding of some biological concepts, have a stronger knowledge base. . ." (Martha, 2nd Interview, 5/25/01). Peg describes her science content goal as wanting the students to have a solid understanding of basic biology concepts. Both Martha and Peg have science content goals as central components in their science teaching orientations. However, both participants have additional central goals. For Martha, developing and maintaining positive science attitudes is of equal importance to learning science content. Peg has an additional central goal of wanting her students to become useful, productive and informed citizens. Peg and Martha place great value on learning science content, but they also have additional central goals of equal importance.

Science content goals are peripheral components of Mike and Sharon's science teaching orientations. Mike is teaching 8th grade students and Sharon is teaching an elective course, in which not all students are college-bound. Mike places a greater value on developing a sense of wonder and appreciation for life than mastering science content. Even in Mike's AP Biology course, his science content goal is a peripheral component of his teaching orientation. Sharon's science content goals are secondary to her central goals of developing positive science attitudes and sound environmental decision-making:

> I don't care if they [the students] remember a single vocabulary term, because that's not going to change their life. I want them to be aware of what environmental problems are, be aware of what's outside of them when they go out for walks, to notice the living things around them and to continue to do that, not just tomorrow when I take them for a walk . . . (Sharon, 1st Interview, 3/14/01)

Mike and Sharon do have goals relating to learning science content, but these goals are peripheral components of their science teaching orientations. In this study, two of the participants have learning science content as central goals, but they also have additional central goals that are of equal importance to them. Science content goals are peripheral components of the other two participants' teaching orientations.

4.4 The Sources of Science Teaching Orientations

The second research question explores the sources of teachers' orientations to teaching science. In this study, I have defined sources as the probable influences on the development of an individual's science teaching orientation. During the interviews, the participants were asked to draw on their personal biographies, broadly defined, to identify probable past influences on their teaching orientations. In the case of Sharon, she was able to readily identify biographical sources during the first interview. With the other three participants, the biographical sources of their orientations unfolded as the data collection progressed. Through repeated questioning and reflection, the participants were able to make connections between biographical sources and the nature of their science teaching orientations, possibly suggesting the implicit influence life events may have on a teacher's beliefs. During the data collection process and subsequent analysis, additional influences emerged, with the critical role of the school context and the students becoming apparent.

In looking across the four participants, an assertion is offered for the second research question. Science teaching orientations appear to be influenced by a multitude of factors (see Figure 4.1). Some of the factors are external to the current classroom context, and are part of the participant's personal biography. In the study, prior work experience and professional development and collaboration are interpreted as important external sources shaping an individual's teaching orientation. Other factors, defined as internal school factors, appear to play an even stronger role in shaping the participants' science teaching orientations. The participants drew strong connections between their teaching orientations and their current students. Time constraints within the schedule of the school day were interpreted as another internal factor shaping the participants' teaching orientations. The remainder of this section describes each of the subpoints of the assertion presented in Table 4.2. Each of the participants brought a unique set of life experiences and school contexts to this study, which in turn contributed to the assertion relating to the sources of the participants' science teaching orientations.

Table 4.2

Assertions Relating to the Sources of Science Teaching Orientations

Research Question: What are the sources of science teaching orientations held by a group of exemplary biology teachers?	
Section	**Assertion**
4.4	**Science teaching orientations appear to be influenced by a multitude of factors external and internal to the classroom, including:**
4.4.1	• Prior work experience
4.4.2	• Professional development and collaboration
4.4.3	• Students and beliefs about learning
4.4.4	• Time constraints

4.4.1 Influence of Prior Work Experiences

For three of the four participants, secondary science teaching was a second career. Sharon had worked as a naturalist; Mike had extensive retail business experience; and Martha had worked as a research assistant in a science laboratory. These three participants made career switches for a variety of reasons: desire to work with youth, desire for full-time, permanent employment, and the compatibility of a teaching career with raising a family. Each of the participants made strong connections between their prior work experiences and their science teaching orientations.

"Developing tools and life skills" is a component of Mike's teaching orientation for both Life Science and AP Biology. Mike supports the school's homework policy because he feels that homework assignments help develop students' sense of responsibility. In his business career, Mike was a manager and valued responsible employees. In his AP course, Mike emphasizes the development of research tools. As a means to achieving this goal, Mike requires his AP students to complete an independent science project. While working on his master's degree, Mike worked as a research assistant in a biology lab. Mike credits this work experience for directly shaping the "development of tools and life skills" component of his science teaching orientation. Sharon worked as a naturalist for the Parks Service, and she credits this prior work experience for directly shaping both her teaching goals and means. When she became a secondary science teacher, Sharon wanted to continue her work in environmental education. Because of her experience as a naturalist, Sharon had developed the skills and knowledge needed to take high school students on field trips. Sharon also uses entertainment as one means to achieve her goals. Sharon attributed this means partially to her personality but also to her work with the public in park settings. In Martha's science classes, the students are frequently engaged in laboratory activities. Martha designs and writes all of her own labs. She also has her students write lab reports, which they keep in a lab notebook. For both of her courses, the "development of lab skills" is a peripheral component of her science teaching orientation. Martha's chosen means and goals make sense in light of her previous five-year work as a research assistant. Prior work experiences were important influences in shaping each of these participants' science teaching orientations.

Peg had been a secondary science teacher for her entire career. In the absence of prior work experience, Peg drew on her personal experiences as a learner, primarily at the college level. To be successful in college, Peg needed to be able to learn course content by reading the textbook. In Peg's College Prep Biology course, "preparing students for college" is one of her peripheral goals, while "developing a solid understanding of basic biology concepts" is a central component of her science teaching orientation. Peg achieves these two goals simultaneously by assigned textbook readings and scheduling tests. Peg sees her teaching role primarily as that of an organizer, assigning chapters to read and testing the students over the material they have read. Martha was the only other participant who discussed the influence of her own experience as a learner. When I asked Martha why she included labs in her science classes, she answered that labs were the part of science that she liked best as a student. Personal learning experiences may have influenced other participants' science teaching orientations, but they identified prior work experiences as being major influences.

4.4.2 Influence of Professional Development and Collaboration

In the interviews, participants were asked to describe their involvement in professional development activities. I defined professional development as activities that the participants voluntarily engaged in for their own professional growth. I began the discussions by asking about attendance at professional conferences, such as the National Science Teachers' Association Conference or the National Association for Biology Teachers Conference. None of the four participants attended conferences for science teachers on a regular basis, if ever. Three participants chose to be involved occasionally in summer workshops for teachers. Two of the four participants collaborated on an informal basis with scientists and foundations, as part of their professional development. One participant attended scientific meetings. Over their years of teaching, each participant had engaged in a consistent, yet unique pattern of professional development activities. The one consistent aspect across the four participants was the strong connection between their choice of professional development activities and the individual's science teaching orientation. The idea of the connection between science teaching orientations and professional development began to emerge in this analytic memo:

> Sharon selects courses and workshops to learn more about the environment and teaching in the environment. Mark takes whatever summer courses strikes his fancy at the time. Peg does not take professional development courses, etc. because she can learn what she needs to by reading books. This very much fits the way she teaches. She has attended professional science meetings to help her with Independent Science. Martha chose to work in a scientist's lab and goes to X College where they can develop new protocols for labs—very much fits her science teaching orientation. This is interesting how what they chose for professional development is greatly shaped by their science teaching orientation. (Analytic Memo, 6/29/01)

To further elaborate on this connection, Sharon talks in great detail about the influence of her collaborations with a private foundation and a marine science consortium. Early in her teaching career, Sharon became involved with these organizations and incorporated their philosophies into her own teaching. Sharon identifies her collaboration with these organizations as a major source of the central component of her science teaching orientation, i.e., “developing environmental decision-making.” Sharon also chooses to collaborate with local scientists on projects than engage her students in environmental studies. In addition, Sharon takes summer courses in environmental studies whenever possible.

Mike chooses to participate in a different science teacher education workshop each summer, with the topics varying greatly from year to year. What might appear as a random selection of professional development activities makes sense when connections are drawn to Mike’s science teaching orientation. In 8th grade Life Science, Mike’s single, central component is for students to “wonder and appreciate the complexity of life.” In Mike’s AP Biology course, a second central component is added, “to develop skills and tools to explore their questions.” So, by choosing a variety of workshop topics, Mike’s appreciation for the complexity of life grows and he also gains knowledge of various lab techniques, which he can share with his AP students and they work on their independent science projects.

Several years ago, Martha applied for a summer program where she worked in a scientist’s lab. Martha felt she probably wasn’t a good candidate for the program because she already knew many of the lab techniques. She was also disappointed because she found that particular research group’s protocols to be too difficult to transfer to a secondary science classroom setting. Martha’s favorite professional development activity occurred at a local college that offers summer workshops for science teachers. When asked to elaborate on why the workshops were so outstanding, Martha said that she enjoyed the opportunity to develop new protocols she could use with her students.

Peg does not engage in typical professional development activities for teachers, such as summer workshops and science courses. She has attended scientific meetings, a type of professional development not mentioned by any of the other participants. Through lengthy discussions, we were able to identify Peg's collaboration with research scientists as a major source of professional growth. Peg finds the greatest professional satisfaction in working with her Independent Science students. Via email, Peg consults with scientists to help her students develop protocols for their research projects. Peg's single, central component of her orientation for this course is to have students engage in scientific research. As a natural extension of this goal, she seeks out and communicates with scientists across the country. Through this interaction, she continues to grow and develop as a teacher of the Independent Science course.

Each of the participants, over the course of their teaching careers, has developed a consistent pattern of professional development. The participants' professional development choices appear to have a strong connection to their individual science teaching orientations. Participants choose professional development activities based on components of their teaching orientations. This connection may operate as a feedback loop. The participants' orientations influence what they choose for professional development. In turn, the professional development they engage in re-enforces the science teaching orientation they hold.

4.4.3 Influence of Students and Beliefs about Learning

In the original design of the study, the emphasis was placed on biographical sources of the participants' science teaching orientations. During the data collection process, the current school context emerged as an important source that influenced and shaped the participants' teaching orientations. The students appeared to play a major role in the current school context. School administration, parents, standardized tests and other teachers in the department played minor roles when compared to the influence of the students. In this study, student-centeredness was a criterion for selection of the participants. The four teachers in the study continually monitored their students' conceptual understanding. The participants actively sought feedback from their students. The participants' students appeared to enjoy their biology classes and respected their teachers. Each of the participants had developed a strong sense of rapport with their students.

In day-to-day classroom interactions, the students greatly influence the instructional strategies or means that the participants use to help students achieve the course goals. Sharon believes that students are bored in school. She tries to vary her instructional strategies and actively engage her students. Sharon explained, "And if you make things interesting and practical and have them doing real stuff, they will have a reason to come to your class and learn stuff" (Sharon, 1st Interview, 3/14/01). Mike talked about trying new activities with his students. When asked to explain how he evaluates the merit of a particular lab or activity, Mike states, "Oh, well, you pick that up from the kids" (Mike, Card Sort, 3/21/2001). In Peg's Independent Research class, her role varies depending on the needs of her students. At times, Peg acts as a cheerleader for the students, while at other times she serves as their mentor or collaborator. Martha's teaching strategies or means seem to be heavily influenced by the students' feedback. Martha described how she modified her labs, changing from an objective format to a question-driven design, based on student reaction. Martha uses lab notebooks rather than worksheets because her students have a negative connotation of worksheets (Martha, 2nd Interview, 5/25/01). Martha uses more review and practice strategies with her Biology II course, than with her Advanced Zoology students. Martha explained, "They [the Advanced Zoology students] would be bored to tears if I reviewed and practiced more than a certain amount. They would hate it" (Martha, 2nd Interview, 5/25/01). In this study, students greatly influenced the teachers' choice of means or instructional strategies.

