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Substantive-Level Theory of Highly Regarded Secondary Biology Teachers' Science Teaching Orientations

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Abstract: Science teaching orientations, defined as teachers' knowledge and beliefs about the purposes and goals for teaching science, have been identified as a critical component within the proposed pedagogical content knowledge (PCK) model for science teaching. Because of the scarcity of empirical studies in this area, this case study examined the nature and sources of science teaching orientations held by four highly regarded secondary biology teachers. Data sources consisted of transcripts from four interviews, a card-sorting task, and classroom observations. Using a grounded theory framework, inductive data analysis led to the construction of a substantive-level theory for this group of participants. 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, was used to represent the complex nature of participants' science teaching orientations. The participants' science teaching orientations included goals related to general schooling, the affective domain, and subject matter, although the latter was not always a central component. In regard to the sources of teaching orientations, participants were strongly influenced by the classroom context and their beliefs about learners and learning; additional influences included prior work experiences, professional development, and time constraints. © 2005 Wiley Periodicals, Inc. J Res Sci Teach 42: 218–244, 2005

The construct of pedagogical content knowledge (PCK) has been proposed as a heuristic device for understanding science teachers' knowledge and beliefs relating to their classroom practice (Gess-Newsome & Lederman, 1999). Within the proposed PCK model for science teaching, science teaching orientations, defined as "teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level," plays a critical role (Magnusson, Krajcik, & Borko, 1999, p. 97). Based on the scarcity of empirical studies on science teaching orientations in the extant literature, this study examines more closely the construct of science teaching orientations. The purpose of this study is to provide a substantive-level theory of

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science teaching orientations. Creswell (1994) defined substantive-level theory as a middle-range theory, ‘‘restricted to a particular setting, group, time, population or problem’’ (p. 83). The substantive-level theory of science teaching orientations presented in this study emerged from an interpretative case study of four highly regarded secondary biology teachers. We chose the term ‘‘highly regarded’’ to reflect the nomination process used in selecting the participants.

Theoretical Framework

Pedagogical Content Knowledge

Shulman (1986) theorized a specialized knowledge base for teaching and defined pedagogical content knowledge as ‘‘subject matter knowledge for teaching’’ and ‘‘the ways of representing and formulating a subject that make it comprehensible to others’’ (p. 9). Pedagogical content knowledge, as a construct of teacher knowledge, has been a visible line of research in science education, in studies of both practicing teachers (Hashweh, 1987; Lederman & Gess-Newsome, 1999; Smith, 1999; Smith & Neale, 1989; Tobin & McRobbie, 1999; Veal, 1997) and prospective science teachers (Mason, 1999; Niess & Scholz, 1999; Zembal-Saul, Starr & Krajcik, 1999). Several science education researchers have suggested modifications to earlier PCK models. Tamir (1988), for example, proposed knowledge and skills of assessment as another dimension of PCK. Carlsen (1999) reiterated the importance of the inclusion of ‘‘understandings of student misconceptions’’ as a component of a PCK model for science teaching (p. 141). Magnusson et al. (1999) proposed a refined model of PCK for science teaching with the following five components: ‘‘(1) orientations toward science teaching, (2) knowledge and beliefs about science curriculum, (3) knowledge and beliefs about student understanding of specific science topics, (4) knowledge and beliefs about assessment in science, and (5) knowledge and beliefs about instructional strategies for teaching science’’ (p. 97) (see Figure 1). In the conceptualization of this study, we have used the Magnusson et al. (1999) PCK model for science teaching.

Science Teaching Orientations

In the Magnusson et al. (1999) PCK model, orientations to teaching science is placed in a pivotal position, influencing the other components of PCK and, in turn, being influenced by these components. This placement follows Grossman’s (1990) model, although Grossman used the descriptive phrase, ‘‘conceptions of purposes for teaching subject matter’’ (p. 8), rather than orientations. Grossman elaborated on this overarching component 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.’s (1999) use of the term ‘‘orientations to teaching science’’ can be traced in the science education literature to Anderson and Smith (1987), who described teachers’ orientations toward science teaching and learning as ‘‘general patterns of thought and behavior relating to science teaching and learning’’ (p. 99). If science teaching orientations do play an influential role, as proposed by the Magnusson et al. (1999) PCK model for science teaching, it is important to closely examine this construct empirically.

Based on the extant literature, Magnusson et al. (1999) identified nine different science teaching orientations: (1) process, (2) academic rigor, (3) didactic, (4) conceptual change, (5)

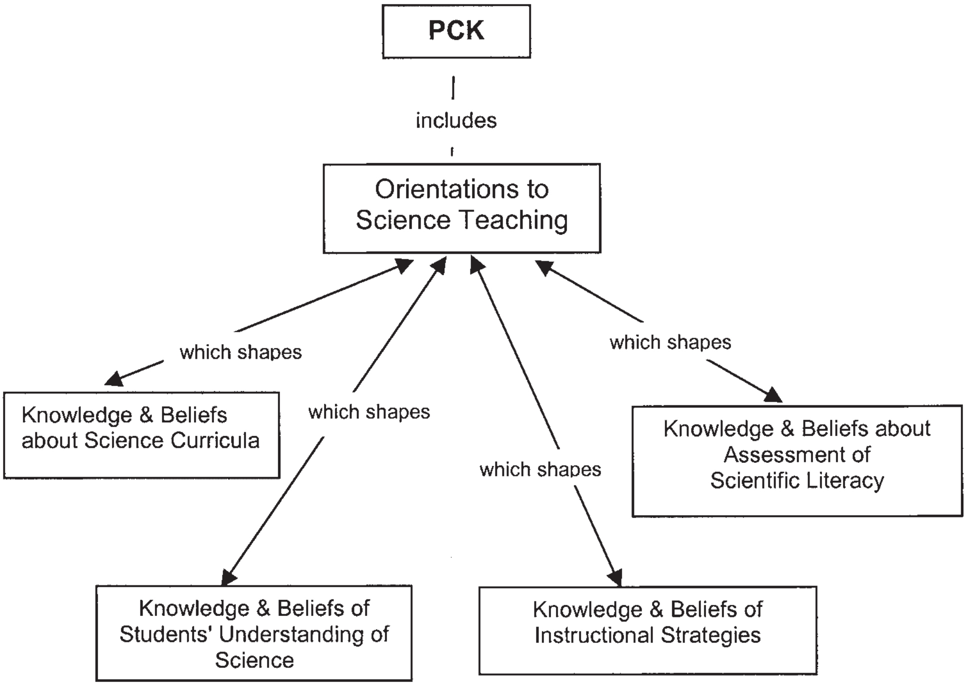

Figure 1. Pedagogical content knowledge (PCK)) model for science teaching (simplified version). Note: Adapted from Nature, Sources, and Development of Pedagogical Content Knowledge for Science Teaching (Figure 2, p. 99), by Magnusson, S., Krajcik, J., & Borko, H., 1999. In J. Gess-Newsome & N.G. Lederman (Eds.), Examining pedagogical content knowledge: the construct and its implications for science education. Kluwer: Dordrecht. With kind permission of Kluwer Academic Publishers.

activity-driven, (6) discovery, (7) project-based science, (8) inquiry, and (9) guided inquiry. In reviewing the science education literature on teaching orientations, several issues emerge. First, few empirical studies specifically examine science teaching orientations of secondary teachers. Lantz and Kass's (1987) study of chemistry teachers is one of the few studies to use an inductive approach to generate categories of "perceptions of teaching," defined as the teacher's view of the requirements for effective teaching as well as the overall aims of teaching science. Similarly, Hewson and Hewson (1989) used a card-sorting task to elicit pre-service teachers' "conceptions of teaching science" (p. 141). While this study was inductive in nature, Hewson and Hewson chose not to label or categorize the orientations of their participants. However, in most of the studies reviewed, the teaching orientation was theoretically based on desired teaching approaches of past science curriculum development projects or contemporary reform-based projects (e.g., Karplus & Thier, 1967; Magnusson & Palinscar, 1995; Marx et al., 1994). (A comprehensive review of the literature on science teaching orientations can be found in Friedrichsen, 2002.)

