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THE INTERACTION OF MICHIGAN ENVIRONMENTAL EDUCATION CURRICULUM, SCIENCE TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE, AND ENVIRONMENTAL ACTION COMPETENCE

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By

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ABSTRACT

THE INTERACTION OF MICHIGAN ENVIRONMENTAL EDUCATION CURRICULUM, SCIENCE TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE, AND ENVIRONMENTAL ACTION COMPETENCE

By

Angelita P. Alvarado

One of the main goals of Environmental Education (EE) is to develop people's environmental stewardship, which includes people's capacity to take environmental action – their action competence (AC). The purposes of my study were to characterize the interactions found in an EE curriculum, science teachers' pedagogical content knowledge (PCK), and their use of AC, and to identify factors that appear to be associated with the use of AC in curriculum and instruction.

My study was divided into three parts: (1) content analysis of the Water Quality Unit of the Michigan Environmental Education Curriculum Support (MEECS, nine lessons); (2) a survey of MEECS training participants (N=131 [28.4% response rate]); and (3) an in-depth examination of pedagogical content strategies and use of AC of four science teachers using class observations (December 2007 – April 2008: N=38), semi-structured interviews (October 2007 – April 2008: N=20), Content Representations (CoRes: N=6), and surveys (N=4).

The extent that individual elements of AC occurred in each data source was variable; that is, some elements were more prevalent in one data source than another. Of the five elements of AC, *knowledge/insight, planning and action*

experiences, and critical thinking and reflection were more prevalent than *commitment* and *visions* in two of the three data sources, namely, the Water Quality Unit (EE curriculum) and the four teachers. *Visions* was consistently the least prevalent element of AC in each of the three data sources.

In general, the types of and/or extent that goals and beliefs, pedagogical approaches, instructional methods, student skills foci, and manifestations of PCK occurred helped explain the prevalence of individual elements of AC across the data sources. For example, use of *activity-driven, project-based*, and *process-oriented* pedagogical approaches appeared important for engaging students in real world *planning and action experiences*. Other factors that appeared to be associated with the use of AC include content taught, personal conviction of teachers, barriers or constraints in teaching context, characteristics of students, and teacher education and professional development experiences. To strengthen use of AC in EE curricula and by teachers, some recommendations include: 1) changing standards and assessments to include the use, development and measurement of AC; 2) emphasizing equally all the elements of AC in curriculum development and instruction; and 3) training teachers on the use of multiple approaches and methods for applying AC in and outside of the classroom, as well as the importance of being intentional and reflective about one's teaching, to help build one's PCK for teaching EE and fostering students' AC.

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CHAPTER 1

INTRODUCTION AND DISSERTATION ORGANIZATION

1.1 VALUE OF ENVIRONMENTAL EDUCATION AND NEEDS AND ISSUES WITHIN THE FIELD

Environmental Education (EE) increasingly plays a crucial role in finding solutions to environmental and developmental issues. This is seen in the proliferation of EE programs in the last twenty to thirty years (Athman & Monroe, 2001; McClaren, 1997; Monroe, 1999; Orr, 1995; Palmer, 1998; Tilbury, 1995; UNDESD, 2005a). In general, these programs are aimed at improving awareness, knowledge, attitudes, skills, and participation of all age groups inside and outside the school system, as well as in local and international settings and contexts (Athman & Monroe, 2001; Palmer, 1998; UNESCO, 1977). Many believe these outcomes (e.g., awareness, knowledge, attitudes) result in a heightened concern of people about their environments, change in personal lifestyles and behaviors, participation in finding solutions to environmental problems or issues, and eventual support for the increasing global agenda to reconcile environment with development (Hungerford & Volk, 1990; Tilbury, 1995; UNDESD, 2005b).

However, despite this recognition of the value of EE, the field is confronted with several contentions, arguments, or questions. First, debates about "What works in EE?" and "Does EE matter?" emerged, and have increased (Jensen, 2002; Jensen & Schnack, 1997; Lee & Williams, 2001; Palmer, 1998; Payne, 2006). An abundance of EE studies have ensued.

Although there is a large increase in the number of EE studies, a quick survey of the literature reveals that studies conducted in the past thirty years focused predominantly on examining the impact of EE programs on students' knowledge, attitudes, skills, and behaviors (Dimopoulos & Pantis, 2003; Hungerford & Volk, 1990; Leeming *et al.*, 1997; Roth, 1992). These types of outcomes are characteristically the focus of behaviorist theories, one of which is the environmental citizenship behavior model of Hungerford & Volk (1990). This model suggests that "the ultimate goal of education is to shape human behavior" (p. 8). Some of the behaviorist researchers have suggested that environmental issues are a result of personal lifestyle choices, and therefore, to solve these problems or issues, education needs to focus on changing individual behaviors (Jensen & Schnack, 1997; Lee & Williams, 2001). Behaviorist theories such as the environmental citizenship model have shaped recent EE research and practice.

I would argue that answering "What works in EE?" or "Does EE matter?" should go beyond measuring changes in knowledge, attitudes, skills, and behaviors. This is not to say that these types of outcomes do not count; they do (Dimopoulos & Pantis, 2003; Hockett *et al.*, 2004; Hsu, 2004; Orams, 1997). But I would argue that more important than change in behaviors is building capacity for taking action, or the capacity to change living conditions. This is a different direction – a different way of viewing, practicing, and studying EE – that some researchers urge EE practitioners and researchers to consider (Jensen, 2000a; Jensen & Schnack, 1997; Wals, 1994).

One alternative EE theory that was proposed in the early 1990s is the action competence (AC) theory. According to this theory, the ultimate goal of education is to develop students' capacity to take action or to change their living condition (Jensen, 2000a, 2000b; Jensen & Schnack, 1997). This theory also suggests that environmental issues are a result of both personal lifestyle choices *and* living conditions (social forces), and therefore, solutions have to be addressed both at the personal and structural (societal) levels (Jensen, 2002; Jensen & Schnack, 1997; Mogensen, 1997).

My dissertation research was grounded in AC theory, and I conducted this research in response to the persistent concerns about the processes, materials, outcomes, and efficacy of EE, and to respond to the call for viewing, practicing, and studying EE differently. In particular, I undertook this research to examine and characterize the interactions found in an EE curriculum and science teachers' focus on AC, and to identify factors that appear to be associated with focus on AC in curriculum and instruction.

The focus on developing students' capacity to take action is accompanied by another need, and that is to identify the styles and content of teaching that help to develop this capacity. This need was expressed by two of the leading proponents of the AC theory – Jensen & Schnack (1997). To date, there is only one other study besides my dissertation research that investigated the kinds of pedagogical approaches that promote AC (Eames *et al.*, 2006).

A second issue is that EE research has given more attention to *student* outcomes than to studies focusing on teachers and their teaching practices. I see this prevalence of studies looking only at student outcomes as resulting in a huge gap in our understanding of what effective EE involves and if we are making an impact. How do we know what student outcomes to measure if we don't know what, how, and why teachers teach EE? In response, my research did not measure student outcomes. Rather, my research focused on the teachers and asked whether they fostered students' capacity to find solutions or to take action. Through this research, I asked whether teachers encouraged students' willingness to participate in finding solutions to environmental issues, or whether teachers integrated students' ideas about their future into the process of finding alternatives and solutions. These questions go beyond easily observable or verifiable variables (Marcinkowski, 1990 cited in Palmer, 1998) such as knowledge, attitudes, skills, or behaviors.

Third, in many parts of the United States, EE is not required in the K-12 curriculum, and many schools do not offer it. EE is not a mandated component of Michigan's K-12 curriculum (DEQ, 2002). In schools where EE is taught, it is often incorporated into science education (Littledyke, 2008; Ross, *et al.*, 2005; Roth & Lee, 2004; Slingsby & Barker, 2003). This connection between EE and science education has prompted me to use the pedagogical content knowledge (PCK) framework to examine how teachers teach EE and their focus on AC in the classroom. PCK, a widely accepted framework in science education research and practice, refers to the type of teacher knowledge that enables the teacher to find the most useful forms of representation of topics, analogies, examples, illustrations, explanations, and demonstrations to teach a particular content to a particular group of students in a particular context (Shulman, 1986). PCK's focus on how teachers teach a particular content and why fits perfectly with the purpose of my study.