The participants' means are also influenced by their beliefs about how students learn in general. Mike believes students learn best when they are curious and explore questions. Mike uses interesting stories, interspersed with questions, to teach science content. Mike also uses intriguing demonstrations and labs to capture the students' interest and foster curiosity. Sharon believes students learn best when they are involved in immersion experiences and real-life projects. Sharon takes her students on field trips and engages them in projects monitoring streams, planting butterfly gardens and building bluebird boxes. Martha believes students learn best when the material is relevant to them. Martha also believes that her Biology II students learn through repetition. In her lectures, Martha makes frequent connections between the science content and the students' lives. She uses labs to re-enforce the content of the lectures. Peg believes that students learn best on their own. Peg has formulated her beliefs about learning based on her own learning style. She learns best by studying textbooks. Assigning textbook readings and class discussion of the assigned readings are important means in Peg's teaching. In this study, beliefs about learning appeared to have a strong influence on participants' science teaching orientations, in particular, influencing the means the teachers use to help their students achieve the course goals.

The interpretations of the influence of students and beliefs about learning are supported in the literature. Current research shows that knowledge is situated in specific physical and cultural contexts, and this view of situated cognition applies to teacher learning (Borko & Putnam, 1996). In this study, the current school context shaped the participants' knowledge and beliefs about the their goals and purposes for teaching biology to a particular group of students. Personal beliefs about how students learn best also shaped the participants' teaching orientations, particularly the participants' chosen means. Teachers' beliefs or views of learning are included in various models for PCK, including Grossman's (1990) model, the science teaching PCK model proposed by Magnusson et al., (1999), and Loughran, Gunstone, Berry, Milroy and Mulhall's (2000) PCK model for secondary science teaching.

4.4.4 Influence of Time Constraints

Issues related to time were woven through each of the participants' interviews. In this study, all of the participants were experienced teachers with strong subject matter knowledge. The participants were not concerned with the need to fill class time with instructional activities; rather the participants saw time as a limiting factor in their teaching. All of the participants were busy working with students after school, helping to prepare the students for AP exams, science fair competitions, Science Olympiad, and other science competitions. The participants discussed time constraints in two different areas, their class time with students and their time for preparing for teaching. Time constraints appear to influence the participants' goals for their courses, as well as the means used to help students achieve the course goals.

A constraint in class time was the first time-related issue to emerge in the interview data. All of the participants felt that they had a limited amount of time in which to help the students achieve the goals of the course. The participants taught in schools with traditional class schedules, with class periods varying 40 and 50 minutes in duration. The participants discussed the need to use this limited classroom time efficiently. In the card sorting activity, participants often weighed each scenario in regard to the amount of time required in comparison to how much the students would learn from the activity. Lanz and Katz (1987) refer to this process as the need for "pedagogical efficiency." In the card sort and in their own teaching, Martha and Peg rejected hands-on, discovery activities because they felt this type of teaching approach was an inefficient use of limited class time.

Two of the participants, Martha and Sharon, were able to negotiate modifications in their weekly class schedule. Martha's Advanced Zoology class met for a double lab period once a week. Martha stated that the schedule of the double lab period dictated her instructional sequence. She preferred to lecture before the students do lab dissection, but in some cases, the schedule dictated that the students completed the dissection prior to Martha's lecture. Sharon negotiated a double class period for the afternoon sections of her Environmental Biology course. These sections alternated days, meeting for double class periods every other day. In these two cases, Martha's Advanced Zoology course and the afternoon sections of Sharon's Environmental Biology course, the amount of total student contact time remained the same as the regularly scheduled courses. Sharon expressed the greatest concern in regard to the structure of the school day. To help her students achieve her central goal of developing environmental decision-making skills, Sharon prefers to rely on immersion-type experiences exploring nature. It is difficult for Sharon to schedule field trips, even within a two-hour time block. Sharon expressed a desire to have a schedule that would allow her to take monthly full-day field trips with each of her classes. Sharon would like to structure units around full day field trips, with a sequence of preparing for the field trip, collecting data on the field trip, and then returning to the classroom to analyze data and synthesize information. In the absence of this idealized schedule, Sharon is forced to make modifications, some times substituting paper and pencil activities for field trips. The daily school schedule greatly affects and limits the means Sharon uses to help students achieve her goals.

Preparation time was the second area in which participants discussed time constraints. In this study, preparation time includes preparing to teach class, time for grading, and for working with individual students. The constraint of limited preparation time tended to influence the participants' goals for their courses. Peg places a great value on engaging students in science fair projects. She began by requiring science fair projects in her ninth grade Physical Science course, with the students working on their projects outside of class. Engaging students in “doing science” has continued to remain a goal in Peg’s Physical Science course. Peg’s goal of involving students in science fair projects led to the development of the Independent Research course. However, “doing science” is not a goal in Peg’s College Prep Biology course. When I asked Peg to explain this discrepancy, she said that she didn’t have the preparation time or energy to manage that many additional science fair projects. Sharon likes to incorporate action projects into her Environmental Biology courses. Sharon thinks that action projects, such as habitat restoration and letter writing campaigns, support her goal of having the students become advocates for the environment. Because of time constraints, Sharon finds that she is not able to engage her students in as many action projects as she would like.

Perceptions of time constraints, both in class time and preparation time, clearly influenced the participants’ teaching orientations. The interpretations from this study are supported by the work of Andy Hargreaves (1994) in his book, Changing Teachers, Changing Times. Hargreaves states, “Time is an important dimension through which teachers’ work is constructed and interpreted by themselves, their colleagues and those who administer and supervise them” (p. 95). This was certainly true for the participants in this study who viewed the structure of their school day and the amount of preparation time as limiting factors. Hargreaves adds, “Teachers take their time seriously. They experience it as a major constraint on what they are able and expected to achieve in their schools”(p. 95). In this study of science teaching orientations, time constraints were interpreted as a source that influenced and shaped the nature of the participants' teaching orientations. In general, time constraints influenced the means the participants used to help students achieve the course goals. However, in some cases, time constraints also influenced the participants' goals for their biology courses.

4.5 Summary and Preview

In this chapter, a substantive-level theory of science teaching orientations was proposed. In Section 4.2, a diagram of the theory was presented. The diagram is a representation of the components of the substantive-level theory and the complex interrelationships between the components. Based on the interpretations of this study, science teaching orientations appear to be influenced by a multitude of factors, including past work experience and professional development. The school context and daily student feedback appear to have the greatest influence on shaping the nature of the participants' science teaching orientations. Means are an important aspect to consider when studying teaching orientations. Goals and purposes shape the means that a teacher chooses, but a limited repertoire of means can also restrict the teacher's goals and purposes.

In Sections 4.3 and 4.4, a set of assertions was presented for each research question. In exploring the nature of science teaching orientations, the first assertion relates to the construct itself. The use of central and peripheral components, as well as the means of achieving these goals, appears to better represent the complex science teaching orientations held by the participants in this study. The need to pay attention to grade level specificity is an important aspect of researching science teaching orientations, as participants held different orientations for each biology course they taught. The next set of assertions focused on the specific commonalities across the four participants in the study. The participants held a more generalized orientation to teaching, rather than a science-specific orientation. Affective domain goals and general school goals were common to all four participants' science teaching orientations. Each participant held science content goals, although these goals were not always central goals.

In exploring the sources of the participants' science teaching orientations, prior work experiences have a strong influence. Professional development provides a feedback loop into science teaching orientations, as participants select professional development that tends to re-enforce their science teaching orientation. The school context plays an important role in shaping participants' science teaching orientations, with the students have the greatest influence on the participants' science teaching orientations. Perceived time constraints within the school day also shaped the nature and means of an individual's teaching orientation.

A discussion of the substantive-level theory is presented in the next chapter, Chapter 5. The substantive-level theory is compared to existing models of domains of teaching knowledge, including the PCK model for science teaching. Commonalities, overlaps and differences between the models are highlighted.

Chapter 5

DISCUSSION

5.1 Overview

In Chapter 4, the substantive-level theory of science teaching orientations was presented. In this chapter, the substantive-level theory is situated within the larger context of the current PCK literature. In Section 5.2, the substantive-level theory of science teaching orientations is mapped onto models of domains of teacher knowledge. In Section 5.3, the substantive-level theory is compared to Magnusson et al.'s (1999) PCK model for science teaching. Section 5.3 concludes with a return to the model of domains of teacher knowledge, offering a simplified version of a model that represents the relationship between domains of teacher knowledge and science teaching orientations.

5.2 Substantive-Level Theory Situated in the Current PCK Literature

Because of its complex nature, the construct of pedagogical content knowledge has been a challenging area of research (Baxter and Lederman, 1999). In an attempt to address the issue of complexity, this study focused on a single component of PCK, that of science teaching orientations. While the interview questions remained focused on the participants' goals and purposes for teaching biology in a specific course, the messiness of the PCK construct remained firmly attached to the study. The diagram of the substantive-level theory illustrates the multitude of complex, inter-relating factors represented in a single component of PCK. For ease of reading, the diagram shown in Chapter 4 is repeated in this chapter as Figure 5.1.

In the following subsections, the substantive-level theory of science teaching orientations will be compared to various models of domains of teacher knowledge. In the introduction of Examining Pedagogical Content Knowledge, Gess-Newsome (1999) reflects on the value of models in the process of attempting to make sense of the complex process of teaching:

> The attempt to understand and reduce the complexity of teaching to enable its study has generated a variety of metaphors and models. Models of cognition are created from data interpretations, are proposed as conceptual tools to identify and discriminate among hypothesized constructs, and represent inferred relationships among constructs. For researchers, a fundamental task is to select, modify, or create a conceptual model from which to work. Good models, like good theories, organize knowledge in new ways, integrate previously disparate findings, suggest explanations, stimulate research, and reveal new relationships. (p. 3)

The goal of this section is to situate the substantive-level theory of science teaching orientations within the current PCK literature. How does the proposed theory of science teaching orientations fit into more general models of domains of teacher knowledge? How does this substantive-level theory of science teaching orientations compare to models of PCK for science teaching? These questions will be explored in more detail in the following subsections.