Second, the orientations theorized in the literature may not provide an accurate description of the orientations held by prospective and practicing teachers. Two studies revealed a mismatch between the categories in the literature and the teaching orientations of prospective teachers. Friedrichsen and Dana (2000), in a pilot study of prospective and practicing elementary teachers, asserted that participants did not hold science-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 nonspecific, generalized theory of how students learn. In a second study, Tsur and Crawford (2001) 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 (Magnusson et al., 1999), individual participants were identified as having between two to five different orientations with one or two primary orientations. Tsur (personal communication, June 2000) confirmed a mismatch between the categories in the literature and the science teaching orientations held by participants in the study. A similar finding emerged from an earlier study surveying the orientations held by practicing social studies teachers (White, 1982); most teachers did not hold a single orientation, but held aspects of two to three of the orientations described in the literature. These studies provide evidence that the theoretical categories of science teaching orientations may not match those of prospective and practicing teachers. The critical position of science teaching orientations in the proposed PCK model for science teaching demonstrates the need to reexamine the construct of science teaching orientations.

Research Rationale and Design

This interpretative case study focuses on four secondary biology teachers in order to examine inductively the construct of science teaching orientations. We used grounded theory methodology, with its primary goal of generating theory inductively from data, as the analytic framework for this study (Glaser & Strauss, 1967). Categories of science teaching orientations have been proposed in the literature in the absence of empirical studies specifically focusing on teaching orientations. Thus, there is a need to generate new theories of science teaching orientations from empirical studies focusing on teachers' thinking about their purposes and goals for teaching science.

Research Questions

This study focused 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 probable sources of the science teaching orientations held by a group of highly regarded biology teachers?

In the first question, the nature of science teaching orientations refers to a description of the components of participants' science teaching orientations, as co-constructed with the participants. In regard to the second question, the probable sources of science teaching orientations are defined as the influences, past and present, that individuals identify as contributing to the formation of their science teaching orientation.

Interpretative Case Study

Grossman (1990) claimed that PCK is influenced by three domains: subject matter knowledge, general pedagogical knowledge, and knowledge of the context. This complex interaction requires that PCK be studied in context, the context of teachers' classrooms. We selected a case study design for this research study due to the blurred boundaries between the phenomenon (PCK) and the context (secondary biology classrooms) (Yin, 1994). The issue of boundaries became even more problematic in this study, as the research questions focused on one component within the PCK model, that of science teaching orientations, which influences and is influenced by the other components of the PCK model. Loughran, Gunstone, Berry, Milroy, and Mulhall (2000) also noted the issue of boundaries in their study of practicing science teachers' PCK.

Participants

In designing the study, we chose to focus on secondary biology teachers. This decision was based on the first author's background as a secondary biology teacher. As PCK is a specialized knowledge base for teaching that draws upon an individual's knowledge of subject matter (Shulman, 1986), we believed that it was important for the interviewer, the first author, to have a strong background in the selected subject matter. In addition, we felt that greater insight for improving practice would be gained by focusing on a smaller group of exemplary biology teachers rather than studying a large cross-section of biology teachers. The Search for Excellence Project (Penick & Yager, 1983) and the Exemplary Practice in Mathematics and Science Project (Tobin & Fraser, 1987) followed this same line of reasoning; both of these projects resulted in heuristic case studies of exemplary practice.

In this study, we used theoretical sampling, selecting participants based on their ability to contribute to the development of theory (Creswell, 1998). After narrowing the study to exploring the science teaching orientations of secondary biology teachers, we used reputational sampling to solicit names of potential participants for the study (Merriam, 1988). We consulted with science education faculty at local universities and colleges, the state science consultant, curriculum consultants at several regional educational service units, as well as officers of the state science teachers' organization to identify potential participants. Tobin and Fraser (1987) acknowledged, "Of course, exemplary practice comes in many forms and is a subjective term that is interpreted in different ways by different educators" (p. vii). We used the following criteria to shape the nomination process: participating teachers needed to be student-centered, emphasize conceptual understanding of biology, be active in professional activities, and teach biology as their primary assignment. To maximize the potential for studying PCK, we also requested that potential participants have extensive experience teaching biology. Loughran et al. (2000) used this same criterion in their research of teachers' PCK. We compiled a list of six potential participants who were nominated by two or more individuals. After being contacted, four of the six teachers agreed to participate in the study. As we did not observe the participants' teaching before selection for the study, we use the term "highly regarded" by colleagues, rather than the term "exemplary."

All the participants taught in high schools located in the mid-Atlantic region of the United States. The high schools were located in small communities in rural areas, with the largest community population being 40,000. The high schools ranged in size from an enrollment of 500–2,500 students (see Table 1). Across the four high schools, the number of students eligible for free and reduced-priced lunches ranged from 10% to 30%. Each of the participating teachers had a minimum of 13 years of experience teaching high school biology.

Sharon[1] was nominated as a potential participant by university faculty. Sharon frequently mentored prospective science teachers placed in her classroom for field experiences. Early in her career, Sharon worked as a naturalist. Desiring more permanent employment, she pursued certification in secondary biology teaching. A strong environmental theme permeated Sharon's high school biology courses. She involved students in environmental projects, including habitat restoration, wetland studies, water quality studies, and bluebird house construction (see Table 1 for additional participant background information). Mike had recently received a statewide

Table 1
Participants' background information

Participant	Educational Background	Teaching Experience	School Size and Grade Levels	Prior Work Experience
Sharon	Natural History[a] Education[b]	16	1,100 Grades 7–12	Naturalist
Mike	Social Studies[a] Biology[b]	15	500 Grades 7–12	Retail Business
Peg	Botany[a] Education[b]	20+	1,400 Grades 9–12	None
Martha	Biochemistry[a] Biochemistry[b]	13	2,500 Grades 9–12	Research Technician

[a] Undergraduate degree.
[b] Masters degree.

science teaching award. He was nominated based on his leadership in professional development workshops and his students' involvement in science fair competitions. Mike worked in retail business for 10 years before pursuing his dream of teaching, returning to college to earn his teaching certification. Peg, too, had received numerous teaching awards and, in addition, had authored several books on facilitating students' independent research projects. Besides teaching biology, Peg taught a science research course. Many of the students in the research course competed in local, state, national, and international science fair competitions. Peg, with the longest teaching career, was unique in that she began her public school teaching career immediately following college graduation. University faculty and the school district's science consultant nominated the fourth participant. Martha was highly regarded as a biology teacher, and was known for developing innovative and engaging student laboratory investigations.

Grounded Theory Analytic Framework: Data Collection and Analysis

We selected grounded theory as an analytic framework, as the primary goal of grounded theory is to generate theory inductively from data (Glaser & Strauss, 1967). Because of the weak literature base, our intent was to generate a substantive-level theory of science teaching orientations. In grounded theory, researchers become familiar with existing theories to develop sensitivity to meanings in the data, but then set aside existing theory in order to collect and analyze data with a fresh perspective (Strauss & Corbin, 1998).

Classroom observations and interviews were the primary methods of data collection. Classroom observations gave us a better understanding of the participants' teaching and the school context. The first author observed each participant a minimum of two class periods for each biology course they taught, with field notes serving as a data source. More importantly, the classroom observations were a source of interview questions (Erlandson, Harris, Skipper, & Allen, 1993). The first author interviewed each participant an average of 4.5 hours, with a range of 3–7 hours. Interview questions were directed toward making explicit connections between the observable classroom actions and the participant's overall purposes and goals for teaching biology to a particular group of students. The interview transcripts served as the primary data source.