1.2 ENVIRONMENTAL EDUCATION (EE) CURRICULUM IN MICHIGAN: MICHIGAN ENVIRONMENTAL EDUCATION CURRICULUM SUPPORT (MEECS)

In November 1998, Michigan citizens approved a $665 million Clean Michigan Initiative (CMI) Bond, which would be used for various environmental improvements in the state. The Budget Appropriations Committee set aside $1 million of the CMI funds for EE curriculum development and tasked the Department of Environmental Quality to lead the project. Consequently, a Technical Advisory Group was formed to guide the curriculum development project. This group consisted of the Department of Environmental Quality, Department of Education, and a team of scientists and educators having technical expertise and practical experience relevant to developing and using a science-based environmental curriculum. The advisory group intended the EE curriculum to provide supplementary materials to science and other subject areas (DEQ, 2002, 2006).

The curriculum development project was based on the assumption that today's youths play a big role in the future of Michigan's environment and natural resources (DEQ, 2002). Consequently, the goal of the project was to help students make data-based choices through improved knowledge of basic science principles associated with the environment, role of government, economic and ecological sustainability, stewardship and pollution prevention, and impacts of individual decisions (DEQ, 2002; Vail, 2006). Thus, each of the five MEECS Units (Energy and Resources, Ecosystem and Biodiversity, Land Use, Air Quality, and Water Quality) aimed to provide students with science-based, accurate, data-based, balanced, and Michigan-specific lessons that are aligned with state benchmarks and standards and Grade Level Content Expectations (GLCEs). The curriculum development project started in 2003 and underwent a series of pilot tests and reviews before it was completed in 2006.

Despite a large funding allocation from the state and the support of many state agencies and partners, the MEECS has received little research attention. One study consisted of an evaluation of the components of the curriculum development project, including educator workshops and a preliminary impact study that examined (1) differences in lesson quality between teachers who taught MEECS and those who taught other materials and (2) student learning as a result of studying the units (SAMPI, 2007). But more studies are needed to assess curriculum content and characteristics of MEECS users. My study contributes in these two areas.

1.3 RESEARCH QUESTIONS

The needs and issues which I described above have led me to explore the following questions in my research:

1) To what extent do the science and environmental education curricula and content materials used by science teachers represent elements of action competence?
2) To what extent does teachers' pedagogical content knowledge in using science and environmental education curricula and content materials represent elements of action competence?

In my study, "extent" simply means the prevalence of individual elements of AC and the prevalence of elements and manifestations of PCK. To address these questions, my research was divided into three parts: (1) analysis of the Water Quality Unit of the MEECS (DEQ, 2005); (2) a survey of MEECS training participants; and (3) an in-depth examination of pedagogical content strategies and use of AC by four science teachers in Michigan.

1.4 THEORETICAL CONTRIBUTIONS

My research offers alternative theories or frameworks to view, practice, and study EE by combining two theories – AC and PCK. A quick search in the literature reveals that, to date, a large number of EE programs focus on increasing people's knowledge or changing their attitudes and behaviors. In terms of EE research, a similar trend is observed – a large number of studies have been based upon behavior modification models. In the United States more specifically, EE studies consisted largely of investigating impacts of EE on people's knowledge, attitudes, and behaviors; use of AC as a framework for viewing, practicing, and studying EE is almost absent (Agyeman, 2006 and Wals, 1994 are exceptions).

My research will, therefore, advance the theory of AC as an alternative EE theory – to go beyond shaping human behavior into developing a person's capacity to take action or to change his or her living condition – both in research and practice. Furthermore, the exact extent of the AC literature is difficult to define due to the difficulty of finding related references. I found only a few studies that have attempted to measure AC empirically (Breiting & Mogensen, 1999; Eames *et al.*, 2006; Fien & Skoien, 2002). Most published references are limited only to the operationalization of the AC concept. Therefore, my research will add to the current body of literature. My research also will advance PCK by testing its utility in evaluating EE. I adopted PCK to examine teachers' goals and beliefs about teaching science, pedagogical approaches, instructional methods, and other possible factors that influence their use of AC.

1.5 PRACTICAL CONTRIBUTIONS

This study provides insights into teachers' use of EE in the classroom and their use of AC by conducting an in-depth examination of how teachers teach a particular content and why. Specifically, this study identifies the pedagogical approaches, instructional methods, content or subject matter taught, and other possible factors that may have contributed to teachers' use of AC in the classroom. This research can help inform and improve teacher training and/or professional development programs (EE and/or Science) by including a strong focus on pedagogical strategies for EE in general, and for AC in particular. This research also identifies possible relationships between elements of AC and content or subjects in a curriculum, which is an unexplored area for future research.

This study can inform us about the nature of the integration of EE with science education, including the barriers or challenges associated with this process. This study also can guide future development of environmental education or science curricula for K-12 schools in Michigan that aim to develop AC, or improve or align existing curricula with AC by assessing an EE curriculum in terms of how it matches characteristics of AC and the types of pedagogical strategies that promote use of AC. Finally, this study also serves as an example for using alternative theories or frameworks in conducting EE research and provides suggestions and recommendations for future research.

1.6 DISSERTATION ORGANIZATION

My dissertation consists of six chapters, beginning with this introductory chapter that describes the needs and issues within EE that helped frame my research.

In Chapter 2, I review related literature on EE, PCK, and AC. I also discuss theories of research and practice within EE and my theoretical perspective in conducting this study. My discussions on EE research and practice include a comparison of two theories – the environmental citizenship behavior model of Hungerford & Volk (1990) and the AC theory of Jensen & Schnack (1997). I also present one commonly cited PCK framework and describe how I utilize it in my dissertation.

In Chapter 3, I address my research question #1: "To what extent do the science and environmental education curricula and content materials used by science teachers represent elements of action competence?" I also report on the extent to which the Water Quality Unit of the MEECS matches characteristics of AC and the types of pedagogical strategies that promote teachers' focus on AC. I use content analysis to examine the Water Quality Unit.

In Chapter 4, I partly address research question #2: "To what extent does teachers' pedagogical content knowledge in using science and environmental education curricula and content materials represent elements of action competence?" I report on characteristics of MEECS participants, including their demographics and curriculum use. I also examine presence of PCK and AC from participants' responses to self-administered mail and web surveys. Finally, I discuss PCK patterns that are more prevalent and seem associated with certain elements of AC.

In Chapter 5, I also address research question #2 and report on four teachers' PCK and use of AC. I used class observations, semi-structured interviews, Content Representations (CoRes), and a self-administered mail survey to examine PCK and AC. I compare the four teachers in terms of goals and beliefs about teaching science, pedagogical approaches, instructional methods, student skills emphasized in the classroom, and manifestations of PCK, and discuss possible relationships between their PCK and use of AC.

In Chapter 6, I summarize and integrate results from previous chapters and discuss implications for EE research and practice.

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CHAPTER 2

ENVIRONMENTAL EDUCATION, ACTION COMPETENCE AND PEDAGOGICAL CONTENT KNOWLEDGE: REVIEW OF RELATED LITERATURE

In this chapter, I review related literature in Environmental Education, Action Competence, and Pedagogical Content Knowledge. I present the issues and concerns within EE that helped frame my dissertation research and illustrate how my research will build upon existing knowledge. I also detail my theoretical perspective, and describe how it guided the conduct of my research.