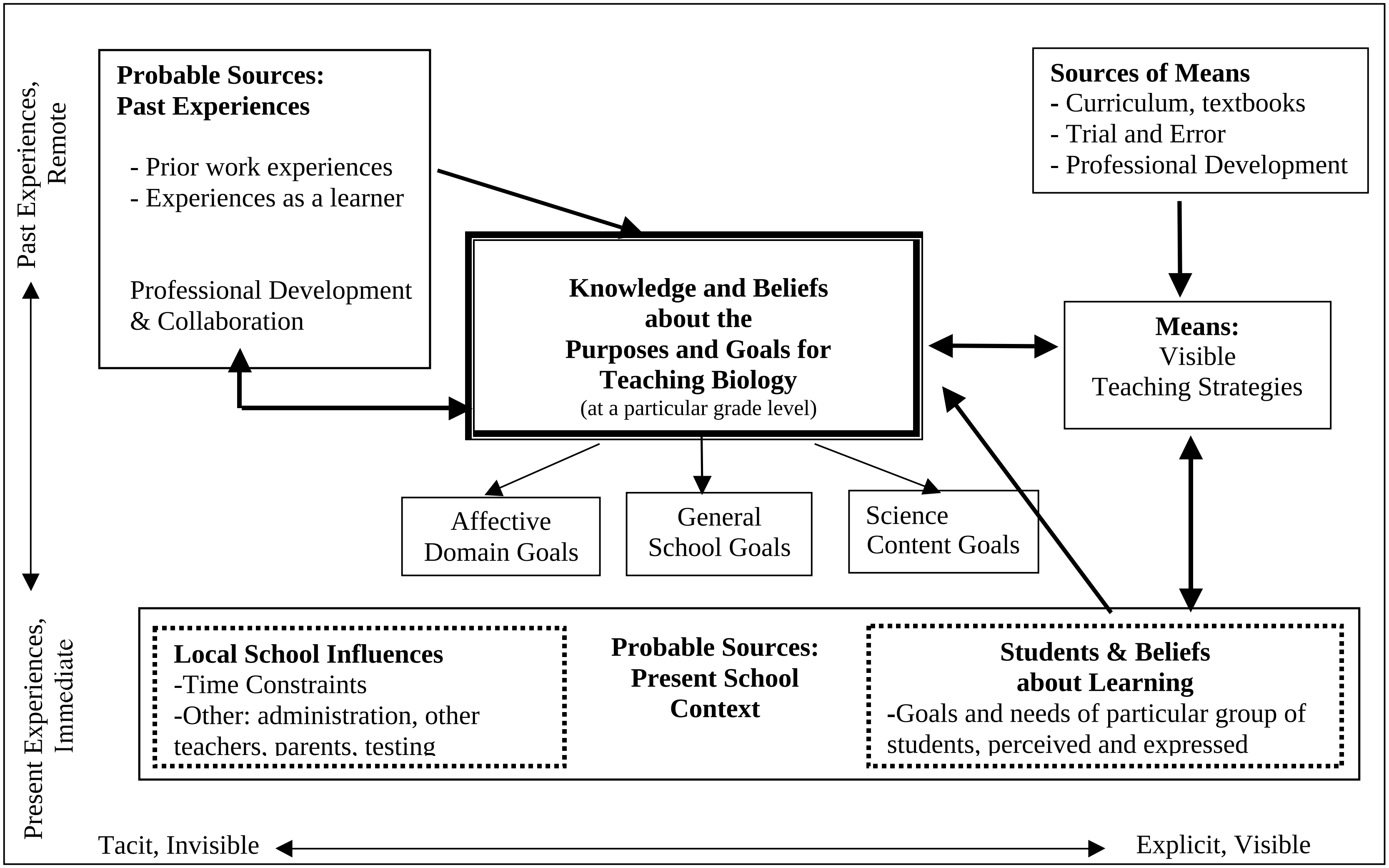

Figure 5.1. Substantive-level theory of science teaching orientations

5.2.1 Comparison with Models of Domains of Teacher Knowledge

In The Making of a Teacher, Grossman (1990) proposed a model of domains of teacher knowledge. This domains model, shown in Figure 1.1, draws on her work with Shulman. Magnusson et al. (1990) make minor modifications to the Grossman (1990) model; this slightly modified model is shown in Figure 5.2. When the proposed substantive-level theory of science teaching orientations (See Figure 5.1) is mapped onto this model of teacher knowledge domains, some additional modifications are suggested. In the domains model, PCK is represented as interacting with the three other domains of teacher knowledge: (a) subject matter knowledge and beliefs, (b) [general] pedagogical knowledge and beliefs, and (c) knowledge and beliefs about context. The interpretations of this study, while concentrating on the subcomponent of teaching orientations within PCK, are in general agreement with the domains model. The participants' science teaching orientations did appear to be shaped by the three domains listed above. However, for the participants in this study, the three domains of teacher knowledge did not carry equal weight in their influence.

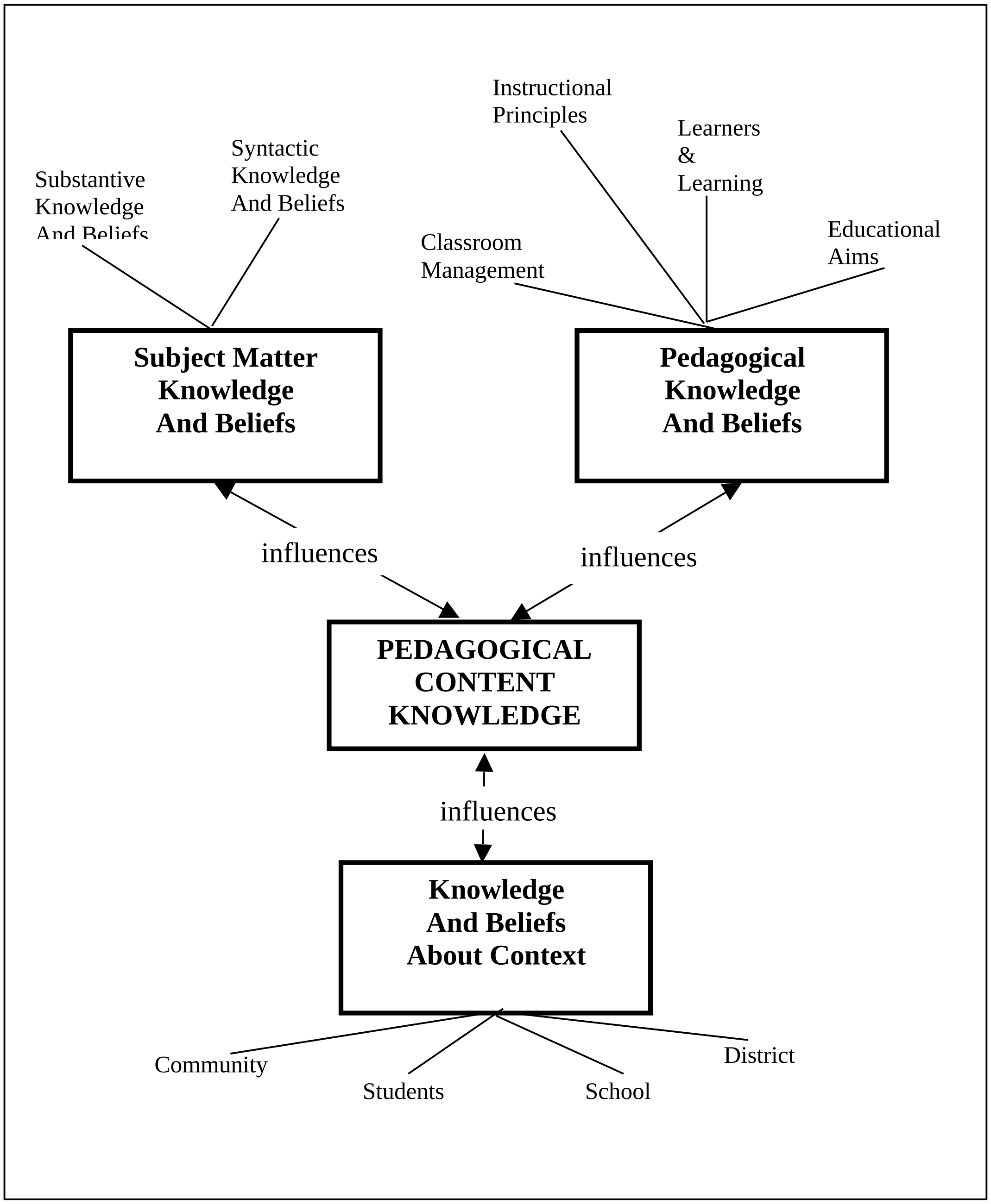

Figure 5.2. A model of the relationships among the domains of teacher knowledge. [Modified from Grossman (1990)] Source: Magnusson et al. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N.G. Lederman (Eds.), Examining pedagogical content knowledge: the construct and its implications for science education (pp. 98). Dordrecht: Kluwer.

In this study, the domain of knowledge and beliefs about the school context had the greatest influence on the participants' science teaching orientations. Within the domain of the school context, the students appeared to have the greatest impact in shaping the participants' goals and purposes. The participants' teaching orientations were also strongly influenced by the domain of [general] pedagogical knowledge and beliefs. The participants' held many goals that were related to the general educational aims of schools, e.g., preparation for college and developing life skills. The domain of subject matter knowledge had a lesser influence on the participants' teaching orientations. This domain is subdivided into knowledge and beliefs about substantive and syntactical aspects of the subject matter (Schwab, 1978). Of these two components, the substantive aspect of the subject matter, i.e., the science content, was represented in the participants' teaching orientations to a greater extent than the syntactical aspect (the nature of the discipline). It should be noted, though, that the subject matter domain appeared to have the least influence on the participants' science teaching orientations.

To accommodate the interpretations from this study of experienced biology teachers, the model of domains of teacher knowledge requires minor modifications. The domains remain constant, but their varying influences would be better represented by the use of weighted arrows. See Figure 5.3. The thickest arrows had the greatest influence in shaping individuals' science teaching orientations. The domain model shown in Figure 5.2 indicates that the PCK domain influences and is influenced by the other three domains. The interpretations from this study represent a snapshot in time of the teaching orientations of four experienced biology teachers. Because the issue of the development of science teaching orientations is beyond the scope of this study, I do not represent two-way arrows in the modified diagram in Figure 5.3.

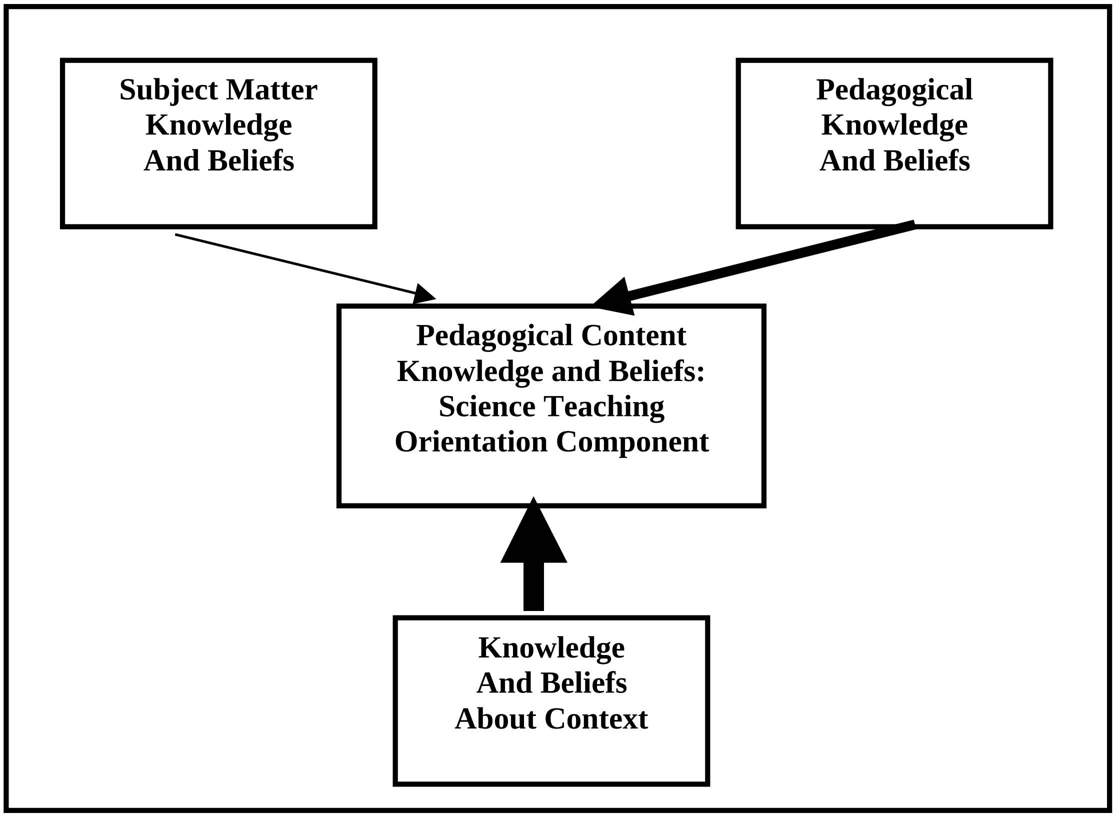

Figure 5.3. Modifications to the domains of teacher knowledge model (using a simplified version).