In the initial interview, the first author collected biographical information and the participants completed a card-sorting task designed to begin to elicit their science teaching orientations. We designed a set of 20 cards, with each card describing an instructional strategy, planning technique, laboratory activity, or assessment strategy commonly used in high school biology teaching.

An overt attempt was made to include scenarios that would represent each of the science teaching orientations offered in Magnusson et al. (1999). Participants are asked to sort the cards based on whether the scenario was representative of their teaching. Throughout the card-sorting task, the interviewer encouraged the participant to talk about his or her teaching, in regard to how their teaching strategies were similar or different from those described on the cards. After sorting and selecting representative scenario cards, participants were asked to describe how the selected scenarios supported their purposes and goals for teaching biology. In using the card-sorting task, we have found that the end result of selecting a particular set of cards is not particularly insightful, rather it is the discourse that occurs during the sorting process that offers insight into the participant's science teaching orientation. (For a complete description of the card-sorting task, refer to Friedrichsen & Dana, 2003.)

We used the process of open coding (Glaser, 1992) to analyze the transcripts from the first interview and the card sort, developing initial categories of the participant's science teaching orientation. As we developed categories, we used a constant comparative method of analysis (Glaser & Strauss, 1967). Theoretical sampling, a defining characteristic of grounded theory, informed the design of subsequent interview questions (Charmaz, 2000). During the interview and initial data analysis phase, we focused on one participant at a time, comparing data taken from each teaching observation, asking how the participant's teaching practice supported or did not support their goals and purposes for teaching biology. In this way, we were ‘‘comparing data from the same individuals with themselves at different points in time’’ (Charmaz, 2000, p. 515). After each round of data collection and analysis, we constructed diagrams to represent our understanding of the nature of each participant's science teaching orientation. We created separate diagrams for each biology course taught by the participant, as it appeared early on that science teaching orientations were course-specific. Each version of an individual's science teaching orientation diagram served as an analytic memo (Strauss & Corbin, 1998).

The purpose of the second interview was to collect additional evidence to support or refute the initial categories we generated. During the second interview, the first author and the participant negotiated the core categories. The focus of the second and third interviews shifted to developing the properties and dimensions of the core categories of the participant's science teaching orientation (Strauss & Corbin, 1998). In the third interview, we asked participants to select a second curriculum unit they considered representative of their teaching. Interview questions focused on using a constant comparative method of data collection and analysis within the context of this new curriculum unit. In the third interview, as a form of member checking, participants gave us additional feedback on the latest version of the science teaching orientation diagrams we had constructed. Working collaboratively with the participants, our discussions focused on the clarification of relationships between categories in order to provide greater depth to our understanding of their science teaching orientation. At the end of the third interview with each participant, it appeared that theoretical saturation had been reached, as the participants were not adding new data in regard to core categories, dimensions of categories, or relationships between categories (Strauss & Corbin, 1998).

Data collection occurred January through May of 2001, with data analysis continuing through December of 2001. In this later phase of data analysis, we continued to theoretically sample the interview transcripts, classroom observation field notes, and analytic memos. To support the diagrammatic representations of each participant's science teaching orientations, a narrative was written which brought clarity to the analysis (Mitchell & Charmaz, 1996) and included information on the individual's educational background, personal biography, a description of the school context and teaching assignment, as well as the nature and sources of their teaching orientation(s).

The final stage of data analysis was the development of a substantive-level theory of science teaching orientations across the four participants. Through a constant comparative method, we developed initial core categories of probable sources of science teaching orientations. In designing the study, we initially conceptualized sources as being primarily biographical in nature, but, through data analysis, our definition of sources was greatly expanded. In the next step, categories of the nature of the science teaching orientations were developed across the four participants. The individual teacher's diagrams, thoroughly grounded in the data, served as analytic memos. Using a constant comparative method, a theory was developed that included core categories and their properties, as well as generalized relationships between categories (Glaser & Strauss, 1967).

Data Interpretations

The data interpretations are divided into three sections. The first two sections are organized around the research questions and are presented as a set of assertions relating to the nature and probable sources of the participants' science teaching orientations. The third section offers an integrated, substantive-level theory of science teaching orientations. We chose a diagrammatic representation to demonstrate the complexity of the theory (Strauss & Corbin, 1998).

Nature of Science Teaching Orientations

In this section, we make two assertions that relate to the nature of science teaching orientations. The first assertion focuses on the construct of science teaching orientations, while the second assertion relates to the nature of the science teaching orientations held by the four participants.

ASSERTION #1: ELABORATED REPRESENTATIONS WITH CENTRAL AND PERIPHERAL GOALS, MEANS, AS WELL AS COURSE SPECIFICITY, ARE NEEDED TO CHARACTERIZE THE COMPLEX NATURE OF SCIENCE TEACHING ORIENTATIONS. During this study, three methodological issues emerged related to the construct of science teaching orientations. First, participants held complex science teaching orientations that required elaborated representations. We devised a scheme of designating central and peripheral goals to help us represent and better understand the complex nature of individual participants' science teaching orientations. Second, the inclusion of the participants' "means" for enacting their goals provided a more complete picture of an individual's science teaching orientation. We defined "means" 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 biology course. Third, participants held science teaching orientations that were specific to courses requiring examination at the course level. Each of these points supports our assertion that a more elaborate representation of science teaching orientations is needed, as the theoretical categories did not adequately describe the teachers in this study.

Representation of Central and Peripheral Components. Participants' science teaching orientations were complex, with each participant having multiple purposes and goals for teaching biology. To illustrate this complexity, we used both central and peripheral components to represent individuals' science teaching orientations. We defined central components as goals that dominated the teacher's thinking and appeared to drive the instructional decision-making process. These goals were highly visible during classroom observations and in curriculum units, and were explicit, repeated themes in interviews. Participants varied in the number of central components represented in their science teaching orientations, from a single central component to as many as three (see Table 2). We also included peripheral purposes and goals to further represent the complexity of individuals' science teaching orientations. In this study, all the participants described a secondary set of goals for teaching biology; however, these goals had less influence than the central goals.

Sharon's teaching orientation consisted of two central goals: (1) for students to develop environmentally based decision-making ethics; and (2) for students to develop positive science attitudes. The central goals were further elaborated by developing dimensions of each goal. For example, Sharon's goal of developing environmentally based decision-making ethics was

Table 2
Participants' science teaching orientations: central and peripheral goals

Participants	Course (grade level)	Central Goals	Peripheral Goals
Sharon	Biology[a] (11th–12th)	• Develop environmentally based decision-making ethics. • Develop positive science attitudes.	• Develop conceptual understanding of subject matter. • Develop science process skills. • Develop life skills (i.e., basic literacy skills).
Mike	Life Science (8th)	• Wonder and appreciate the complexity of life.	• Become familiar with key biological concepts. • Develop tools and life skills.
	AP Biology[a] (11th–12th)	• Wonder and appreciate the complexity of life. • Develop skills and techniques to explore scientific questions.	• Develop conceptual understanding of biological concepts. • Preparation for college academics.
Peg	College Preparation Biology (10th)	• Become useful, productive, informed citizens. • Develop a solid understanding of biology concepts. • Be prepared for college academics.	• Develop laboratory skills.
	Independent Research[a] (11th–12th)	• Engage in the "doing" of science (independent science research).	• Consider careers in science. • Develop a belief in personal success.
Martha	Biology (10th)	• Develop positive attitudes toward biology. • Develop conceptual understanding of the subject matter.	• Be successful in school and life.
	Zoology[a] (11th–12th)	• Develop conceptual understanding of the subject matter. • Maintain positive attitudes toward biology.	• Be successful in college science courses.