2.1 ENVIRONMENTAL EDUCATION (EE)

2.1.1 Historical Background

Much of what has occurred in the field of Environmental Education since 1978 has evolved from two founding documents, the Belgrade Charter and the Tbilisi Declaration (NEEAC, 2005; Palmer, 1998). The Belgrade Charter was produced by the International Environmental Education Programme (IEEP) in 1975, as the first inter-governmental statement on EE, listing its aims, objectives, key concepts, and guiding principles (Palmer, 1998). The objectives for EE stated within the Belgrade Charter are summarized as follows:

1. *to foster clear awareness of and concern about economic, social, political, and ecological inter-dependence in urban and rural areas;*

2. *to provide every person with opportunities to acquire the knowledge, values, attitudes, commitment and skills needed to protect and improve the environment; and*
3. *to create new patterns of behavior of individuals, groups, and society as a whole towards the environment.*

(UNESCO, 1975)

The Tbilisi Declaration in 1977 was built on the Belgrade Charter and called on EE for the improvement of awareness, knowledge, attitudes, skills, and participation for all age groups, both inside and outside the school system, and in local and international settings and contexts (Athman & Monroe, 2001; Palmer, 1998; UNESCO, 1977). Ten years later, the Brundtland Report proposed the reconciliation of development with environment in the global agenda. This proposal was embraced during the Earth Summit in 1992, and the resulting document, Agenda 21, called for a reorientation of EE toward "education for sustainability" to bring about changes toward sustainable lifestyles (UNDESD, 2005a). This transformed EE into a multidisciplinary approach that integrates development education and EE through acknowledgement of social, cultural, economic, and environmental dimensions (Eames *et al.*, 2006; UNDESD, 2005a; UNESCO, 1992).

Since the Belgrade Charter and the Tbilisi Declaration, EE played an increasingly crucial role in finding solutions to environmental and developmental problems. This is seen in the proliferation of EE programs in the last thirty years (Athman & Monroe, 2001; McClaren, 1997; Monroe, 1999; Orr, 1995; Palmer, 1998; Tilbury, 1995; UNDESD, 2005a). Many practitioners believe EE programs help promote people's concern about their environments, change in personal lifestyles and behaviors, participation in finding solutions to environmental problems, and eventual support for the increasing global agenda to reconcile environment with development (Hungerford & Volk, 1990; Tilbury, 1995; UNDESD, 2005b).

More recently, EE is facing a process of continuous conceptual reconstruction as a consequence of the complexity of the social and political changes occurring throughout the world, in turn because of the environmental crises and the different perspectives through which they are understood in different contexts (Payne, 2006). In this conceptual reconstruction, debates about "What works in EE?" and "Does EE matter?" emerged (Jensen, 2002; Jensen & Schnack, 1997; Palmer, 1998).

2.1.2 Review of EE Research

My review of EE research revealed some trends:

- Quantitative studies remain dominant in the field (Hart & Nolan, 1999; Lee & Williams, 2001; Palmer, 1998; Rickinson, 2001). Many of these studies focus on impacts of EE on students.
- There is a considerable increase in the number of qualitative studies, although there remains a need to strengthen constructivist and critical approaches to research (Ballantyne & Packer, 1996).
- There are persistent concerns about the processes, materials, outcomes, and efficacy of EE (Lee & Williams, 2001; Palmer, 1998; Payne, 2006).

- There is a widening range of themes pursued by EE researchers. Emphasis is placed primarily on EE implementation across the curriculum, development of curriculum resources, influence of EE, and student assessments. Teaching about the environment through the science curriculum and effectiveness of teaching styles gained momentum in the research field (Lee & Williams, 2001; Palmer, 1998).
- Global efforts in EE appear to be dominated by teacher education models and development of responsible environmental behavior, in addition to integrating EE across the curriculum and development of curriculum resources (Palmer, 1998).
- Recurring issues and concerns within EE include conflicts between different paradigms of research and practice (rhetoric-reality gaps), developmentally inappropriate curricula, structural issues or barriers, and dynamics of schooling, which make it difficult to integrate EE into the curriculum (Barrett, 2006; Connell, 2006; Fridgen, 2005; Payne, 2006; Stevenson, 2007).
- There has been a call for the use of multiple paradigms to enhance EE research, because some authors believe that different paradigms are complementary and can enhance understanding of EE theory and practice better than any one paradigm can alone (Haggerson, 1986; Marcinkowski, 1993).

Studies conducted in the past thirty years focused predominantly on examining the impact of EE programs on students' knowledge, attitudes, skills, and behaviors (Dimopoulos & Pantis, 2003; Hungerford & Volk, 1990; Leeming, *et al.*, 1997; Roth, 1992). These types of outcomes are characteristically the focus of the environmental citizenship behavior (ECB) model of Hungerford & Volk (1990). This model suggests that "the ultimate goal of education is to shape human behavior" (p. 8). The ECB model has largely shaped EE research and practice since its inception.

In addition to the focus on measuring knowledge, attitudes, skills, and behaviors, EE research has given more attention to *student* outcomes than to studies focusing on teachers or educators and their teaching practices. I see the prevalence of studies looking only at student outcomes as resulting in a huge gap in our understanding. How do we know what student outcomes to measure if we don't know what, how, and why teachers teach EE?

2.1.3 Theoretical Perspectives in EE Research

Reviews of EE research also found three leading paradigms, or what I call theoretical perspectives, in EE research – positivism, interpretivism, and socially critical theory. Although recent analyses of the field of EE research found a rapid increase in the number and diversity of research studies (Hart & Nolan, 1999), and an encouraging attempt to use different theories and perspectives other than the positivist-objectivist paradigm, this perspective is still the dominant approach to EE research (Rickinson, 2001).

Marcinkowski (1990) described the positivist-objectivist perspective in research as reflecting the tradition of scientific *inquiry*. Those who adhere to this perspective seek to describe, predict, and explain, and are generally required to remain detached from the research setting (including the subjects or participants) to maintain objectivity (Marcincowski, 1990 cited in Palmer, 1998). The majority of positivist-objectivist-oriented research studies in the 1970s and 1980s are characterized by a focus on matching outcomes with assumed goals, making generalizations from empirical observations, and on identifying, measuring, or controlling variables that were believed to influence responsible environmental behavior (Robottom & Hart, 1993 cited in Palmer, 1998). In addition, positivist-objectivist oriented studies are predominantly quantitative (Iozzi, 1981; Rickinson, 2001).

Calls for interpretivism (or constructivism, as synonymously used by some researchers) in EE research first emerged in a 1994 report by Robertson who wrote about the dire lack of constructivist-oriented studies at that time (Palmer, 1998). Robertson (1994 cited in Palmer, 1998) argued that constructivist approaches to research are important because these can provide a coherent framework through which to understand learning, subjective experiences of individuals, perspectives of participants, and socially constructed meanings, categories and issues. Several years after Robertson's call, there was an upsurge in support for and interest in interpretivist research and for a more broadly based view of EE (Palmer, 1998). Rickinson (2001) saw a similar increase in support in his literature review on learners and learning in primary and secondary education.

Interpretivists do not believe that research is value free, as is the claim of positivists. Thus, instead of being detached from their subjects or from the phenomena being investigated, researchers are actively and directly involved (Cohen & Manion, 1989). Interpretivists also do not believe that human behavior theories can be abstracted and generalized; rather, they believe that human behavior is situation-specific (Fien & Hillcoat, 1996 cited in Palmer, 1998).

In contrast to positivists, interpretivists attempt for transferability of findings (Palmer, 1998). Constructivist-oriented research studies also tend to be qualitative and include the use of case studies, participant observation, semi-structured interviews, and discourse analysis (Green, 1990). For an example of a constructivist mode of research, see Palmer's study (1993, 1995).

The critical tradition in EE research emerged at about the same time that calls for interpretivism surfaced. Like interpretivism, socially critical theory emerged in response to critiques of the positivist paradigm. Critical researchers agree with interpretivist researchers that their methods provide understanding and meaningful dialogue (Palmer, 1998). Where there is a difference, however, is in the belief regarding how subjective views are constructed. Interpretivists argue that these views are internally constructed (constructivist); critical theorists, on the other hand, argue that they are internally constructed **and** are influenced by social forces; hence they cannot be separated from their social context (Fien &

Hillcoat, 1996 cited in Palmer, 1998). The identifying characteristic of socially critical theory is captured by Robottom & Hart (1993) below:

> *"…becoming critical means exposing one's ideological bases, penetrating one's ideological assumptions through critique…developing an analytic posture towards arguments, procedures, and language using a lens related to issues of power and control in relationships, and developing an action-oriented commitment to common welfare…" (p. 11).*

According to Robottom & Hart (1993 cited in Palmer, 1998), a socially critical perspective to EE is participatory and collaborative in nature, so ideally it should involve students, teachers, and the community in framing and investigating a real environmental issue in their local environment. The participants should seek to uncover and make explicit the values and vested interests of the individuals and groups who adopt positions with respect to the issue. This supports the belief of critical researchers that subjective views are influenced by individual (internal) constructs as well as outside social forces. Key approaches for data collection and analysis that are being used in the critical tradition of EE research are discourse analysis, ethnography, and action research. An example of project using a socially critical approach is the Organization for Economic Cooperation and Development (OECD) Environment and School Initiatives Project (see Elliot, 1991; Posch, 1993).