Carlsen (1999) offers an up-dated model of domains of science teacher knowledge. See Figure 5.4. In his revised version of the model, Carlsen emphases knowledge of context by placing it as a backdrop for the domains of general pedagogical knowledge, subject matter knowledge and PCK. Knowledge of context is represented in two layers: (a) knowledge about the general educational context and (b) knowledge about the specific context. The interpretations of this study align with the modifications suggested by Carlsen. The participants in this study held teaching orientations that were greatly influenced by the students they taught. The participants held distinctly different teaching orientations, specific to a particular course and group of students. As part of the teaching orientations, participants' also held goals that reflected the general educational aims of schools. The interpretations of this study appear to be better represented by the updated heuristic offered by Carlsen than the earlier model of domains of teacher knowledge shown in Figure 5.2. Carlsen offers other modifications specific to science teaching. Within the domain of subject matter knowledge, Carlsen includes knowledge of the nature of science and technology. I agree with Carlsen that this is a necessary component of teacher knowledge if teachers are to meet the guidelines outlined by current reform documents. However, in this study, participants did not appear to draw on knowledge or beliefs of the nature of science and technology.

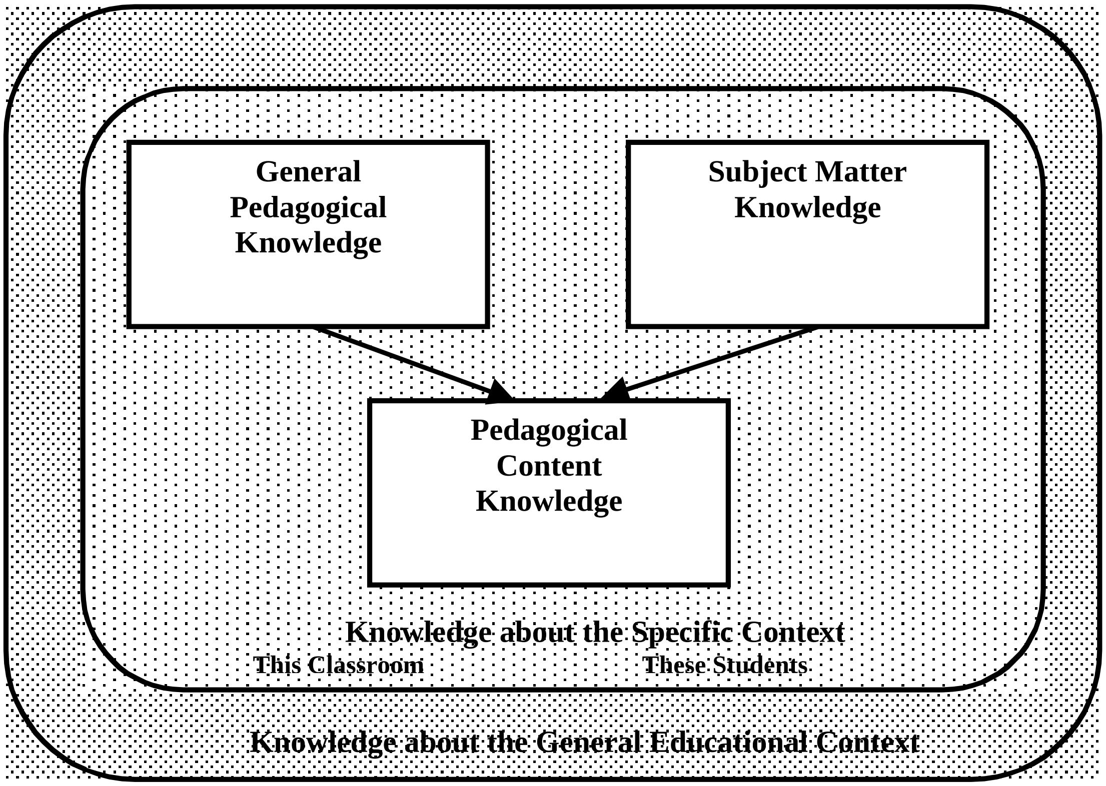

Figure 5.4. Simplified version of Carlsen's updated model of domains of teacher knowledge. Source: Carlsen, W. S. (1999). Domains of Teacher Knowledge. In J. Gess-Newsome & N. G. Lederman (Eds), Examining pedagogical content knowledge the construct and its implications for science education (p. 136). Dordrecht: Kluwer.

5.2.2 Comparison with PCK Models for Science Teaching

In Section 5.2.1, the proposed substantive–level theory of science teaching orientations was mapped onto models representing domains of teacher knowledge. In this section, the proposed model of science teaching orientations is mapped onto more specific models that focus on the PCK domain of teacher knowledge. Magnusson et al. (1999) proposed a PCK model for science teaching. A simplified version of the model was shown in Figure 1.2. The full version of the model is shown in Figure 5.5.

The Magnusson et al (1999) PCK model for science teaching places "orientations to teaching science" as an overarching component within the domain of PCK. The placement of the orientations component is consistent with Grossman's (1990) PCK model. In this study of secondary biology teachers, participants did have a consistent set of goals and purposes for each course they taught. This set of goals and purposes, or orientation, appeared to act as a filter in their instructional decision-making process. Lanz and Kass (1987), report similar interpretations in their study of chemistry teachers. Lanz and Kass use the term "functional paradigm" to describe a core set of beliefs and values that teachers use when they transfer new curriculum materials into classroom practice. Within the broader teacher education literature, a review of research supports the premise that a teacher's orientation to teaching plays a critical role in shaping the teacher's classroom practice (Borko and Putnam, 1996).

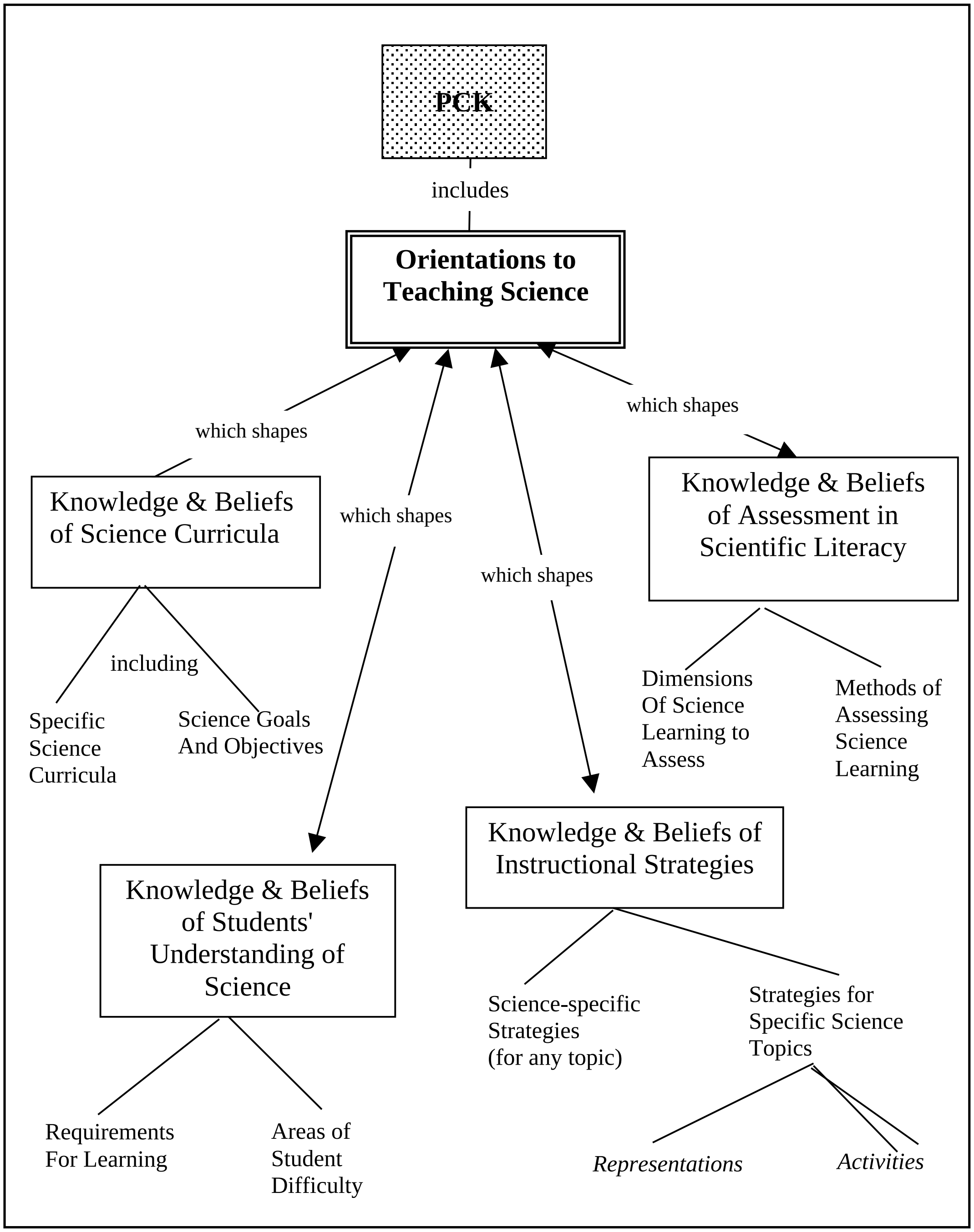

Figure 5.5. Components of pedagogical content knowledge for science teaching. Source: Magnusson, S., Krajcik, J. & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N.G. Lederman (Eds.), Examining pedagogical content knowledge: the construct and its implications for science education (p. 99). Dordrecht: Kluwer.

The Science Teaching PCK Model proposed by Magnusson et al (1999) indicates that the teaching orientations component shapes and is shaped by the other components within the model, those being knowledge of science curricula, students' understanding of science, instructional strategies and assessment of scientific literacy. While this may hold true for beginning teachers, a different interpretation emerged from this study of experienced teachers. For the participants in this study, their science teaching orientation acted more as a filter than as an interacting component. The participants evaluated their use of different instructional strategies and assessment based on their current set of established goals and purposes for a particular biology course. This may be an artifact of the research design (e.g., the card sort task) and the limited scope of this study, with its focus on nature rather than development of science teaching orientations. However, in this study, the participants' teaching orientations appeared to be shaped by other domains of teacher knowledge, in particular, knowledge and beliefs about [general] pedagogy and about the school context. For example, participants' science teaching orientations were influenced to a greater extent by their knowledge and beliefs about learners and learning (in the domain of [general] pedagogical knowledge) than their knowledge of students' understandings in science (a component within the PCK model). The assertion presented in Chapter 4.3.2, that participants held more general rather than science-specific orientations, supports this suggested model revision.