[a] Elective course.

comprised of the following dimensions: (1) awareness of the environment; (2) caring for the environment; and (3) valuing and becoming an advocate for the environment. Sharon had three peripheral goals: (1) to have students develop science process skills; (2) develop science content understanding; and (3) to develop students' life skills. To support this latter goal, students read and summarized environmental articles from the local newspaper. Sharon did not feel that this was a critical assignment, but included it to support her peripheral goal of developing life skills. See Figure 2 for a representation of Sharon's science teaching orientation for her elective biology course.

In Mike's Advanced Placement (AP) Biology course, he held two central goals: (1) develop the students' curiosity, and (2) develop the skills and techniques to explore scientifically oriented questions. To support his purposes and goals, Mike required the AP students to design and conduct an independent research project. Mike's peripheral goals consisted of (1) developing conceptual understanding of biological concepts, and (2) preparing the students for college-level academics.

The number of Peg's central goals varied with the courses she taught. Peg had three central goals for her 10th-grade college-bound biology students: (1) become useful, productive, and informed citizens; (2) develop a solid understanding of biology concepts; and (3) preparation for the "rigors of academics in college." Peg's peripheral goal was to develop basic laboratory skills, such as using a compound light microscope and constructing graphs. For Peg's Independent Research students, she held one central goal, that of "doing science." Through interview prompts, the dimensions of this goal emerged as: (1) using the scientific method (i.e., engaging the students in an independent science research project; (2) developing specialized laboratory skills and techniques; and (3) realizing that scientific knowledge is built upon past knowledge. Although Peg held one central goal, this goal was complex and multidimensional. Peg held two peripheral goals for her Independent Science students. This set of peripheral goals did not drive the design of the course, but still played a role in Peg's thinking. As peripheral goals, Peg wanted the students (1) to thoughtfully consider pursuing careers in science; and (2) to develop a belief in personal success.

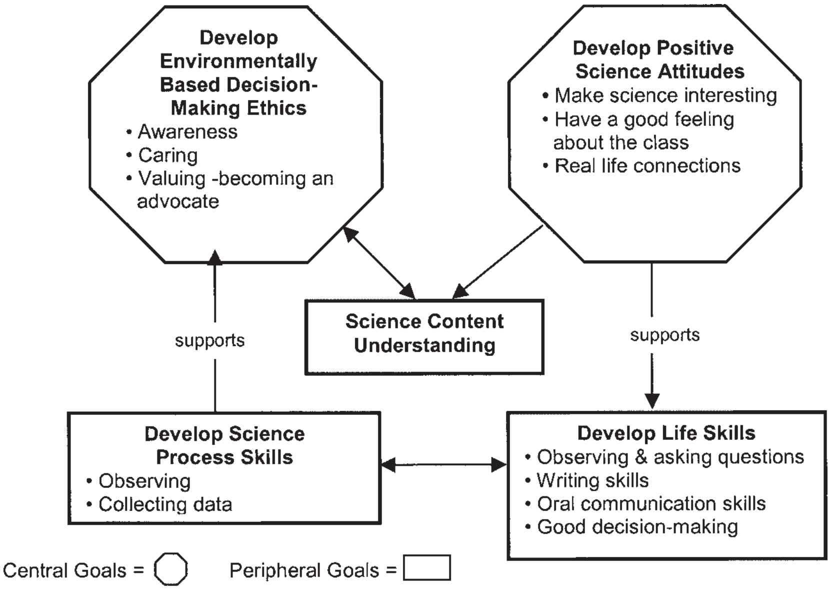

Figure 2. Representation of Sharon's science teaching orientation for the elective biology course.

Martha taught a General Biology course for college-bound students not intending to major in science. Martha held two central goals for these students, which she ranked in the following order of importance: First, develop a positive attitude toward biology, and second, develop conceptual understanding of biological concepts. Martha also taught an elective Zoology course, and for these students, she retained the same central goals, but switched their order of importance. In Martha's General Biology course, she held the peripheral goal of wanting the students to ''be successful in school and life.'' One dimension of this goal was the development of laboratory skills. Martha felt that science lab skills (e.g., following a protocol, developing organizational skills, making observations, analyzing data, and drawing conclusions) were not science-specific skills, but were skills necessary to be successful in school and life (Field notes, 5/30/01). Developing group skills was another dimension of Martha's peripheral goal of ''being successful in school and life.'' For the Zoology students, Martha's peripheral goal was more narrow in focus; she wanted these students to ''be successful in college science courses.'' There were two dimensions to this goal: (1) developing confidence in their lab skills, and (2) developing general study skills for college (e.g., learning to read a science text, study skills, group skills, and being attentive in class). For each of the participants, their science teaching orientations were complex, consisting of multiple central components as well as peripheral components. Table 2 summarizes participants' central and peripheral goals for each course they taught.

Inclusion of Means. A teacher's means (i.e., the purposeful selection and use of curricula, as well as instructional and assessment strategies) is an essential component of representing science teaching orientations. In Sharon's case, knowledge of her extensive use of field trips[2] is critical to understanding her science teaching orientation. Sharon used field trips as a means to help her students achieve two central goals: (1) to develop positive science attitudes; and (2) to develop environmentally based decision-making ethics. Sharon expended considerable energy and personal time to take her students on numerous field trips throughout the school year. Sharon justified her means through her belief that field trips were the best way to meet her course goals. In Mike's Life Science course, his central goal was to help students develop a ''sense of wonder and appreciation for the complexity of life.'' Mike chose to use entertainment, in the form of stories and engaging demonstrations, as his means to help students achieve this goal. In the Independent Science Research course, Peg's students designed and investigated college-level scientific research projects, competed in national and international science competitions, and wrote journal-quality research papers as a means of achieving the goal of ''doing science.'' Clearly, one gains a better understanding of each participant's science teaching orientation when means are included with purposes and goals.

Course Specificity. Participants' science teaching orientations differed based on the course they were teaching. Mike, Martha, and Peg had distinctively different science teaching orientations for each course they taught. (During this study, Sharon was teaching multiple sections of the same biology course.) Peg's science teaching orientations are the most illustrative of the course specificity aspect of teaching orientations. In Peg's 10th-grade biology course for college-bound students, she held three central goals: (1) for students to become useful, productive, and informed citizens; (2) for students to develop a solid understanding of biology concepts; and (3) for students to be prepared for the rigors of academics in college. Peg had a single peripheral goal for these students, and that was to develop basic laboratory skills (e.g., focusing a microscope). In Peg's Independent Science Research course, she held one central goal for her students, that of ''doing science.'' Through specific interview probes, Peg identified three dimensions of this central goal of ‘‘doing science’’: (1) using the scientific method (i.e., having students engaged in an independent science research project); (2) having students develop specialized laboratory skills and techniques; and (3) having students realize that scientific knowledge is built upon past work. For the students in Peg’s Independent Research course, she held the peripheral goal of developing a belief in personal success, with recognition and self-satisfaction being two dimensions of this goal. These central and peripheral goals are absent in her teaching orientation for the college preparation biology students. Mike and Martha retained similar goals for each course they taught; however, their central and peripheral goals changed status depending on the course (see Table 2).

ASSERTION 2: PARTICIPANTS’ SCIENCE TEACHING ORIENTATIONS WERE COMPLEX, AND INCLUDED AFFECTIVE DOMAIN GOALS, GENERAL SCHOOLING GOALS, AS WELL AS SUBJECT MATTER GOALS. Although participants held differing goals depending on the course they taught, some commonalities in the nature of their orientations existed. While all the participants held goals of learning science subject matter, this goal was never a single, central component of a participant’s science teaching orientation. Each of the participants described affective domain and general schooling goals as being important components of their science teaching orientations.