2.2 MY UNIQUE RESEARCH FOCUS AND THEORETICAL PERSPECTIVE

My dissertation research is an attempt to address various aspects of EE trends described above. First, this dissertation research was conducted in response to the persistent concerns about the processes, materials, outcomes, and efficacy of EE. In particular, I undertook my dissertation research to examine and characterize the interactions found in an EE curriculum and science teachers' focus on action competence (henceforth referred to as AC), and to identify factors that appear to be associated with use of AC in curriculum and instruction.

Second, in response to the lack of focus on studying teachers' teaching practices, my research did not attempt to measure outcomes on students. Rather, my research focused on teachers, and I asked whether they fostered students' capacity to find solutions, to change a situation, or to take action. My research also focused on whether teachers encouraged students' willingness to participate (*commitment*) in finding solutions to environmental problems, and whether they integrated students' ideas about their future (developing *visions*) into the process of finding alternatives and solutions. These questions go beyond easily observable or verifiable variables (Marcinkowski, 1990 cited in Palmer, 1998) such as knowledge, attitudes, skills, or behaviors.

Third, although the integration of EE into science education is not a primary area of *inquiry* in this study, this research enhances our knowledge about how these two fields can be integrated. This area of research is gaining interest especially because science education receives considerably higher curriculum status compared to EE (Littledyke, 2008; Slingsby & Barker, 2003), although relatively less compared to math and language arts. Some researchers believe that because of this higher curriculum status, science education has tremendous opportunity to support EE in various ways, e.g., help students apply science concepts to socially relevant questions (Slingsby & Barker, 2003), equip students with skills that enable them to participate in discussions or debates related to lifestyle sacrifices or political changes (Slingsby & Barker, 2003), develop their sense of relationship with the environment (Littledyke, 2008), develop environmental awareness (Ross *et al.,* 2005), and allow students to participate in community life (Roth & Lee, 2004).

In many parts of the United States, however, EE is not included in the formal K-12 curriculum, and despite the benefits of teaching EE (Athman & Monroe, 2004; Ernst, 2005; Pennock, 1994), incorporating it into the classroom has never been easy for teachers (Kim & Fortner, 2006). Thus, my research will contribute to our knowledge about the structural issues or barriers, dynamics of schooling, and other factors that make it difficult to integrate EE into the science curriculum.

This connection between EE and science education has prompted me to use the PCK framework to examine teachers' use of AC. PCK, a widely accepted framework in science education research and practice, refers to the type of teacher knowledge that enables him/her to find the most useful forms of representation of topics, analogies, examples, illustrations, explanations, and demonstrations to teach a particular content to a particular group of students in a particular context (Shulman, 1986). PCK's focus on how teachers teach a particular content and why fits perfectly with the purpose of my study to examine teachers' use of AC.

Fourth, and more importantly, I would argue that we should go beyond measuring changes in knowledge, attitudes, skills, and behaviors when answering "What works in EE?" or "Does EE matter?" This is not to say that these types of outcomes do not count; they do (Dimopoulos & Pantis, 2003; Hockett, McClafferty, & McMullin, 2004; Hsu, 2004; Orams, 1997). I would argue that more important than change in behaviors is building capacity for taking action or the capacity to change a complex situation, and I suggest EE research and practice ought to look in this direction. One perspective that examines this (other) direction is the theory of action competence (AC). In this theory, the ultimate goal of EE is to develop students' capacity to take action or to change a situation (Jensen, 2000a, 2000b; Jensen & Schnack, 1997).

The need to focus on developing students' capacity to take action is accompanied by a need to identify the styles and content of teaching that help to develop this capacity. This need was expressed by two of the leading proponents of the action competence theory – Jensen and Schnack (1997). To date, I found only one previous study that investigated the kinds of pedagogical approaches that promote AC (Eames *et al.*, 2006).

While the three major research theoretical perspectives I have described above have clearly shaped the way EE research has been conducted in the past four decades, I agree with Scott & Oulton (1999) that adopting only one perspective would limit our views and understanding of environmentally-related situations, thereby isolating and reducing EE instead of broadening its theory, research, and practice. If I embrace only the positivist perspective, I will prevent myself from obtaining a profound and holistic understanding of the nature of environmental problems (Jensen, 2002; Jensen & Schnack, 1997; Wals & Bawden, 2000). In this case, this perspective would be limiting my understanding of how teachers teach EE and their use of AC in the classroom.

If I embrace only the subjective interpretivist paradigm, I will overlook the importance of technical and applied knowledge that could contribute to my understanding of EE teaching, and use of this perspective can add richness to my work. Thus, an interpretivist view alone is not complete either.

Furthermore, if the socially critical theory is to be accepted as the sole representation of EE, then there is a tendency to perceive EE as a tool to attack society, the government, and ourselves. This is because socially critical theory is grounded on critique of any forms of oppression and power structures (Robottom & Hart, 1993). Although this perspective may be useful in understanding many contexts related to EE, it may not be appropriate for other contexts, and it may be unacceptable to members of society who view the role of education as providing only fundamental knowledge and skills.

Thus, in this research, I assume a critical pluralist perspective. This is in response to suggestions made by some researchers on the need to be open to multiple perspectives (Scott & Oulton, 1999). I also agree with other authors that, because of the highly complex nature of the content that EE needs to address and the different ideologies in which EE is embedded (Palmer, 1998), as well as the multiple ways that EE is theorized and practiced, adopting only one research theoretical perspective will be limiting and unjustified. This is certainly true for my investigation of teachers' use of AC in the classroom.

As a critical pluralist, I value the reliability and generalizability of findings that a positivist theoretical perspective can generate, but I also appreciate the beauty of a subjective approach (e.g., interpretivist or socially critical) because it adds richness to my work. This perspective fit my research because the goal of my research was not primarily to predict and generalize my results, but to examine and characterize use of AC in an EE curriculum and how teachers teach EE and use AC in the classroom. Adopting a critical pluralist perspective allowed me, the researcher, to adopt different but complementary perspectives (Scott & Oulton, 1999).

2.3 THEORETICAL FRAMEWORK

I will now describe the theories that frame my research. First, I will discuss the theory of AC and compare it with another theory – the environmental citizenship behavior model. I believe these two theories are fundamentally different and therefore worthy of comparison and further discussion. Second, I will discuss PCK and illustrate how it is used in my research.

2.3.1 Theories of Environmental Education

2.3.1.1 Environmental Citizenship Behavior (ECB)

Many environmental educators believe that behavior change results from making people more knowledgeable about the environment and its associated issues and that the "ultimate aim of education is shaping human behavior" (Hungerford & Volk, 1990, p. 8). The earliest assumption was that increased knowledge and awareness about environmental problems will result in responsible environmental behaviors[1] (REBs) (Hungerford & Volk, 1990), implying a linear relationship between variables. It was also believed that influencing learners' attitudes toward the environment will develop REBs. Research has found, however, that there are no strong direct causal relationships between knowledge and REBs, or attitudes and REBs (Gardner & Stern, 1996; Orr, 1992; Stern, 2000; Volk *et al.*, 1984). Instead, the relationships among these variables are complex (McKenzie-Mohr *et al.,* 1995; Stern, 2000).