5.2.3 A Revised Model of Domains of Teacher Knowledge

To better represent the interpretations from this study, a simplified model is proposed which situates science teaching orientations within the models of domains of teacher knowledge and PCK models for science teaching (see Figure 5.6).

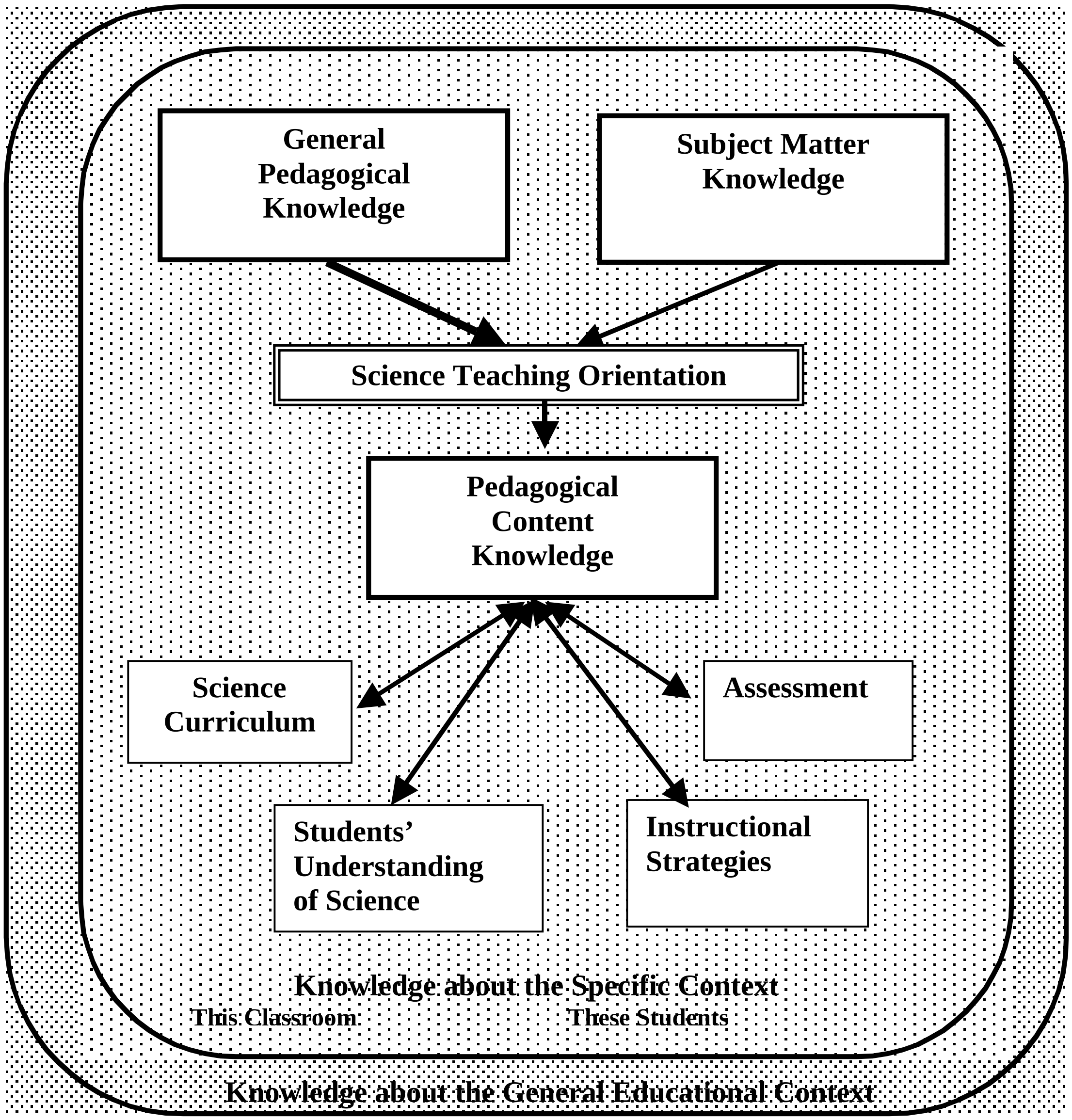

Figure 5.6. A revised model situating science teaching orientations with models of domains of teacher knowledge and the PCK model for science teaching

The model shown in Figure 5.6 represents the interpretations from this study of experienced biology teachers, and places science teaching orientations within a broader model of domains of teacher knowledge. In some cases, I have used one-way arrows due to the design of the research study. The research questions focused on the nature and sources of science teaching orientations, rather than the development of teaching orientations. At the time of the study, participants' teaching orientations appeared to be greatly influenced by their knowledge and beliefs of the generalized educational context and the specific context of their classrooms. General pedagogical knowledge and subject matter knowledge also influenced the participants' science teaching orientations. The arrow from the general pedagogical knowledge domain is more heavily weighted to indicate it's relative greater influence when compared to the influence of subject matter knowledge and beliefs. The component of science teaching orientations is placed outside of the PCK domain to represent its function as a filter through which participants make instructional decisions.

5.3 Conclusions and Preview

Borko and Putnam (1996) state, "A potential danger inherent in any description of categories of knowledge is that people may come to see the categories as representing an actual storage system in the human mind rather than a heuristic device for helping us think about teacher knowledge" (p. 677). The reader is reminded that the models presented in this chapter are not intended to be viewed as representations of reality, but as the researcher's interpretations based on classroom observations and interviews of a group of four secondary biology teachers. These interpretations and models are offered in an attempt to better understand teacher knowledge. Based on the interpretations of this study, the science teaching orientation component within the PCK domain appears to be misplaced and would better be represented as a filter through which participants based their instructional decisions. The models presented in this chapter are intended to be heuristics to help us think about teacher knowledge. The final chapter, Chapter 6, discusses implications relating to the substantive-level theory presented in Chapter 4 and the models of teacher knowledge discussed in this chapter. Implications are proposed in light of teacher education programs, professional development, research and policy development.

Chapter 6

IMPLICATIONS

FOR PRACTICE, RESEARCH AND POLICY

6.1 Review of Study and Overview of Implications

The final chapter of the study offers a set of implications stemming from the assertations and model of the substantive-level theory of science teaching orientations. Before the implications are introduced, a summary of the study is given. The first research question focused on the nature of the science teaching orientations held by a group of highly-regarded biology teachers. Two sets of assertions were proposed for this research question. The first assertion relates to the study of science teaching orientations in general. In representing an individual's science teaching orientation, there is a need for a more elaborate system of representation. The participants in the study held complex teaching orientations consisting of central and peripheral components. Representations of individuals' science teaching orientations are further enhanced with the inclusion of the teacher's means for helping students achieve the goals and purposes of the course. The interpretations from this study offer further evidence that science teaching orientations are course-specific. The teachers in this study held different teaching orientations for each course they taught. The second set of assertions relate to the nature of the teaching orientations held by this particular group of four highly-regarded biology teachers. The participants held more general teaching orientations than science-specific orientations. The participants held goals in the affective domain, e.g., the development of positive attitudes toward the study of biology. The participants also held general school goals, including preparing students for college and the development of life skills. Although each participant had science content goals, they were not always a central component of the science teaching orientation.

The second research question focused on the sources of the science teaching orientations held by a group of highly-regarded biology teachers. In this study, science teaching orientations appear to be influenced by a multitude of factors external and internal to the classroom. External factors, such as prior work experiences and professional development, influenced the nature of the participants' teaching orientations. The school context, with its time constraints, was another contributing factor. However, the strongest influence appears to be the teacher's daily interaction with the students. The participants' teaching orientations were strongly influenced by their beliefs about learners and learning.

The substantive-level theory was presented in a diagram that represents the complex interactions that influenced and shaped the participants' science teaching orientations. This substantive-level theory of science teaching orientations was situated within the current literature of domains of teacher knowledge. In this study, the participants' science teaching orientations served more as a filter, than as an interacting component within the PCK domain. I proposed new representations that emphasize the role of the school context and the important influence of general pedagogical knowledge and beliefs.

In this final chapter, I conclude the study by offering a set of implications arising from the assertions and models summarized above. Readers should scrutinize these implications with care, as they arise from my work with a small group of secondary biology teachers. For ease of reading, the implications are organized into three sections. The implications in Section 6.2 relate to science teacher education practice, at the level of prospective teachers and professional development for practicing teachers. In Section 6.3, implications are offered for continued research in the construct of science teaching orientations, and implications for policy development are found in Section 6.4. These implications are offered in the hope that they may be helpful to researchers and teacher educators who are interested in gaining a better understanding of the construct of science teaching orientations.

6.1 Implications for Practice: Science Teacher Education and Professional Development

In this section, I offer implications relating to science teacher education and professional development practice. The need to make explicit individuals' science teaching orientations is discussed in Section 6.2.1. The need for explicit attention to the syntactical aspects of science is discussed in Section 6.2.2. In the following section, Section 6.2.3, the significance of a teachers' "toolbox of means" is explored in light of the interpretations of this study. The need to address issues of time constraints and pedagogical efficiency as they relate to inquiry-based science teaching is discussed in Section 6.2.4.

Table 6.1

Implications for Practice: Science Teacher Education and Professional Development

Section	Implications for Practice: Science Teacher Education and Professional Development
6.2.1	In order for beliefs to become targets of change, there is a need to make explicit individuals' science teaching orientations, as part of: a) science teacher education programs. a) professional development for practicing teachers.
6.2.2	There is a need for explicit attention to the syntactical aspects of science in: a) science content courses and science education courses for prospective teachers. a) professional development for practicing teachers.
6.2.3	There is a need to assess practicing teachers' "toolbox of means" and a) find compatible means for supporting reform-based teaching. a) expand the teachers' toolbox.
6.2.4	For practicing teachers, there is a need to address issues of time constraints and pedagogical efficiency in inquiry-based teaching.

6.1.1 Making Beliefs Explicit

Teachers' knowledge and beliefs about teaching play an important role in influencing teaching practice (Borko and Putnam, 1996). One implication for this study is the importance of making beliefs about teaching explicit. In this study, the absence of teacher education programs as a component of the substantive-level theory of science teaching orientations is no accidental omission. When questioned about their teacher education programs, participants acknowledged that their education courses had little or no influence on the way they taught today. Two of the participants credited methods courses for giving them a few strategies for working with students, but none of the participants identified their teacher education program as an influence that shaped their goals and purposes for teaching biology. This may be an artifact of the research design, in that all of the participants had 13 or more years of teaching experience. Their teacher education courses may have been too distant for participants to recall influential aspects of their courses. However, many of the participants recalled influential experiences even more distant, including childhood experiences and work experiences prior to their entry into teacher education programs.

In his review of the literature on beliefs, Pajares (1992) notes, “Beliefs about teaching are well established by the time a student gets to college” (p. 326). Borko and Putnam (1996) discuss the role of pre-existing beliefs: “Research on learning to teach shows that teachers’ existing knowledge and beliefs are critical in shaping what and how they learn from teacher education experiences”(p. 674). In science teacher education courses and field experiences, it is important to help prospective teachers make their beliefs about teaching explicit. It is only when beliefs are made explicit, that they can become targets of change (Freeman, 1991). As prospective teachers share their beliefs about teaching, specifically their goals and purposes for teaching science, they can examine their beliefs in light of reform-based science teaching. The card sorting task, one of the research protocols in this study, has been shown to be a useful strategy with prospective teachers as well as practicing teachers (Friedrichsen and Dana, 2000).