Affective Domain Goals Held a Prominent Position. Krathwohl, Bloom, and Masia (1964) used the term ‘‘affective domain’’ to describe instructional objectives that emphasize a ‘‘feeling tone, an emotion, or a degree of acceptance or rejection’’ (p.7). We drew on this definition to describe a set of central goals held by three of the participants. Sharon’s central goal of developing environmentally based decision-making ethics included dimensions of caring for the environment and giving value to natural resources. Martha had affective domain goals for both of her courses. In the General Biology course, Martha wanted to develop positive attitudes toward science, and in her Zoology course, her goal was to maintain students’ positive science attitudes. Martha believed that her students preferred labs to lectures, and she engaged the students in frequent lab activities to support her goal of developing/maintaining positive attitudes toward science (interview, 5/25/01). We placed Mike’s central goal of promoting student curiosity in the affective domain, as well. In the Independent Science Research course, Peg had a peripheral goal of helping students develop a belief in personal success. This course was time-consuming, as Peg regularly spent three to four additional hours a day helping students prepare for science fair competitions. Peg stated that her ultimate goal was not to win competitions; rather she viewed competitions as a means for students to develop confidence in their ability to be successful in college. In this study, affective domain goals held a prominent place in participants’ science teaching orientations.

General Schooling Goals: College Preparation and Life Skills. All the participants held goals of preparing students for the next phase in their lives, either preparation for college or general life skills. In the category of developing life skills, participants discussed developing responsibility, critical thinking skills, oral and written communication skills, and a belief in personal success. This set of general schooling goals did not relate specifically to science learning. For three of the participants, these general schooling goals were peripheral goals. However, in Peg’s teaching orientation for her 10th-grade biology students, two of her three central goals were general schooling goals.

When teaching college-bound students, particularly in upper level elective courses, participants held goals of preparing the students to be successful academically in college. Mike’s science teaching orientation for the AP Biology course had a peripheral component of preparing students for college. In the elective Zoology course, Martha fostered the development of lab skills and lab confidence because she felt they were important to being successful in college science courses. Martha also stressed the development of general study skills, as another dimension of helping students be successful in college. Peg prepared her Independent Science Research students for college science courses by helping them develop specialized lab skills and confidence in their ability to do scientific research. Martha and Peg did discuss the development of science-specific laboratory skills, but 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.

Participants tended to have life skill goals for younger students in required courses or for students enrolled in elective science courses who did not plan to attend college. In Mike's Life Science course, he wanted his students to learn to think logically, to explore questions and to develop a sense of responsibility. Many of Sharon's biology students were not college-bound. Sharon valued developing skills in observing, questioning, writing, speaking, as well as decision making. In describing their goals, participants often listed traditional science process skills, such as making observations, classifying, organizing data, analyzing data, and drawing conclusions. Participants viewed the development of science process skills not as end in itself, but as a means to develop general life skills.

Participants were asked to consider their goals in the context of teaching a course in another discipline, such as mathematics or social studies. The participants stated that they would continue to have this same set of goals for their students, i.e., preparation for college and developing life skills. Mike reflected on when he had taught geography courses. In both his geography and science courses, Mike valued having the students explore questions and being able to think logically. Martha summarized this set of general schooling 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, second interview, 4/25/01)

Other participants in the study expressed a similar viewpoint to the one give above. The four participants in this study possessed strong identities as biology teachers. However, they viewed themselves, first, as teachers of children, and held goals of preparing students for college and developing life skills.

Subject Matter Goals Present, But Not Always Central. Each of the four participants held subject matter goals; however, these goals were not central components of Mike and Sharon's science teaching orientations. In Mike's Life Science course, he placed a greater value on having students develop a sense of wonder and appreciation for life than on mastering science content. Even in Mike's AP Biology course, his subject matter goal was a peripheral component of his teaching orientation. Sharon's subject matter goals were 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, first interview, 3/14/01).

Subject matter goals were central components of Martha and Peg's science teaching orientations. However, both participants held additional central goals of equal importance (e.g., developing and maintaining positive science attitudes). For all the participants, subject matter goals were present, but not as a single, central component of their science teaching orientation.

Probable Sources of Science Teaching Orientations

The second research question explored the sources of participants' science teaching orientations, with sources defined as the probable influences on the development of an individual's science teaching orientation. Initially, we viewed sources as being biographical in nature, i.e., occurring in the past. During the data collection process and subsequent analysis, the critical role of the current school context and the students became apparent. Each of the participants brought a unique set of life experiences and school contexts to this study, which in turn contributed to the sources of the participants' science teaching orientations.

ASSERTION #3: EXTERNAL SCHOOL FACTORS: NONTEACHING WORK EXPERIENCES AND PROFESSIONAL DEVELOPMENT CONTRIBUTED TO PARTICIPANTS' SCIENCE TEACHING ORIENTATIONS. During the interviews, participants were asked to identify people and/or experiences that were influential in shaping their beliefs about the purposes and goals for teaching biology. Sharon was able to readily identify sources during the first interview and consistently thereafter. With the other three participants, the sources of their orientations unfolded as the data collection progressed. Through questioning and reflection, the participants made connections between probable sources and the nature of their science teaching orientations. This suggests the implicit influence life events may have on teachers' beliefs.

Influence of Prior Nonteaching Work Experience. For three of the four participants, science teaching was a second career. After college, Sharon worked as a naturalist. Mike had extensive retail business experience and Martha was a laboratory technician in a research 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 parenting. Each of these participants made strong connections between their prior work experiences and their science teaching orientations.

Sharon worked as a naturalist for the National Parks Service, and identified this work experience as a major influence in shaping both her teaching goals and her means. As a secondary science teacher, Sharon continued to focus on environmental issues. Drawing on skills she developed as a naturalist, Sharon made extensive use of field trips as a means to support her teaching goals. For both of Mike's biology courses, he held the goal of helping students "develop tools and life skills." Mike supported his school's mandatory homework policy because he felt homework assignments helped students develop responsibility. In his business career, Mike was a manager and valued responsible employees. In his AP Biology course, Mike emphasized the development of research "tools," i.e., laboratory skills. As a means to achieving this goal, Mike required his AP students to complete an independent science research project. While working on his master's degree, Mike was a research assistant in a biology laboratory. Mike credited these two work experiences for directly shaping his goal of "developing tools and life skills." Martha frequently engaged her students in laboratory activities. She required students to write lab reports, which they keep in bound lab notebooks. Martha valued the lab notebooks as a record of the students' successes and as a communication tool, allowing her to give personal encouragement to each student. Martha's chosen means and goals made sense in light of her previous work as a laboratory technician. These prior work experiences were important influences in shaping each of these participants' science teaching orientations.

Immediately after graduation from college, Peg began her career as a secondary science teacher. Peg did not have any additional work experience and drew on her college experiences as the source of her science teaching orientation. Peg attributed her college success to being able to read science textbooks. In Peg's college preparation biology course, one of her central goals was to develop conceptual understanding of the subject matter, with a peripheral goal of preparing students for college. Peg achieved these two goals simultaneously by using textbook readings as a primary means of instruction. In this course, Peg envisioned her teaching role as that of an organizer, assigning chapters to read and testing the students for mastery of the content in the reading assignments. Past experiences as science learners may have influenced the other participants' science teaching orientations. However, in extensive interviews, Sharon, Mike and Martha continually referred to prior work experiences as being a major influence in shaping their goals and purposes for teaching science.

Influence of Professional Development and Collaboration. Over the course of their teaching careers, participants engaged in a consistent, yet unique pattern of professional development. 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 participants did not attend National Science Teachers Association conferences or the National Association of Biology Teachers conferences on a regular basis, nor did they identify these organizations as a source of their professional development. What did emerge was a strong connection between each individual's science teaching orientation and their choice of professional development.