From the earlier models of behavior modification, Hungerford & Volk's (1990) Environmental Citizenship Behavior[2] model evolved (see Figure 2.1), henceforth referred to as ECB. In their model, Hungerford & Volk (1990), through meta-analyses, demonstrated that entry level variables, ownership variables, and empowerment variables contribute to behavior and that these variable categories "act in more or less of a linear fashion, albeit a complex one" (Hungerford and Volk, 1990, p. 10). They also noted that "while the categories of variables probably operate in a linear fashion, the variables within each category do not necessarily operate in a similar manner" (p. 11), and that the variables probably function synergistically. Subsequent research has further developed our

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[1] Earlier researchers (e.g., Hines *et al.,* 1986/87) referred to the "desired" behavior as "responsible environmental behavior."
[2] Hungerford & Volk (1990) called their model Environmental Citizenship Behavior but used "responsible citizenship behavior" when referring to behavior throughout their paper.

understanding of the relationship between these variables and behavior. Table 2.1 provides short descriptions for each variable.

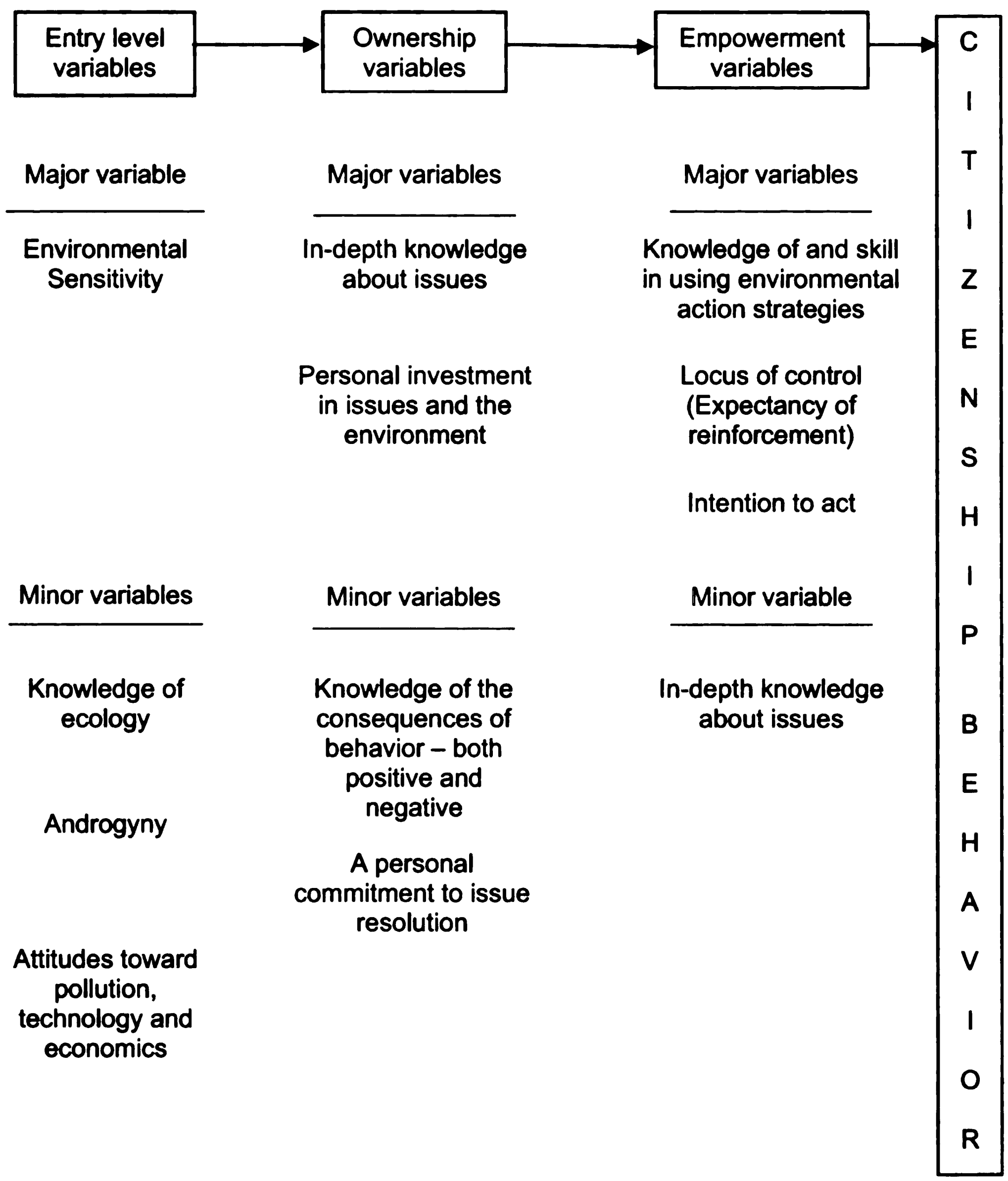

Figure 2.1. Environmental Citizenship Behavior Model
(Hungerford & Volk, 1990, p. 11)

Table 2.1. Environmental Citizenship Behavior Model: Entry Level, Ownership Level, and Empowerment Variables (Hungerford & Volk, 1990, pp. 11-13)

Entry-level variables: good predictors of behavior, or appear to be related to responsible citizenship behavior

Environmental sensitivity – defined as an empathetic perspective toward the environment; has shown dramatic relationship to behavior

Androgyny [in a psychological sense] – refers to human beings who tend to reflect non-traditional sex-role characteristics (example: an androgynous male may be a very sympathetic individual and able to cry in a sad situation – a traditional female characteristic); not as strong a predictor for behavior as environmental sensitivity

Knowledge of ecology – refers to an ecological conceptual basis for *decision making*, e.g., concepts associated with population dynamics, nutrient cycling, succession, homeostasis, etc; does not in itself produce environmental behavior but is considered almost always a prerequisite for *decision making*

Attitudes toward pollution, technology, and economics – they did not provide definition for attitudes, but noted that some research found that these attitudes appeared to be related to behavior although the extent of their involvement is still unknown

Ownership variables: those that make environmental issues very personal, as in the individual "owns" the issue, i.e., the issues are extremely important at a personal level to him/her

In-depth knowledge (understanding) of issues – understanding the nature of the issue and its ecological and human implications, appears crucial before individuals can engage in responsible citizenship behavior

Personal investment (in an issue or an action) – much like "ownership" itself in that the individual identifies strongly with the issue because he/she has a proprietary interest in it; hypothesized as a major factor in ownership

Empowerment variables: give human beings a sense that they can make changes and help resolve important environmental issues

Perceived skill in using environmental strategies – human beings believing that they have the "power" to use citizenship strategies to help resolve issues; probably dependent on the knowledge of environmental action strategies variable to a great extent

Knowledge of environmental action strategies – was not defined but was considered an important part of the perceived skills in using environmental strategies

Internal locus of control –an individual's belief in being reinforced or will experience success for a certain behavior

Intention to act – intention of a person to take some sort of action increases the chances of that action occurring

The focus of the ECB model on knowledge, attitudes, skills, and behaviors stems from the positivist's assumption that environmental problems are external to individuals and are a consequence of individual lifestyle choices (Mogensen, 2000; Palmer, 1998). This implies that solutions to environmental problems can be attained by changing individual behaviors. It is also clear that this model upheld a behaviorist learning theory, because it deemed that shaping behavior is the ultimate aim of education.

Mogensen (1997) claimed that ECB model's assumption about the existence of environmental problems or issues[3] has influenced EE's focus of teaching on gathering information, developing knowledge, and increasing awareness about environmental problems. He further contends that learners need to be taught about behaviors or actions that can improve the state of the environment. Critics say that the ECB model, therefore, is moralistic and engenders an expert-driven teaching and learning model, i.e., the teacher is the expert who first judges and then delivers information to the students; students are passive recipients of knowledge or "repositories" who collect and use the information (Greenall Gough & Robottom, 1993; Jensen, 2000a; Robottom & Hart, 1993; Tilbury, 1994). Freire calls this the "banking" model of education (Freire, 2000).

[3] Hungerford & Volk (1990) distinguished between "problems" and "issues." They believed ""problems" exist when something is at risk, for example, an animal being endangered. An environmental "issue" exists when human beings have differing beliefs and values concerning what should be done about the problem; for example, people may differ in their beliefs about what should be done to manage the endangered animal" (p. 17).