Borko and Putnam (1996) state, “Experienced teachers’ attempts to teach in new ways also are highly influenced by what they already know and believe about teaching, learning and learners” (pp. 684-685). In planning and implementing professional development for practicing science teachers, it is important to make explicit the nature of practicing teachers’ science teaching orientations. In <u>Designing Professional Development for Teachers of Science and Mathematics</u>, effective professional development programs are described as including a cycle of learning, practicing and reflecting (Loucks-Horsley, Hewson, Love and Stiles, 1998, p. 263). As an integral part of the reflection phase, teachers’ should examine the nature of their teaching orientations, therefore, allowing their knowledge and beliefs about teaching to become targets of change.

6.2.2 Explicit Attention to the Syntactical Aspects of Science

The participants in this study did not draw upon a strong knowledge base of the syntactical aspects of the discipline of biology. Based on the interpretations in this study, there is a need to emphasize the syntactical aspects of science in undergraduate courses, both in science content courses and in science education courses. Lederman and Gess-Newsome (1999) studied prospective secondary biology teachers’ subject matter structures. They found that the teachers’ subject matter structures tended to reflect the content of their college science courses, and that they possessed fragmented knowledge of the nature of their disciplines. Borko and Putnam (1996), in their review of the literature on learning and teaching of subject matter knowledge, state “It appears that prospective teachers typically have few opportunities to gain, either in education courses or in humanities and science courses, the sorts of rich and flexible knowledge *of* and *about* subject matter they need to teach successfully for understanding" (p. 688).

In this study, the articulation of a generalized teaching orientation may also underscore the need for science-specific professional development opportunities that challenge teachers to think about learning and teaching of science using ideas specific to the science education literature. Lederman and Gess-Newsome (1999) expanded their research on subject matter structures (SMS) to include practicing secondary biology teachers. Again, SMSs were found to be shaped by past college science courses, but they were also modified in the teaching process. Lederman and Gess-Newsome state, "Opportunities to articulate beliefs about content and teaching appear to be critical factors in SMS formation and translation" (p. 206). In designing professional development for science teachers, explicit attention needs to be given to syntactical aspects of subject matter knowledge. This implication is supported in Designing Professional Development for Teachers of Science and Mathematics, "As professional developers plan activities to increase teachers' ability to teach science and mathematics in ways consistent with national standards and state frameworks, it is important for them to understand and consider the current beliefs about the nature of these disciplines" (Loucks-Horsley et al., 1998, p. 34).

6.2.3 Toolbox of Means

In this study, teachers appeared to have a repertory or "toolbox of means" they routinely employed to help students achieve the goals and purposes of the biology course. In the case of one teacher, limited means restricted the teacher's goals and purposes for teaching a particular biology course. In professional development programs for science teachers, there is a need to assess individuals' toolboxes of means. Loucks-Horsley et al. (1998) support this implication in their recommendation that professional developers assess current teaching practices as they plan professional development programs. For true reform to occur, teachers' toolboxes must contain means that are compatible with supporting reform-based teaching.

In the absence of compatible means, teachers will need to expand their repertory of means. As part of effective professional development programs, professional developers must model reform-based teaching strategies and teachers need to be given opportunities to try new these strategies with their own students (Loucks-Horsley et al., 1999). In this study, means appear to be closely interconnected with the teacher's purposes and goals for teaching biology. Based on this interpretation, there are implications for professional development. Specific attention should be given to assessing and expanding teachers' preferred means as they relate to supporting reform-based science teaching and learning.

6.2.4 Issues of Time Constraints and Pedagogical Efficiency

Participants consistently expressed concerns about time constraints and the need for pedagogical efficiency. They viewed time as a limiting factor that influenced their goals and purposes for teaching biology, as well as the means they employed. The participants expressed the need to use class time wisely and the recognition that their own time and energy were limited. Effective professional development programs need to take into considerations these concerns. In this study, pedagogical efficiency was a common component of science teaching orientations. For the teachers in this study, aspects of inquiry-based science teaching conflicted with the pedagogical efficiency component of their teaching orientations. This concern must be address in professional development programs advocating reform-based inquiry teaching of science.

6.3 Implications for Research

This section discusses implications for research, with the implications summarized in Table 6.2. The first implication focuses on the further elaboration of this study of highly-regarded biology teachers (see Section 6.3.1). In Section 6.3.2, implications are made for studies of a broader nature focusing on the construct of science teaching orientations. Section 6.3.3 focuses on implications relating to research into the connection between teacher education programs and critical factors influencing the development of science teaching orientations. In Section 6.3.4, the final implications for research relate to the connection between science teaching orientations and reform-orientated professional development for practicing teachers.

Table 6.2

Implications for Research

Section	Implications for Research
6.3.1	**Elaboration of the Substantive-Level Theory** Need for elaboration of the substantive-level theory of science teaching orientations: a) by increasing the number of participants in this study. b) including teachers from different school settings, urban vs rural vs suburban. c) include teachers in various career stages to include development in the proposed model.
6.3.2	**Elaboration of the Construct** Need for continued research to further develop the construct of science teaching orientations by: a) continued protocol development. b) collaborative work with teachers. c) inclusion of means as an integral part of science teaching orientations. d) expanded longitudinal studies that examine the development of science teaching orientations over time. e) additional empirical studies that include middle and secondary science teachers from all disciplines. f) drawing on new fields of study, i.e., situated perspective of cognitive psychology.
6.3.3	**Science Teacher Education Practice and Professional Development** Need to identify critical experiences in science teacher education programs that have a strong potential for shaping the development of individuals' science teaching orientations. Need for additional research in professional development studies: a) How does explicit attention to science teaching orientations influence the effectiveness of reform-based professional development? b) How do science teaching orientations change as a result of reform-based professional development?

6.3.1 Elaboration of the Substantive-level Theory

Additional research studies are needed to further develop the robustness of this substantive-level theory of science teaching orientations. There are several levels at which this study could be expanded. First, the study could be expanded by increasing the number of participants. Creswell (1998) notes that interviews with 20-30 individuals are typically needed to achieve the detail desired in a grounded theory study. Strauss and Corbin (1998) avoid specifying the number of participants needed, but state that sampling should continue until theoretical saturation is reached. They define theoretical sampling in the following way, "This means until (a) no new or relevant data seem to emerge regarding a category, (b) the category is well developed in terms of its properties and dimensions demonstrating variation, and (c) the relationships among categories are well established and validated"(p. 212). Additional participants in the study would either add to the robustness of the substantive-level theory or confirm that theoretical saturation has been reached. As the school context plays a critical role, a greater variation in the data might be obtained by including highly-regarded biology teachers from a wider range of school settings, urban vs. suburban vs. rural. This study lacked participants who taught in urban schools. At a second level, this study could be expanded to include the development of science teaching orientations. In the absence of longitudinal studies, one potential way of studying the development of science teaching orientations would be to interview biology teachers at different career stages, from first year teachers to veteran teachers nearing retirement. Therefore, this study could be expanded by including more participants to test the theoretical saturation of the current theory, and the theory could be expanded to include the development of science teaching orientations.

6.3.2 Further Development of the Construct

There is a need for continued research to further develop the construct of science teaching orientations. The first efforts should be concentrated on protocol development. In this study, I have used a combination of data collection techniques, including semi-structured interviews, a task-based interview using a card sorting activity, and classroom observations. While these strategies were useful ones for eliciting experienced teachers' purposes and goals, they were also time-consuming. Baxter and Lederman (1999) concur with this finding. To further the knowledge base on science teaching orientations, the first phase should be concentrated on protocol development. The protocols need to be tested with teachers at different stages in their careers. Different protocols may be more effective at specific stages in a teacher's career. Protocols that work effectively with experienced teachers may not be effective with prospective teachers.

While researching science teaching orientations, the importance of working collaboratively with teachers is emphasized. The work in this study re-iterated the implicit, invisible nature of teachers' knowledge and beliefs (see Kagan, 1990). Teachers' goals and purposes for teaching a particular subject matter cannot be inferred solely from classroom observations. The complexity of teaching orientations is missed when we view orientations through the lens of an objective observer of the teacher's means. Teachers need to be viewed as collaborators in the research process, particularly if we are to gain insight into the sources and development of teaching orientations. This implication is supported by recent recommendations of the National Research Council (NRC). In How People Learn, recommendations are given for future directions in research on learning, including how research should be conducted. The National Research Council recommends that learning research be conducted in teams that combine the expertise of researchers and the wisdom of practitioners, and that more classroom practice studies be conducted (NRC, 2000, p. 252).

As mentioned above, means are an important aspect of science teaching orientations. In past studies, means have been used as a method of labeling teachers in regard to their teaching orientation as perceived by an outside observer. In this study, means were used a way of eliciting the teacher's knowledge and beliefs about teaching biology. Also, the inclusion of means in the representation of an individual's teaching orientation added a richness of detail to the representation. Work in this study suggests that there is a complex interaction between teaching orientations and means. During this study, several questions emerged related to means. What are additional sources of individuals' means? In what ways do means limit a teacher's goals and purposes? There is a need for further research into the connection between teachers' means and their teaching orientations.

With an expanded repertory of research protocols, an emphasis on collaborative research with teachers, and the inclusion of means, the development aspect of the science teaching orientation construct can be vigorously pursued. One way to collect this type of data is to interview teachers from various career stages. However, this is also a need for longitudinal studies that follow individual teachers over time. From my work in this study, several questions in this area emerged. How does a teacher's orientation change over time? Are the changes incremental, such as shifts between central and peripheral components, or are the changes more dramatic? How does a change in the school context (e.g., moving from a rural to an urban school) affect an individual's science teaching orientation? What experiences are the most powerful in shaping an individual's science teaching orientation? Data from longitudinal studies will give us more information about the changing nature of an individual's teaching orientation and the critical incidents that influence its development.

This research study explored the construct of science teaching orientations by studying a group of highly-regarded secondary biology teachers. The construct may be better defined and elaborated through additional empirical studies conducted with middle school and secondary science teachers from all disciplines. Using data from middle school science teachers, new categories of central and peripheral components may emerge. Chemistry teachers may differ from physics teachers in the nature of their teaching orientations. The nature of the discipline may be reflected in teachers' science teaching orientations. New categories, dimensions of existing categories, or relationships between categories may emerge through additional studies of chemistry teachers, physics teachers and earth science teachers, at both the middle and secondary levels.

In this study, the school context played an important role in shaping the individual's science teaching orientation. Due to the influence of context, the conceptual framework for teaching orientations may be enhanced by drawing on the field of cognitive psychology. The situated perspective within cognitive psychology may offer insights into science teaching orientations. One of the themes within the situated perspective is that knowledge and learning is situated in physical and cultural contexts. Putnam and Borko (2000) state, “The classroom is a powerful environment for shaping and constraining how practicing teachers think and act” (p. 6). This theme was certainly present in the interpretations of this study. Two other themes from the situated perspective may also inform the conceptual framework of science teaching orientations. The theme of cognition as a social process has not been explored in the science teaching orientations literature. Future research should include study of teachers’ discourse communities and the creation of new discourse communities that support reform-based science teaching. Attention to discourse communities seems to be particularly important as teachers and researchers work collaboratively. Cognition as distributed across people and tools is a third theme from the situated perspective. Past studies on teaching orientations have focused on individuals, but viewing cognition as distributed may inform the design of future research studies of teaching orientations. In How People Learn, the National Research Council supports this implication by calling for a commitment to basic research programs in cognition, learning and teaching (NRC, 2000, p. 276).