Early in her teaching career, Sharon developed collaborative relationships with a private environmental foundation and a marine science consortium. As Sharon worked with these organizations, she incorporated their philosophies into her own teaching. Sharon identified these collaborations as an important source of professional development, and attributed these collaborations to shaping her central goal of developing environmental decision-making ethics. In her current position, Sharon occasionally collaborated with university scientists as a way to involve her students in environmental research projects. Sharon also participated in environmental education workshops and enrolled in graduate environmental science courses.

Mike chose to participate in a different science teacher education workshop each summer, with the topics varying greatly from year to year. The wide-ranging topics of Mike's professional development activities make sense in light of his science teaching orientation. In the Life Science course, Mike's single, central goal was for students to develop a sense of wonder and appreciation for the complexity of life. In Mike's AP Biology course, a second central goal was to "develop skills and tools to explore scientific questions." By participating in an eclectic mix of workshops, Mike's own curiosity was satisfied and his appreciation for the complexity of life grew. In addition, Mike gained a variety of lab skills, which further facilitated the AP students' independent research projects.

Martha's primary source of professional development was an annual summer workshop hosted by a local college. During the workshop, high school teachers developed new laboratory protocols for their science courses. For Martha, labs were an important means of supporting her central goal of developing and/or maintaining positive science attitudes. For her Zoology students, Martha held the peripheral goal of preparing students to be successful in college science courses. One dimension of this peripheral goal was to have students develop confidence in their laboratory skills. Martha selected professional development activities that enhanced her means (i.e., laboratory activities) of supporting her purposes and goals for teaching biology.

Peg's professional development activities differed from those of the other three participants. She preferred to attend scientific research meetings and collaborate with scientists, rather than attend science teaching workshops. In the Independent Research course, Peg's central goal was for students to engage in scientific research. To help her students develop laboratory protocols for their research projects, Peg consulted, via email, with scientists from around the world. Peg identified her communication with scientists as an important part of her professional development. Each of the participants, over the course of their teaching careers, developed a consistent pattern of professional development. The participants' choice of professional development activities was strongly influenced by their individual science teaching orientations.

Teacher Education Programs: Missing Influence. In this study, the absence of teacher education programs as a source of science teaching orientations was not an accidental omission. When questioned directly about their teacher education programs, participants stated that their science methods courses had little or no influence on the way they currently taught. Sharon credited her science methods course with giving her a few strategies for working with students, but none of the participants identified their teacher education program as an influence that shaped their purposes and goals for teaching biology. This may be an artifact of the research design; the participants had 13 or more years of teaching experience and their teacher education programs may have been too distant for participants to recall influential aspects of their courses. However, many of the participants recalled influential experiences, such as work experiences, which occurred prior to their entry into teacher education programs.

ASSERTION #4: CURRENT SCHOOL CONTEXT: TEACHERS' MEANS WERE INFLUENCED BY THEIR BELIEFS ABOUT STUDENTS AND LEARNING, AND BY TIME CONSTRAINTS. The participants' current school context was a major influence that shaped their science teaching orientations. We use the term, "current school context" to refer to the particular high school settings in which the participants taught. The four participants were established teachers in their high schools, having taught in the same building for many years. Within the school context, participants were greatly influenced by their daily interactions with students. The participants' beliefs about their students and how they learn guided their instructional decision-making process. In addition, perceptions of time constraints influenced participants' purposes and goals for teaching science, as well as their means.

Influence of Student Feedback. The participants' daily interactions with students greatly influenced the means that participants used to support their purposes and goals. During classroom observations, it was apparent the students enjoyed their biology classes and respected their teachers. The participants had established good rapport with their students. They monitored their students' conceptual understanding and actively sought student feedback. Therefore, it is not surprising that the students were a major influence on participants' choice of means to support their course goals.

Based on her observations of students, Sharon believed that students were bored in school. Sharon's instructional decision making was driven by this belief. Accordingly, Sharon tried to vary her teaching strategies to actively engage her students. She designed practical projects for her students, such as building nesting boxes for bluebirds. Sharon explained, "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'' (Sharon, first interview, 3/14/01). When Mike was asked how he evaluated the merit of a new laboratory activity or instructional strategy, he replied, ''Oh, well, you pick that up from the kids'' (Mike, Card Sort, 3/21/2001). Martha had recently modified all her laboratory activities. In each lab, she omitted the list of objectives and redesigned each lab around a central, driving question. This change might be viewed as better reflecting the nature of scientific inquiry; however, Martha stated that she made this modification because she found that students were ignoring the list of objectives. Martha avoided lab worksheets, preferring lab notebooks because she felt that worksheets had a negative connotation for her students (Martha, second interview, 5/25/01). Martha used more review and practice strategies with her biology students than with her Zoology students. Martha explained, ''They [the Zoology students] would be bored to tears if I reviewed and practiced more than a certain amount. They would hate it'' (Martha, second interview, 5/25/01). In this study, students greatly influenced the means used by the participants to support their purposes and goals.

Influence of Beliefs About Learning. The participants' means were also influenced by their beliefs about learning. Mike believed learning opportunities were optimized when students were curious and explored questions. Mike used interesting stories, interspersed with questions, to teach subject matter content. Mike also used discrepant events to foster student curiosity. In contrast, Sharon believed that learning occurred when students were engaged in immersion-type experiences and practical projects, such as stream monitoring for water quality. Martha believed that students needed to see the relevancy of the material before they could engage in the learning process. Throughout her lectures, Martha made frequent connections between the subject matter and the students' lives. Martha also believed that her biology students learned through repetition, and she used labs to reenforce the content of the lectures. Peg formulated her beliefs about learning based on her own learning style. She viewed learning as an individual process, and preferred to learn by reading. Textbook reading assignments were an important means in Peg's teaching. In this study, beliefs about learning influenced participants' science teaching orientations, specifically, the means the teachers used to support their course goals.

Influence of Time Constraints. Participants repeatedly discussed the effect of time constraints on their teaching. In this study, all the participants were experienced teachers with strong knowledge of the subject matter. The participants were not concerned with the need to fill class time with instructional activities; rather participants saw time as a limiting factor in their teaching. The participants discussed time constraints in two different areas, class time and preparation time.

All the participants felt that they had a limited amount of time to help students achieve the course goals. The participants taught in schools with traditional class schedules, with class periods of 40 to 50 minutes. The participants discussed the need to use this limited classroom time efficiently. Sharon expressed the greatest frustration with her school's 42-minute class periods. Sharon preferred to immerse her students in natural settings as a means of supporting her central goal of developing environmental based decision-making skills. In response to time constraints, Sharon negotiated a modified class schedule, with afternoon classes meeting for double class periods on alternating days. It was still difficult for Sharon to schedule field trips, even within this modified schedule. Sharon expressed a desire to structure curriculum units around daylong, monthly field trips. Ideally, students would prepare for the field trip, collect data on the field trip, and then return to the classroom to analyze data and synthesize information. The daily school schedule greatly affected and limited the means Sharon used to help students achieve her goals.

Participants also felt constrained by their limited preparation time for grading papers, tutoring students and preparing for classes. The constraint of limited preparation time influenced the participants' goals for their courses. Peg placed a high value on engaging students in science fair projects, and her involvement with science fairs led to the creation of the Independent Science Research course. Peg required her one class of ninth grade Physical Science students to enter a science fair competition, with the students working on their projects at home. However, engaging student in science research projects was not a goal in Peg's College Preparation Biology course. Limited preparation time did not allow Peg to facilitate additional science fair projects. As Peg viewed science fair competitions as her only means for engaging students in the "doing of science," she modified her goals for the College Preparation Biology course. Lack of sufficient preparation time also influenced Sharon's choice of means for supporting her goal of developing environmental decision making. Sharon liked to involve her students in what she referred to as "action projects," such as habitat restoration projects and letter writing campaigns. Because of time constraints, Sharon needed to reduce the number of action projects in her courses. Perceptions of time constraints, both in class time and preparation time, clearly influenced the participants' means of supporting their goals, and in one case, Peg's college preparation biology course, her course goals were also influenced.