2.3.1.2 Action Competence (AC)

AC theory is the most notable alternative perspective to the ECB model found in the literature. AC played a central role in the pedagogical discussion of EE in Denmark in the 1990s and consequently shifted the overall objective of EE in this country (Breiting & Mogensen, 1999). Outside of the United States, AC has been adopted in New Zealand, Australia, the United Kingdom, Canada, and Scotland (Barrett, 2006; Eames *et al.*, 2006; Fien & Skoien, 2002; Laing, 1998; Palmer, 1998). Early proponents advanced the concept of AC as a response to the increasing preponderance of behavior modification models in EE, one of which is the ECB model. AC researchers are critical of focusing on changing behaviors in our attempts to solve environmental problems. For them, focusing on individuals alone does not and will not solve environmental problems (Bishop & Scott, 1998).

Action competence is referred to as a person's ability to act on an environmental problem or issue, and or his/her ability to influence or change his/her living conditions (Jensen, 2000a, 2000b; Jensen & Schnack, 1997). The focus, therefore, is developing capacity for action. AC is grounded in socially critical theory and suggests that environmental problems or issues are a result of *both* lifestyle choices and living conditions (social forces). Thus, for proponents of AC, the purpose of education is to question and understand how individuals' choices *and* social structures contribute to environmental problems or issues to attain solutions (Jensen, 2002; Jensen & Schnack, 1997; Mogensen, 1997). Finding solutions requires a reconstructivist learning framework, which views education as an avenue for or agent of change and social reform by emphasizing creativeness, nonconformity, self-actualization, and providing learners with "direct experience in democratic living and political or social action which prepares students for freedom" (Ornstein, 1991, p. 7).

Critics of the AC theory, however, regard this focus on social contexts as too ambitious and believe it is daunting to place the responsibility on schools and students to change society (Bishop & Scott, 1998). Opponents of AC argue that, often, there is a mismatch between the problem at hand and the educational intervention, i.e., "the environmental problem chosen was insoluble by students' action, in some cases, insoluble simply because the problem was too large" (Walker, 1997 cited by Bishop & Scott, 1998, p. 227). Proponents of AC counter the argument by saying that AC does not place the responsibility of social change on students. Instead, what AC emphasizes are students' *critical thinking skills* (Mogensen, 1997).

Jensen & Schnack (1997) differentiated between action, behavior, and activity. They stressed that, in order for something to be considered an 'action,' it has to be performed consciously and purposively. In other words, actions are intentional, considered, and must be targeted to a solution of a problem (Jensen, 2002; Jensen & Schnack, 1997). This implies that AC equips an individual with an ability to act in whatever way he or she chooses; it is democratic, not prescriptive (Bishop & Scott, 1998; Jensen & Schnack, 1997). In contrast, Jensen & Schnack (1997) argue that *behavior* may be manifested with or without an intention or personal worth to the person exhibiting it. For example, students may display a certain behavior because the teacher asked them to do so. Thus, the observed behavior is not a result of personal choice; it is predetermined or prescribed (Jensen & Schnack, 1997). Schnack (1994) also suggests that a behavior may be just a habit, i.e., something performed or acquired by an individual without thinking about it.

'Action' is also differentiated from 'activity.' An 'action' is focused on the resolution of a problem that an individual regards as important (Jensen, 1994). Action is also targeted to addressing the causes, not the effects or symptoms of a problem (Bishop & Scott, 1998). In contrast, an 'activity' is being actively engaged in a limited task; activity is 'doing something' (Jensen, 1994). Jensen & Schnack (1997) further contend that an activity is not part of something bigger or a more substantial goal (e.g., to resolve an environmental problem). Furthermore, Jensen & Schnack (1997) assert that only actions that are directed toward solving an environmental problem can be characterized as environmental actions. Table 2.2 summarizes the "action" component of AC according to Jensen & Schnack (1997).

Table 2.2. Summary of Jensen & Schnack's (1997) Conception of Environmental Action

An action...
• is conscious/intentional: it involves making up of one's mind before it is conducted
• has to be purposive/targeted
• is more than activity (i.e., something being done)
• must be focused on the resolution of a problem which the actor sees as important
• has to be addressed to causes rather than effects or symptoms

Adapted from Jensen (2000a) and Bishop & Scott (1998, p. 229)

Researchers who have used the AC theory in EE and health education suggest the following elements that comprise AC: *knowledge/insight*, *visions*, *commitment*, *action experiences, critical thinking and reflection, trust in one's power to act, social skills, investigative skills, communication skills, participation,* and *emotional response* (Bishop & Scott, 1998; Breiting & Mogensen, 1999; Eames *et al.,* 2006; Fien & Skoien, 2002; Jensen, 2000a, 2002; Jensen & Schnack, 1997,1994; Laing, 1998; Otero & Mira, 2003). As might be expected, the relationships among these components are largely unknown, although there seems to be a consensus that *knowledge/insight* and *critical thinking and reflection* are central to AC (Breiting & Mogensen, 1999; Jensen, 2000a; Jensen & Schnack, 1997; Mogensen, 1997; Uzzell, 1994). Consequently, it cannot be assumed that a linear relationship exists among the variables (Uzzell, 1994). My study is in part a response to the call for further research into how these elements are constructed and interconnected (Jensen & Schnack, 1997).

Furthermore, much of what is found in the literature consists of the operationalization of AC, and structural and theoretical arguments. There are two exceptions. One is the Roxbury Environmental Empowerment Project in Boston's Roxbury District in the United States, which uses an AC framework to build capacity and power of communities to attain environmental justice (see Agyeman, 2006). The other is the AR & CPS (Action Research – Community Problem Solving) model of EE used in the Piston Middle School Project in Detroit, Michigan (United States), which followed AC-oriented steps to help middle school students identify an issue in their school community and take action to alleviate it (Wals, 1994).

Only a few attempts have been made to measure AC empirically; studies have included investigations on selected aspects of this concept (e.g., trust in their own act, knowledge of conflicting interests, action possibilities, types of action experiences) (Breiting & Mogensen, 1999); documentation of emergence of AC in community groups (Fien & Skoien, 2002); examination of the types of methods to engage students in learning about health (Simovska, 2007); and investigation of teachers' pedagogical approaches in EE that promote students' AC (Eames *et al.,* 2006). Below are descriptions of the AC elements that I examined in my study. These elements are limited to those suggested as central to the development of AC, or those that have been used by other researchers in the past.

1) *Knowledge/Insight*

Proponents of AC strongly suggest that four types of knowledge must be present in any EE curricula to develop AC (see below). These types of knowledge are characterized as integrative and are crucial to giving students a holistic perspective of a particular environmental issue or problem in which they are interested (Jensen, 2000a, 2000b; Uzzell, 1994).

> *a) Knowledge of Effects: What kind of a problem is it? This knowledge is about the existence and spread of environmental problems. This form of knowledge is mainly scientific in nature and does not give any explanation why a problem exists or how people can contribute to solving them.*
>
> *b) Knowledge of Causes: Why do we have the problems that we have? These root causes include associated social factors behind environmental*

problems. This knowledge belongs mainly to the sociological, cultural, and economic areas.

c) Knowledge about Change Strategies: How do we change things? This knowledge deals with both knowledge about how to control one's own life and how to contribute to changing living conditions in society. Who do we turn to, and with whom could we ally ourselves? This type of knowledge also includes knowing how to encourage cooperation and how to analyze power relations. It is often to be found within psychological, political, and sociological studies and is central to an action-oriented education.

d) Knowledge about Alternatives and Visions: Where do we want to go? This knowledge deals with the necessity of developing one's own visions – one's dreams and ideas for the future in relation to one's own life, work, family, and society. One way to help develop visions is to know about how people go about things in other cultures and other places.

2) *Visions*

Jensen & Schnack (1997) argue that developing students' *visions* is important because it allows students to think about the kinds of lifestyles or environment they want, what they think will happen in their future and the effects of environmental problems at hand on their future. Developing *visions* also lets students ponder what alternative ways of development are available; thus, it is closely tied with the 'alternatives and *visions*' component of knowledge. Jensen (2000a) maintains that students should be given opportunities to build their *visions* as they dialogue with other students. Having a *vision* facilitates taking actions, because students will then have a target, a purpose for the skills and knowledge that they need to seek.