6.3.3 Research Implications for Science Teacher Education Practice and Professional Development

The following section includes implications for research into teacher education practice, on the prospective teacher level and on the level of professional development for practicing teachers. The participants in this study did not identify experiences in their teacher education programs as being influential in shaping their science teaching orientations. There is a need for research on science teaching orientations that focuses on the nature, sources and development of prospective teachers' teaching orientations. Longitudinal studies could be designed that follow individual prospective teachers as they progress through their teacher education program. Some possible research questions include: (1) In what ways, if any, does an individual's teaching orientation change during the course of the teacher education program? (2) What critical experiences in the science teacher education program contribute to the development of an individual's teaching orientation? (3) What roles does explicit attention to teaching orientations play in the development of science teaching orientations?

This study focused on capturing the nature and probable sources of experienced biology teachers' teaching orientations. A connection was seen between the participants' teaching orientations and their choice of professional development activities. In professional development settings, additional research needs to be conducted around the following questions: How does explicit attention to science teaching orientations influence the effectiveness of reform-based professional development? How do science teaching orientations change as a result of reform-based professional development?

6.4 Implications for Policy

In this section, implications for policy are given. The implications are summarized in Table 6.3. The two implications focus on the need for additional funding for research studies on protocol development and longitudinal studies.

Table 6.3

Implications for Policy

Section	**Implications for Policy**
6.4.1	Need for funding studies for the development of protocols for assessing teachers' science teaching orientations.
6.4.2	Need to fund longitudinal studies of teacher development, focusing on the changing nature, sources and development of teaching orientations.
6.4.3	Need for policy implementation studies. What is the effectiveness of current professional development practices, such as Pennsylvania's Act 48?

6.4.1 Funding for Protocol Development

The construct of PCK, due to its complex nature, is a messy and difficult area to research (Baxter and Lederman, 1999). My personal experience researching science teaching orientations adds further evidence to this claim. In this study, I have used a combination of data collection techniques, including semi-structured interviews, a task-based interview using a card sorting activity, and classroom observations. While these strategies were useful ones for eliciting experienced teachers' purposes and goals, they were also time-consuming. To further our understanding of science teaching orientations and PCK, there is a need for studies that concentrate on the development of protocols for gathering data on teachers' knowledge and beliefs. The protocols need to be tested in a variety of settings, with teachers at different points in their career. Different protocols may be more effective at specific stages in a teacher's career. Protocols that work effectively with experienced teachers may not be effective with pre-service teachers. To strengthen the knowledge base on teacher thinking, there needs to be a concentrated effort on protocol development. Policy makers can aid this process by funding more research for the development of protocols for eliciting teachers' pedagogical content knowledge.

6.4.2 Need for Funding of Longitudinal Studies

This study focused on trying to gain a better understanding of one overarching component within the current PCK model, that of science teaching orientations. Yet, this single component of PCK appears to be more complex than originally portrayed in the teacher education literature, particularly the science education literature. This study only offers a snapshot of the nature and probable sources of four biology teachers' teaching orientations. To develop a more robust theory of science teaching orientations, longitudinal studies must be conducted that explore the nature, sources, and particularly the development of teaching orientations across the span of teaching careers. There appears to be a complex interaction between biographical sources and the present school context in forming and shaping individuals' science teaching orientations.

During the study, the participants occasionally brought up references to how they taught as a beginning teacher. Exploring the development of science teaching orientations was beyond the scope of this study. But it's the development component of science teaching orientations that gives us the most insightful look into teachers' thinking. As teacher educators, we need to better understand the sources of individuals' teaching orientations and how these sources shape the development of teaching orientations over time. This data will only come from long-term research studies. Longitudinal studies are needed in which researchers follow prospective teachers, beginning with their science content courses as undergraduates. Only limited data can be obtained from studying individuals in a single course. Prospective teachers need to be followed beyond their science teacher education programs, in the early years of teaching and beyond. By funding long-term longitudinal studies of science teaching orientations, policy makers can support the development of a robust theory of the changing nature, sources and development of science teaching orientations.

6.4.3 Need for Policy Implementation Studies

Lastly, we need to examine the effectiveness of current professional development policies for educators. In Pennsylvania, Act 48 requires that teachers participate in professional development in the form of either six credit hours of collegiate study, six credits of continuing professional development or 180 hours of continuing professional activity hours within a five year time period (PDE, 2001). Credits and hours are available from a variety of sources, including universities, intermediate units, school districts, professional organizations and approved private providers. Teachers are free to choose any combination of professional activities with the stipulation that the professional development activity relates to their certificate type or area of assignment. Act 48 requires teachers to engage in continuing professional development without requiring teachers to focus their professional development in a coherent plan. The data from this study show that experienced teachers tend to select professional development activities based on their science teaching orientations. Mark's science teaching orientation has a central goal of promoting curiosity. Mark's professional development has consisted of an eclectic mix of summer workshops for teachers. Sharon's science teaching orientation has a central goal of promoting environmental decision-making, and she seeks out environmental education workshops and courses for her own professional development. If current professional development involvement acts as a feedback loop into an individual's science teaching orientation, how can change be effected? How effective is the current Act 48 professional development policy in supporting reform-oriented changes in teaching? Policy implementation studies are needed to address these questions.

6.5 Summary of Implications

For quick reference, the implications from each of the sections above have been included in a summary table, Table 6.4.

Table 6.4

Summary of the Implications for Teacher Education, Research and Policy

Areas of Consideration	**Implications**
Practice: Science Teacher Education and Professional Development	In order for beliefs to become targets of change, there is a need to make explicit individuals' science teaching orientations, as part of: a) science teacher education programs. b) professional development for practicing teachers. There is a need for explicit attention to the syntactical aspects of science in: a) science content courses and science education courses for prospective teachers. b) professional development for practicing teachers. There is a need to assess practicing teachers' "toolbox of means" and a) find compatible means for supporting reform-based teaching. b) expand the teachers' toolbox. For practicing teachers, there is a need to address issues of time constraints and pedagogical efficiency in inquiry-based teaching.
	Elaboration of the Substantive-Level Theory Need for elaboration of the substantive-level theory of science teaching orientations: a) by increasing the number of participants in this study. b) including teachers from different school settings, urban vs rural vs suburban. c) include teachers in various career stages to include d) development in the proposed model.

Research (continued)	**Elaboration of the Construct** Need for continued research to further develop the construct of science teaching orientations by: a) continued protocol development. b) collaborative work with teachers. c) inclusion of means as an integral part of science teaching orientations. d) expanded longitudinal studies that examine the development of science teaching orientations over time. e) additional empirical studies that include middle and secondary science teachers from all disciplines. f) drawing on new fields of study, i.e., situated perspective of cognitive psychology. **Research in Science Teacher Education Practice** Need to identify critical experiences in science teacher education programs that have a strong potential for shaping the development of individuals' science teaching orientations. **Research in Professional Development** Need for additional research in professional development studies: a) How does explicit attention to science teaching orientations influence the effectiveness of reform-based professional development? b) How do science teaching orientations change as a result of reform-based professional development?
Policy	• Need for funding studies for the development of protocols for assessing teachers' science teaching orientations. • Need to fund longitudinal studies of teacher development, focusing on the changing nature, sources and development of teaching orientations. • Need for policy implementation studies. What is the effectiveness of current professional development practices, such as Pennsylvania's Act 48?

6.6 Concluding Thoughts

Today, teachers find themselves teaching in a complex, changing world (Hargreaves, 1994). Science education reform documents call for even more dramatic changes in teaching to better support students' conceptual understandings. As teacher educators, professional developers and researchers, it is critical that we examine the role of teachers' knowledge and beliefs as it affects learners and classroom practice. To effectively enact reform, the gap between educational research and practice must narrow. Researchers and teachers need to find ways to work collaboratively so that we may better understand the complex interaction between teachers' knowledge and beliefs and classroom practice.

I want to thank the teachers who participated in this study. These four individuals were incredibly busy teachers with a multitude of demands on their time. Yet, in the midst of their hectic days, they found time to sit down and talk with me about their teaching. Through their insights and reflections, this study became possible. Science teaching orientations appear to play an important filtering role in instructional decision-making. By proposing a substantive-level theory, I hope to have stimulated additional thought and research into the nature, sources and development of science teaching orientations.

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APPENDICES

Appendix A

Protection of Human Research Subjects

1. We propose to study the science teaching orientations of practicing biology teachers for the purpose of developing grounded theory. Science teaching orientations are defined as one's knowledge and beliefs about the goals and purposes for teaching science. We will investigate the following questions: 1) What is the nature of the science teaching orientations held by a group of practicing biology teachers? 2) What are the sources of the science teaching orientations held by a group of practicing biology teachers?

2. The investigators are: Patricia Friedrichsen, graduate student in C & I
Dr. Thomas M. Dana, Associate Professor in C & I

The investigators are experienced teachers and teacher educators familiar with the population to be studied, and Dr. Thomas Dana is knowledgeable in the research techniques proposed in this study. Patricia Friedrichsen, a graduate student, will be supervised by Dr. Dana.

3. The requirements of the subject population are that the subjects are reform-minded, practicing teachers currently teaching middle or high level biology. There are no requirements for gender, race or other special characteristics.

4. The subjects will be recruited in the following ways: Practicing teachers will be recruited through a nomination list prepared by the science education faculty at The Pennsylvania State University. Potential participants will be contacted and given an overview of the study, as well as an invitation to participate. Participants in the study may be asked to nominate additional potential participants.

5. The study will consist of a series of four semi-structured interviews and two classroom observations. In the first interview, biographical information and contextual information about the school setting will be gathered. The second and third interviews will follow classroom observations of the participant teaching biology. In these interviews, the participant will be asked to reflect on the activities that occurred during the observation period. The final interview will occur at the end of the study and the participant will be asked to comment on the emerging grounded theory constructed during the study. The interviews will be conducted in the school building of each participating teacher.

6. The only personnel involved in the study will be the investigators. The data will only be accessible to the investigators and an experienced transcriptionist. An audio cassette recorder is the only required equipment for this study.

7. I will set up individual interviews with individuals who indicate an interest in participating in this proposed study. During this initial contact, I will verbally explain the proposed study in detail. If the individual is interested in participating in the study, an informed consent form will be given to them. I will read the informed consent form to the individual. Participants will indicate their consent to participate in the study by signing the informed consent form. Participants will be given a copy of the form for their own records.

8. There are no known potential risks to the study participants.

9. N/A

10. By participating in the study, subjects may gain a better understanding of their own purposes and goals for teaching science. This increased understanding may lead to a more articulated philosophy of science teaching.

11. Confidentiality safeguards include: 1) storage of audiotaped interviews will be kept in a locked file drawer in Patricia Friedrichsen's office, 2) all identifying information will be removed from data sources and replaced with a pseudonym selected by the participant, and 3) all data will be destroyed no later than January, 2006.