Substantive-Level Theory of Science Teaching Orientations

Our representation of the substantive-level theory of science teaching orientations for the four participants is presented in Figure 3. This form of representation was chosen to illustrate the complex interrelationships between the nature and probable sources of science teaching orientations, as well as the means associated with supporting students' attainment of these goals. 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. The science teaching orientations should not be viewed as static, but represent our interpretations at the time of the study.

In this study, the nature of the participants' science teaching orientations consisted of three major types of goals: (1) affective domain goals, (2) general schooling goals, and (3) subject matter goals. The probable sources of these goals are divided into past experiences and present experiences from the school context. Prior work experiences were an important influence that shaped the nature of an individual's science teaching orientation. In the absence of prior work experiences, one teacher drew on past experiences as a college science learner. Professional development activities acted as a feedback loop, and this relationship is denoted with a double arrow. Participants selected professional development activities based on their current science teaching orientations. In turn, experiences in these professional development workshops appeared to reenforce the participants' science teaching orientations.

The current school context greatly influenced the nature of science teaching orientations and is shown in the lower portion of the diagram. Within the context of the school, the participants' beliefs about learning and the needs of their students had the greatest influence in shaping the participants' teaching orientations, primarily influencing the teacher's chosen means. Within the current school context, time constraints also influenced the participants' goals and means.

Means are included as an important component of an individual's science teaching orientation. The relationship between the nature of the teaching orientation and means is represented with a double arrow. For example, in the Independent Research course, Peg's central goal was for the students to engage in scientific practice, what she refers to as the "doing of

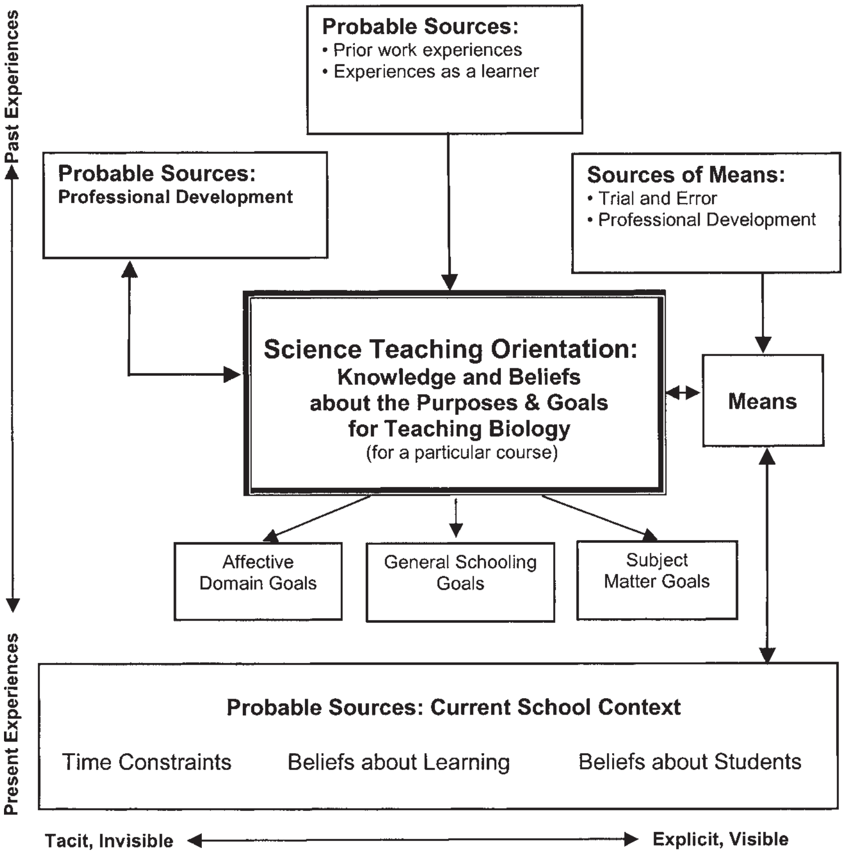

Figure 3. Substantive-level theory of science teaching orientations.

science." Peg used independent science research projects as her means of helping students engage in the "doing of science." However, this chosen means was extremely time-consuming and energy-intensive. Peg did 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 influenced the nature of her goals for the College Prep Biology course. Peg made a decision to exclude the "doing of science" as a goal for the College Prep Biology students. On a daily basis, the students greatly shaped and influenced the means used by the teachers. Participants identified professional development workshops as additional sources of means. However, trial-and-error was the major process that the participants used to develop a repertoire of means, with the students' daily feedback as the major component in this trial-and-error process.

Discussion

Assertion #1

In this study, we interpreted the participants' science teaching orientations as complex in nature. In pilot studies, we initially attempted to match participants' orientations to those described in the PCK literature, but found them to be insufficient for characterizing our participants. Through interviews with the participants, we co-constructed diagrams of their science teaching orientations reflective of their complexity. Our interpretations differ from the science education literature in which an individual science teaching orientation is represented as a single, homogenous entity (e.g. Magnusson et al., 1999). Based on the findings of this study, we found that science teaching orientations are better represented as complex entities, with central and peripheral components.

To aid in representing the complexity of the participants' science teaching orientations, we found it useful to include the teacher's means of supporting his/her goals. Sharon's central goals of developing environmental decision-making ethics and positive science attitudes is better understood in light of her preferred means (i.e., fieldwork). The extent of Peg's goal of "doing science" is best illustrated through Peg's means (i.e., involvement in regional and national science fairs). Based on this study, the inclusion of means as part of a teacher's science teaching orientation provides the reader with a more holistic representation.

In addition, teachers' means need to play a critical role in researching science teaching orientations. The teacher's means, due to their visible nature in classroom observations, offer the researcher critical interview probes for eliciting the teacher's purposes and goals for teaching science (e.g., "Why did you decide to include identification of common birds as part of your unit test?). Early studies of science teaching orientations involved the use of teacher interviews (e.g., Roth, 1984); however, later studies often assigned teaching orientations based on classroom observations without input from the teacher (Friedrichsen, 2002). We advocate that the participants play an active role, as co-researchers, in co-constructing representations of their science teaching orientations.

In this study, the participants held different teaching orientations for each course they taught. Of the four participants, Peg demonstrated the most striking dichotomy in science teaching orientations. She held one set of goals for the sophomore College Preparation Biology students, and a different set of goals for the upper grade-level students in the Independent Research course. Consequently, there was a striking difference in the way Peg taught each of these two courses. Peg described her 10th-grade College Preparation Biology course as being taught in a traditional manner, while the Independent Science Research course had the appearance of a college research laboratory. These findings are congruent with Magnusson et al. (1999) in their definition of science teaching orientations as "teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level" (p. 97). However, based on this study of secondary biology teachers, we suggest an elaboration of the definition to include course specificity or grade level, or both.

Assertion #2

The participants' science teaching orientations were not only more complex, but were broader in scope than those described in the literature. The participants' teaching orientations included not only subject matter goals but also affective domain and general schooling goals. In the PCK literature, an academic rigor orientation has the central goal of "representing a particular body of knowledge" and is characterized by "challenging the students with difficult problems and activities," whereas a didactic orientation has the goal of "transmitting the facts of science" and is characterized by the use of lecture or discussion (Magnusson, et al., 1999, pp. 100–101). In this study, participants did not hold orientations that could be interpreted as being solely didactic or academic rigor in nature. For example, Martha tended to follow an instructional pattern of lecturing to introduce new concepts followed by an illustrative laboratory activity. The label of a didactic orientation might be given to Martha, in which the goal is to transmit the facts of science (Magnusson, et al., 1999). However, we argue that the use of a single label, that of a didactic orientation, completely masks Martha's other central goal of having her students develop and/or maintain positive attitudes toward biology. To support this latter goal, Martha designed engaging laboratory activities organized around a central question relevant to her students' lives (e.g., "What is the effect of raw versus seven minute cooked hamburger on the bacterial population in ground hamburger?" field notes, 5/9/01). Martha also designed creative group project assignments in each marking period to facilitate student interest. 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. Within the affective domain, participants held the following goals: developing and maintaining positive science attitudes, developing an environmental ethic, and developing students' curiosity. Participants also held general schooling goals as part of their science teaching orientation; these goals included: developing reading literacy, being successful in school and life, as well as being responsible, informed citizens.