3) *Commitment*

Commitment ensures that any efforts that students make (e.g., development of skills, knowledge, and action) are directed toward achieving their *visions* (Jensen & Schnack, 1997). To foster *commitment*, students should be encouraged to identify their own position regarding an environmental issue or problem (Mogensen, 1997; Wals & Bawden, 2000), and should be given opportunities to work in groups because *commitment* is often developed within a social context (Jensen, 2000a, p. 149).

Students also should be encouraged to think about their feelings regarding the issue or problem at hand. This will go hand in hand with examining their positions. Some researchers suggest that motivations go hand in hand with *commitment*, such that students should be encouraged to reflect on their motivations, i.e., the things that underpin their desire to learn the skills and knowledge needed to help solve environmental problems or issues (Fien & Skoien, 2002). Students' *commitment* is also believed to influence their intention or wish to act (Jensen & Schnack, 1997).

4) *Planning and Action Experiences*

Students need real life experiences for acting individually and collectively (Jensen, 2000a). Jensen & Schnack (1997) only referred to this element as "action experiences," but I added "planning" and refer to it as "*planning and action experiences*" because I believe planning experiences are an important piece before taking action. As Mogensen (2000) pointed out, the role of the teacher in creating opportunities that allow students to take part in problem identification, planning, investigation, presentations of findings, and *decision making* is paramount. This will teach students the value of co-influence (how their thoughts, decisions, or actions affect other students) and co-responsibility (assuming group responsibility to participating in the action to (re)solve a problem or an issue), as well as how to identify difficulties or barriers to change, action possibilities, or priorities for action. More importantly, students will be given the opportunity to decide on what actions to take (Jensen, 1994, 2000a).

5) *Critical Thinking and Reflection*

Proponents of AC called this element "*critical thinking skills*," and because they highlighted the importance of reflection in thinking critically, I refer to this element as "*critical thinking and reflection*." Critical thinking skills are referred to as the students' ability to recognize different points of view, work with conflicts of interest through self-reflection, question values, perceptions, and opinions, challenge current practices, and examine and analyze a problem or an issue both at the structural level of society and the scientific and personal level and the connections between them (Mogensen, 1997; Wals, 1994). Furthermore, Mogensen (2000) and Wals (1994) suggest that *critical thinking and reflection* generates knowledge that presents concrete possibilities for empowering students to transform an intention to act into actual action.

2.3.1.3 Comparing Environmental Citizenship Behavior (ECB) and Action Competence (AC)

It is difficult to compare and contrast ECB with AC because of differences in the names of variables, and some of the variables in ECB were not defined. For example, in ECB, *in-depth knowledge of issues* included understanding of "the nature of the issue and its ecological and human implications" (Hungerford &

Volk, 1990, p. 12). This may embody both *knowledge of effects* and *knowledge of causes (AC)*. Hungerford & Volk (1990) did not elaborate on the knowledge of consequences of behavior (both positive and negative) variable, but this could be represented in AC's *knowledge of effects*. Hungerford & Volk (1990) combined *knowledge of environmental action strategies* with *perceived skill in using environmental action strategies*, which they referred to as people believing they have the "power" to use citizenship strategies to help resolve issues" (p. 12). Action or citizenship strategies may be similar to AC's *knowledge of change strategies*. ECB's *knowledge of ecology* is included in AC's *knowledge of effects*, through which a scientific emphasis of a problem or issue is emphasized. *Knowledge about alternatives and visions* is not found in the ECB model.

The *critical thinking and reflection* variable is central to the development of AC. In ECB, *critical thinking* is not articulated explicitly, but it may be embodied in the *in-depth knowledge about issues* (major ownership variable) or in the *knowledge of and skill in using environmental action strategies* (major empowerment variable). In addition, reflection is absent in ECB. Development of *visions* in AC is also absent in the ECB model. *Commitment* is present in both, although it is a minor variable in ECB. Both theories consider that participation in resolving issues or problems is important, although the nature of participation is probably different.

Hungerford & Volk (1990) did not make a distinction between action, behavior, and activity. They used behavior and action synonymously (e.g., citizenship action and citizenship behavior) as clarified later by Hungerford that he referred to "behavior as a series of actions" or as "a pattern of actions" (Simmons & Volk, 2002, p. 8).

In summary, although there are some similarities between ECB and AC, their differences are substantial and fundamental. Key differences include the following:

1) absence of *visions* in ECB;
2) ECB's lack of recognition of other factors that may influence behavior, for example social structures, cultures, and beliefs and personal experiences (Hockett *et al.,* 2004);
3) ECB does not take into account demographic, social contextual, and external and internal factors that are also strong influences on pro-environmental behaviors[4] (Kollmuss & Agyeman, 2002); and
4) ECB's focus on behavior change versus AC's focus on capacity to take action or change a situation. This is a result of both theories' difference in assumptions about the reality of environmental issues. ECB assumes that environmental problems or issues are primarily a result of individual lifestyle choices, whereas AC assumes that environmental problems are a result of both individual lifestyle choices and social structures.

This last difference between the two theories is crucial because assumptions about the nature of environmental problems have significant

[4] Hungerford later acknowledged that he would include more 'cultural' values into the structure now that we know ecological considerations are not the only ones that need to be addressed (Simmons & Volk, 2002).

implications on curriculum theorizing, learning theories, and roles of teachers and students. For example, the primary purpose of ECB is to increase knowledge and awareness and to develop skills (vocational/technical) necessary to enact responsible citizenship behavior. As this theory's critics say, the end goal is still behavior change. Critics also believe that, in the ECB model, students are prescribed with predetermined behaviors[5] (behaviorist); hence, the teacher is more of an expert or authority (Jensen & Schnack, 1997). The purpose of AC, on the other hand, is ideological critique through *critical thinking and reflection* (socially critical) and empowerment of individuals to change their situation (emancipatory). Additionally, students decide for themselves what they want to do and how they want to respond to an environmental issue or problem (reconstructivist/emancipatory). I summarize the differences between ECB and AC in Table 2.3.

Table 2.3. Comparing ECB and AC

	ECB	AC
Theoretical perspective	Positivist	Socially critical
Goal of EE	Shape environmental citizenship behavior	Develop action competence
Learning theory	Behaviorist	Reconstructivist
Action focus	Direct actions, individual, collective	Direct and indirect actions, individual and collective, action capacity
Dominant curriculum concern	Course or subject content	Critical pedagogy or action-orientation
Role of the teacher	Expert and authority	Collaborative participant

[5] Hungerford responded to his critics regarding the ECB model's focus on behavior by clarifying that there is a difference between behavior and behaviorist tactics (Simmons & Volk, 2002). The latter, he said, are strategies that "evoke manipulative instructional ploys designed to bring about specific targeted behaviors" (p. 8). He strongly disagreed that the ECB model uses or refers to behaviorist tactics.

Table 2.3 Continued:

Assumption	Environmental problems or issues are a result of lifestyle choices	Environmental problems or issues are a result of both lifestyle choices and social conditions
Target solutions	Primarily at the individual level	Individual and societal/collective
Major elements	Entry level: environmental sensitivity Ownership: in-depth knowledge about issues, personal investment in issues and the environment Empowerment: knowledge of and skill in using environmental action strategies, internal locus of control, intention to act	Knowledge, *visions, commitment, planning and action experiences, critical thinking and reflection*

(Extracted from Breiting & Mogensen, 1999; Eames *et al.*, 2006; Fien & Skoien, 2002; Hungerford & Volk, 1990; Jensen, 2000a, 2000b; Jensen & Schnack, 1997, 1994; Lee & Williams, 2001)

2.3.2 Pedagogical Content Knowledge (PCK)

Lee Shulman (1986) first coined the term pedagogical content knowledge and identified it as a specific form of knowledge for teaching – different from other domains of content knowledge such as subject matter knowledge, pedagogical knowledge, or curricular knowledge. Shulman defined PCK as the *transformation* of subject matter knowledge per se into subject matter knowledge *for teaching*. He still spoke of PCK as content knowledge, but of particularly the form that "embodies the aspects of content that is most germane to its teachability" (p. 9).