12. N/A

13. N/A

Informed Consent Form for Behavior Research Study

The Pennsylvania State University

Title of Project: Exploring Practicing Biology Teachers' Orientations to Teaching Science

Person in charge: Dr. Thomas M. Dana
173 Chambers Building
(814) 865-2197

1. This section provides an <u>explanation of the study in which you will be participating:</u>

This study in which you will be participating is part of research intended to explore the science teaching orientations of prospective and practicing science teachers. By conducting this research, we hope to better understand secondary teachers' purposes and goals for teaching science.

A. If you agree to take part in this research, you will be asked to participate in a series of interviews and tasks.

1. An initial interview to collect information about your teaching background and current teaching assignment. (Approx. 90 minutes)
2, Two classroom observations, each followed with an interview of approximately 90 minutes in length.
3, A fourth interview for the purpose of sharing the results of the research. (Approx. 60 minutes)

B. Your participation in this research will take approximately seven and a half hours.

C. This research will involve the use of audio tape recording.

D. The audiotapes will be destroyed no later than January, 2006.

2. This section describes <u>your rights as a research participant:</u>

A. You may ask any questions about the research procedures, and these questions will be answered. Further questions may be directed to Dr. Thomas Dana.

B. Your participation is this research is confidential. Only Dr. Dana and Patricia Friedrichsen will have access to your identity and to information that can be associated with your identity. In the event of publication of this research, no personally identifying information will be disclosed. To insure your participation is confidential, you will be asked to select a pseudonym.

C. Your participation is voluntary. You are free to stop participating in the research at any time, or to decline to answer any specific questions without penalty.

D. This study involves minimal risk; that is, no risks to your physical or mental health beyond those encountered in the normal course of everyday life.

3. This section indicates that you are giving your informed consent to participate in the research.

I agree to participate in a scientific investigation of Science Teaching Orientations, as an authorized part of the education and research program of the Pennsylvania State University.

I understand the information given to me, and I have received answers to any questions I may have had about the research procedure. I understand and agree to the conditions of this study as described.

To the best of my knowledge and belief, I have no physical or mental illness or difficulties that would increase the risk to me of participation in this study.

I understand that I will receive no compensation for participating.

I understand that my participation in this research is voluntary, and that I may withdraw from this study at any time by notifying the person in charge.

I am 18 years of age or older.

I understand that I will receive a signed copy of this consent form.

____ ________________

Signature Date

Researchers:

I certify that the informed consent procedure has been followed, and that I have answered any questions from the participant above as fully as possible.

____ ________________

Signature Date

____ ________________

Signature Date

Appendix B

Principal's Informed Consent Form

To: The Pennsylvania State University Office of Regulatory Compliance

Our school has agreed to participate in the study, "Exploring Practicing Biology Teachers' Orientations to Teaching Science," IRB #01B0112-00. Patricia Friedrichsen, the principal investigator, has provided an explanation of the study and we acknowledge that our participation is voluntary.

____________________________________ ____________

Principal's Signature Date

____

Participating School

Appendix C

First Semi-Structured Interview Protocol

Purpose of the interview

1. Explain the purpose of the study,
2. Develop a trusting relationship with the participant,
3. Gather background information to construct a biography of the participant,
4. Collect contextual information that may be useful in analyzing the possible sources of the individual's orientation(s), and
5. Begin to solicit data on the participant's orientation to teaching science.

Initial Interview Tasks:

1. Explanation of the study.
a) Define the term "science teaching orientations."
b) Described the extent of the participant's involvement: number of interviews, tasks, classroom observations, etc.
c) Explain what I hope to learn from this study.
d) Discuss what the participant may gain from the study: increased awareness and understanding of their own science teaching orientation.
2. Ask participant to share their interest in being part of this study.
3. Ask participant to read and sign the human consent form.

Interview Questions:

1. What is your current teaching assignment? What other types of science courses have you taught in the past?
2. Tell me about your background in science:
a) College science courses?
b) What areas of biology did you concentrate or specialize in? What areas of biology are your favorite?
c) Graduate coursework in science?
d) Experiences conducting scientific research? Or lab tech work?
3. Describe your teacher education program.
a) Have you taken any graduate courses in education?
b) In what ways did your teacher education program influence the way that you teach?
4. Describe professional development activities in which you have been involved in the past five years. Describe any impact these experiences may have had on your teaching.
5. Why did you decide to become a biology teacher?

6. Describe any role models that have influenced the way you teach.
7. How would you describe the school setting and the student population? Do you feel there are restrictions or barriers that prevent you from teaching the way you would like to?
8. Tell me about what you see as the reasons for studying biology in high school. What are your goals for your students? What areas of biology do you want to cover in your classes? Why?.
9. What unit(s) are you currently teaching in your biology classes? What purposes and goals do you have for your students in this unit?
10. How would you describe the current curriculum you are using in biology? Have you used other curriculum/texts to teach biology?

Note: Schedule the first classroom observation and follow-up interview.

Assignment: In the second interview, we will be discussing events that occur during the classroom observation. What unit will you be teaching during the observation? Please bring materials from the unit that we can discuss during the follow-up session. You don't need to prepare special material for the next interview, just bring any planning notes, worksheets, activities sheets, exams, etc. that you are using in the unit.

Appendix D

Second Semi-Structured Interview Protocol

Purpose of the Interview:

To elicit and elaborate on the participant's knowledge and beliefs about the purposes and goals for teaching biology by:

a) reflecting on class activities that occurred during the observation; and

b) reflecting on artifacts from the unit currently being taught.

Interview Questions:

1. In reflecting on today's lesson, which aspects of the lesson best support your goals and purposes for teaching biology? In what ways?

2. Based on field notes, I will ask the participant to reflect on other aspects of the lesson:

a) Discuss the teaching strategies you used in this lesson. How do these strategies help you meet your purposes and goals for teaching biology?

b) Discuss the students' understanding of this topic. As a teacher, how can you best help students understand the information in this unit?

c) Discuss student interactions or grouping during the lesson. How did student-student or student-teacher interactions support your goals and purposes for teaching biology?

3. Please share artifacts from the current unit that you are teaching.

a) How do you plan for an entire unit? What aspects/variables influence you as you plan for a unit? What resources do you use in planning a unit? How does this unit fit into the curriculum for the entire year?

b) What other teaching strategies will you include in the unit that were not used in today's lesson? How will these additional strategies support your purposes and goals for teaching biology?

c) How will you assess the students' learning in this unit? Why do you use this particular assessment tool?

Note: Schedule the next observation and follow-up interview. This lesson may or may not be in the same unit of study.

Assignment: Bring artifacts from the new unit of study, if the observation occurs within a different unit. If the observation is scheduled to occur within the same unit that was observed in the first interview, the participant will be asked to bring artifacts from their favorite unit.

Appendix E

Third Semi-Structured Interview Protocol

<u>Purpose of the Interview:</u>

To elicit and elaborate on the participant's knowledge and beliefs about the purposes and goals for teaching biology by:

a) reflecting on class activities that occurred during the observation;

b) looking for consistency across classroom observations;

c) reflecting on artifacts from the unit currently being taught; or

d) reflecting on an additional unit of the participant's choice; and

e) verifying the initial categories and their properties and dimensions.

<u>Interview Questions:</u>

1. In reflecting on today's lesson, how does this lesson help you meet your purposes and goals for teaching biology?

2. Using my field notes, I will ask about specific parts of the lesson to clarify dimensions and properties of categories that I have constructed through open and axial coding of the second interview.

3. I've asked you to bring material from the current unit that you're teaching. (If the unit is the same unit that we've discussed in the last interview, the participant will be asked to bring materials from their favorite unit.)

a) How did you plan for this unit? What aspects/variables influenced you as you planned this unit? What resources do you use in planning the unit? How does this unit fit into the curriculum for the entire year?

b) What other teaching strategies will you include in the unit that were not used in today's lesson? How will these additional strategies support your purposes and goals for teaching biology?

c) What difficulties will the students have with the material in this unit? How can you best support the students' learning during this unit?

d) How will you assess the students' learning in this unit? Why do you use this particular assessment tool?

4. Share the initial categories and their properties and dimensions. Ask the participant for feedback on the emerging theory constructed from the field data.

Note: Thank the participant for their involvement in the study. Share my timeline for continued data analysis. Obtain contact information for the final interview that will be conducted during the summer either in person, by email or by phone. The purpose of the final interview will be to confirm the theory that I constructed from the data.

Appendix F

Card Sorting Interview Protocol

Card Sorting Task: Participants are given a set of scenario cards. The participants are asked to sort the cards into the following stacks: 1) this scenario represents how I would teach, 2) this scenario does not represent how I would teach, and 3) unsure.

After the initial sort, participants are asked to do a continuum sort of the cards in the stack that represents how they teach. After completing the continuum sort, the participant is asked to think aloud during the decision-making process. Participants' thinking will be probed with the following question: "How does this scenario represent/not represent your goals and purposes for teaching science?"

Card Scenarios
As a teacher, you begin the year by having students learn how to use a microscope.
In teaching a unit on cells, you begin the unit by presenting information on cell structures and their corresponding functions.
As a teacher, you have students place potato cubes of varying sizes into an iodine solution. From this activity, students can discover the importance of surface area to volume ratios.
As a teacher, you organize an environmental unit around the question, "What's in our drinking water?"
As a teacher, you collect newspaper articles about local environmental issues. You help the students design investigations to explore a local environmental issue of their choice.
As a 7^{th} grade life science teacher, you begin a unit on animals by having the students share their ideas about the differences between plants and animals.
As a 10^{th} grade biology teacher, you have your students learn the reactions in the Krebs cycle.
At the end of a dissection unit, you give students a practical examination.
As a means of assessment, you have students role-play the process of meiosis.
As a 10^{th} grade biology teacher, you have students identify different trees in the schoolyard, using a classification key.

To help your students understand arthropod characteristics, you organize a series of stations. Each station contains representatives of different groups/classes.
To teach genetics, you collect a variety of activities for the students to engage in. For example, you have the students observe human genetic traits, play a game of probability, do a version of "Make a Baby", play a computer simulation, etc.
In your unit of evolution, you have students debate creation versus evolution.
You, as a teacher, have your students observe earthworms and generate questions about earthworm behavior. Each small group designs and carries out their own experiment to test a hypothesis related to the group's questions.
As a 7th grade life science teacher, you want your students to learn about classification. You give the students a variety of odd tools, bolts, buttons, etc. and ask them to devise a classification system for the items.
As a 10th grade biology teacher, you decide the best way to teach photosynthesis is to design a well-organized series of lectures.
As a 10th grade biology teacher, you decide the best way for students to learn about organic compounds is to organize the students into small groups. Each small group will present information on a different type of organic compound.
In teaching DNA replication you have students build models of DNA.
As a 7th grade life science teacher, you decide that the best way to learn about parts of a cell is for students to assemble a "jello cell," where various shaped candies represent different cell parts.

VITA

Patricia Jean Friedrichsen

In 1981, I graduated from Wayne State College in Nebraska with undergraduate degrees in biology and communicative arts. After graduation, I taught seventh grade life science for three years at the Norfolk Junior High School in Norfolk, Nebraska. In 1987, I earned a Master of Education degree in Curriculum and Instruction from the University of Nebraska-Lincoln. From 1985-1995, I taught biology at Lincoln High School in Lincoln, Nebraska. I left high school teaching to work as a project specialist for a K-12 distance education teacher enhancement project at the University of Nebraska-Lincoln. At the end of that project, I continued to work at UNL as an instructor in the Elementary Teacher Education Program. I began my doctoral studies at The Pennsylvania State University in 1998. My research interests are in the area of teachers' knowledge and beliefs.