Assertion #3

To gain a better understanding of the construct of science teaching orientations, this study included an exploration of the probable sources of the participants' science teaching orientations, as identified by the participants. In the first interview, Sharon readily identified sources for her science teaching orientation. Sharon explained that her goal of helping students develop environmentally-based decision-making ethics was a direct result of her prior work as a naturalist. For the other three participants, the sources contributing to their science teaching orientation became explicit through subsequent interviews and reflection. For three of the four participants, prior work experience was identified as a major influence, and their central goals could be traced back to their prior work experiences. Greenwood (2003), in a study of third-year teachers, reported a similar finding. Greenwood proposed that prior careers in science shaped the individuals' conceptions of science, which strongly influenced their science teaching orientations. This study of experienced science teachers (13+ years of teaching experience) contributes to the literature in that it shows the long-term effect of prior work experience on science teaching orientations.

To explore further the sources of science teaching orientations, we included interview questions regarding involvement in professional development activities. The interview questions were based on our assumption that professional development would be a potential source contributing to science teaching orientations. We did find a strong connection between participants' choice of professional development activities and their science teaching orientations; however, the connection was more complicated than we first envisioned. With the experienced teachers in this study, their science teaching orientations appeared to drive their choice of professional development activities. In turn, the selected professional development appeared to reenforce the participants' science teaching orientations. There is a substantial literature base regarding effective science teacher professional development (e.g., Loucks-Horsley, Hewson, Love, & Stiles, 1998); however, a literature search revealed no information on how experienced science teachers make professional development choices. This study sheds light on one component of this decision-making process.

Assertion #4

The influence of beliefs about students and learning is supported by current research suggesting knowledge is situated in specific physical and cultural contexts. This view of situated cognition makes sense in the context of teacher learning (Borko & Putnam, 1996). In this study, the current school context greatly shaped the participants' science teaching orientations. As stated earlier, the participants were established teachers in their high schools. The participants' beliefs about how students learn appeared to be shaped by their many years working with the student population at their high schools. Specifically, participants' beliefs about their students' learning influenced their chosen means for supporting their purposes and goals for teaching biology. 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. This study contributes to a clarification of the influence of beliefs. In this study, the teachers' beliefs related to how students learn influenced the means used by the teachers to help students achieve the teacher's goals. However, further research is needed to better understand the role of a specific school context in forming beliefs about student learning. Teachers who have taught in a variety of school settings would better inform the relationship between school context and beliefs about student learning.

Time constraints also influenced participants' science teaching orientations. In the card sorting activity, participants often accepted or rejected scenarios based on the amount of time required to do the activity when compared with how much the students would learn. Lanz and Katz (1987) reported a similar finding in their study of secondary chemistry teachers implementing a new curriculum. These investigators coined the term "pedagogical efficiency" to describe the influence of time constraints on teachers' decision making. In the card sort task and in their own teaching, Martha and Peg consistently rejected hands-on, discovery activities because they felt it was an inefficient use of class time. The interpretations from this study are supported by the work of Hargreaves (1994), who stated, "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). This study contributes to the literature base in that it indicates that time constraints primarily influenced the teachers' choice of means to support students in achieving the course goals. In the absence of alternative means, time constraints also influenced one participant's goals for a particular course.

Substantive-Level Theory

We present a substantive-level theory of science teaching orientations for this group of four highly regarded secondary biology teachers. The role of teaching orientations has been established in the literature. Grossman (1990) described teaching orientations as a "conceptual map for instructional decision-making" (p. 86). Magnusson et al. (1999) described science teaching orientations as "a general way of viewing or conceptualizing science teaching" (p. 97). Nine different science teaching orientations have been identified in the science education literature (Magnusson et al., 1999). This study contributes to the literature by taking an inductive approach to science teaching orientations. The single label orientations in the literature (e.g., activity-driven or didactic) did not describe the participants' complex teaching orientations. Teachers were active participants in this study, co-creating with the researchers a representation of their teaching orientation reflective of its complexity. Additionally, the substantive-level theory contributes to an increased understanding of the interplay of factors influencing the development of teaching orientations. By examining probable sources of teaching orientations, we gain a deeper understanding of the construct of teaching orientations. In this study, prior work experiences, professional development choices, beliefs about students and about learning, as well as time constraints, were seen as influential factors shaping the nature of the participants' science teaching orientations.

Implications

Implications for Professional Development

One implication from this study is the importance of making beliefs about teaching explicit. 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). It is only when beliefs are made explicit that they can become targets of change (Freeman, 1991). Based on the interpretations of this study, we recommend that professional development programs support teachers in examining the nature of their science teaching orientations. The card-sorting task, one of the research protocols in this study, has been shown to be a useful strategy. As teachers share their beliefs about teaching, specifically their purposes and goals for teaching science, they can begin to examine their beliefs in light of reform-based science teaching; therefore, allowing their knowledge and beliefs about teaching to become targets of change.

Participants in this study possessed a repertory or "toolbox of means" they routinely employed to help students achieve their course goals. We recommend that assessment of individual teachers' toolboxes of means occur early in 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. In professional development programs, we recommend that specific attention be given to assessing and expanding teachers' means in light of reform-based science teaching and learning.

Implications for Future Research

There is a need for continued research to further develop the construct of science teaching orientations, with initial efforts concentrating on protocol development. The data collection techniques used in this study, (i.e., semi-structured interviews, a card-sorting task, and classroom observations) were effective, but time intensive. Baxter and Lederman (1999), in their review of PCK assessment, concurred with this finding. New protocols need to be developed and tested with teachers at all career stages, including prospective teachers.

Our work reiterated the implicit, invisible nature of teachers' knowledge and beliefs (see Kagan, 1990), and the need to work collaboratively with teachers. Teachers' purposes and goals for teaching a particular subject matter cannot be inferred solely from classroom observations. The complex nature of teaching orientations is obscured when we view orientations through the lens of an objective observer of the teacher's means. Means should be viewed as a way to elicit the teacher's knowledge and beliefs about their purposes and goals for teaching subject matter. 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.

With an expanded repertory of research protocols and an emphasis on collaborative research with teachers, the development aspect of the science teaching orientation construct can be vigorously pursued. Longitudinal studies, which begin with prospective teachers, are needed to provide insight into the development process. The participants in this study did not identify their teacher education programs as being influential in shaping their science teaching orientations. In what ways, if any, does an individual's teaching orientation change during the course of a teacher education program? What are the most powerful experiences in teacher education programs that contribute to the development of an individual's teaching orientation? Longitudinal studies need to be conducted with experienced teachers as they progress through various career stages. Are the greatest changes in science teaching orientations seen only in the induction years? 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 the nature of an individual's science teaching orientation? Are beliefs about how students learn tied to a specific school context or do beliefs remain unaltered when the school context changes? In this study, a connection was seen between the participants' teaching orientations and their choice of professional development activities. Additional research needs to be conducted in professional development settings. How does explicit attention to science teaching orientations influence the effectiveness of reform-based professional development? 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.

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Notes

[1] We have assigned pseudonyms to all participants.

[2] Sharon used the term "field trip" to refer to fieldwork, in which the students made observations and collected data at a field site. For example the students conducted a bird survey at a particular site or conducted water quality testing at a stream site.

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