PCK is widely embraced in the research community, especially in science education, both for the improvement of science teaching and learning as well as teacher education (Bransford *et al.,* 2000; Cochran, 1997; Lee, *et al.,* 2007; Magnusson *et al.,* 1999). In the field of science, PCK has been used most often in research and publications to refer to the knowledge that teachers must have to teach science (Magnusson *et al.,* 1994; NRC, 1996). Despite this vast support, however, there are few science topic-specific examples in the literature to illuminate PCK (Loughran *et al.,* 2004).

Many researchers have attempted to redefine, reconceptualize, expand, or elaborate on PCK. Researchers, however, differ in their conceptualizations. Many believe that PCK is that knowledge that resulted from the *transformation* of subject matter[6] knowledge, pedagogical knowledge, and context knowledge (Magnusson *et al.,* 1999; Shulman, 1986). Others prefer to use the term "*integrated*" or "*integration*", that is, PCK is the integration of the individual knowledge domains, including knowledge of student learning, curricular knowledge, goals, and orientations (Cochran, 1997; Fernandez-Balvoa & Stiehl, 1995; Gess-Newsome, 1999; Loughran *et al.,* 2001; Loughran *et al.,* 2004; Marks, 1990). Still others suggest that individual teacher knowledge domains *contribute* to the development of PCK (Morine-Dershimer & Kent, 1999).

Whether it is the integration, transformation, or contribution of individual teacher knowledge domains, many researchers seem to be in agreement that

[6] Shulman (1987) and others refer to "subject matter knowledge" as content knowledge (per se). To avoid confusion, I am using subject matter knowledge as knowledge of a particular subject/topic, and I am using the term "content knowledge" to refer to the overarching "teacher knowledge," of which subject matter knowledge is one type.

PCK is a unique domain of content knowledge, and that it is highly concept-specific, that is, it varies from topic to topic or discipline to discipline (Bransford *et al.*, 2000; Cochran, 1997; Van Dijk & Kattmann, 2007; Van Driel *et al.*, 1998).

Researchers also differ in their characterizations of the relationships between various domains (and sub-domains) of teacher knowledge, and in the elements that comprise PCK. For example, readers will notice that some of the elements that are believed to contribute to the development of or that are transformed into PCK are, in fact, the same names as the domains of teacher knowledge itself. To illustrate, subject matter knowledge is considered by many authors as one of the domains of teacher knowledge. But others also suggest that subject matter knowledge is an element of PCK. The same is true for context knowledge, curriculum knowledge, knowledge of instructional strategies (part of pedagogical knowledge), and a few others. This means that the elements that comprise PCK depend on how PCK is viewed or conceptualized.

It is important to remember, however, that, although the *names* of the domains of content knowledge (teacher knowledge) and the elements of PCK are the same, their focus is different. One can think of this in two parts. First, there is content knowledge, or what other researchers call "teacher knowledge," and PCK is one type of teachers' content knowledge. Subject matter knowledge and pedagogical knowledge are other types of content knowledge. Within PCK, one will also find subject matter knowledge, pedagogical knowledge, and context knowledge, but these *elements* are *specific to a particular topic* because, as mentioned earlier, PCK is concept- or topic-specific. In other words, only the subject matter knowledge, pedagogical knowledge, and context knowledge that are relevant to a particular topic is included in PCK.

In addition, there are also differences in how the PCK elements are described or defined (Van Driel *et al.,* 1998). I tend to view PCK from an integrative perspective, and the elements below are drawn from research with this view of PCK. It is believed that the different elements contribute to teachers' PCK in varying degrees based upon their expertise; that is, all teachers have many, if not all, of the suggested elements, but the emphasis of each component varies as a teacher makes instructional decisions (Lee *et al.*, 2007).

PCK elements suggested in the literature include:

1) Knowledge of science/subject matter knowledge – includes knowledge of the nature of science, scientific processes, and relationships among various areas in science or making connections among scientific concepts, units, and even other subjects[7] (Lee *et al.*, 2007); includes knowledge of how concepts and principles of science are organized as well as the ways in which accepted truths are validated or legitimated (Shulman, 1986).
2) Orientations toward teaching science – knowledge and beliefs about the purposes and goals for teaching science at a particular grade level (Magnusson *et al.*, 1999, p. 97); overall conceptions of teaching a particular subject (Grossman, 1990), or a general way of viewing or conceptualizing science teaching (Magnusson *et al.*, 1999); serve as a

[7] Lee *et al.*, 2007 placed the "making connections among scientific concepts, and units, and even other subjects" in "Knowledge of science curriculum organization."

conceptual map that guides instructional decisions (Borko & Putnam, 1996 cited in Magnusson *et al.*, 1999, p.97). Magnusson *et al.* (1999, pp. 100-101) characterized teaching orientations based on two elements – goals and nature of instruction. Schwarz & Gwekwerere (2007, pp. 181-184) did not distinguish between orientations and pedagogical approaches.

3) Knowledge of student learning or understanding of science – this includes knowledge about preconceptions or conceptions that students bring (Shulman, 1986); knowledge of abilities, skills, and prerequisite knowledge that students need to learn specific concepts; knowledge about students' learning styles or preferences related to learning a concept or topic; and knowledge of areas or concepts that students find difficult to learn (Lee *et al.*, 2007; Magnusson *et al.*, 1999).
4) Knowledge of assessment – knowledge of aspects of student learning that are important to assess within a particular unit of study (WHAT to assess) and knowledge of methods that might be used to assess specific aspects of learning (HOW to assess) (Magnusson *et al.*, 1999).
5) Knowledge of instructional representations or strategies – knowledge of subject-specific or topic-specific strategies (Magnusson *et al.*, 1999); knowledge of the most useful forms of representation of topics, analogies, examples, illustrations, explanations, and demonstrations (Shulman, 1986).

6) Context knowledge – knowledge of specific or general educational contexts (community, school, district, students) (Grossman, 1990; Magnusson *et al.,* 1999; Morine-Dershimer & Kent, 1999); teachers' understanding of the social, political, cultural and physical environments in which students' learning is embedded (Cochran, 1997; Grossman, 1990).
7) Classroom reality/management – ways of organizing a class and resources so that teaching and learning can proceed in an efficient and safe manner (Carlsen, 1999).
8) Knowledge of science curriculum – knowledge about mandated goals and objectives for students in the subjects taught, including what students have learned in previous years and what they are expected to learn in the coming years as well as knowledge of specific curriculum programs and materials relevant to a particular science topic[8] (Lee *et al*., 2007; Magnusson *et al*., 1999; Shulman, 1986).

2.3.2.1 Issues with PCK

There are three main issues related to the problem of PCK conceptualization. First, there is no universally accepted conceptualization of PCK (Hashweh, 2005; Van Driel *et al.,* 1998). Researchers suggest different *definitions* and structures of PCK, what it looks like, or what comprises it (Fernandez-Balvoa & Stiehl, 1995; Gess-Newsome, 1999; Lee *et al.,* 2007;

[8] Lee *et al.,* 2007 placed "knowledge of resources and materials" under "Knowledge of Resources."

Loughran *et al.,* 2001; Loughran *et al.,* 2004; Magnusson *et al.,* 1999; Marks, 1990; Morine-Dershimer & Kent, 1999; Shulman, 1986; Van Dijk & Kattmann, 2007; Van Driel *et al.,* 1998).

Figure 2.2 shows Magnusson *et al.*'s (1999) transformation conceptualization of PCK specific for science teaching. Note that this model does not show all the elements that I listed earlier as suggested by other researchers as comprising PCK. In particular, it is interesting that subject matter knowledge is not represented in this model for science teaching when it is supposed to be a prerequisite for the development of and transformation of other knowledge domains into PCK (Van Driel *et al.*, 1998). Magnusson *et al.* (1999) considers subject matter knowledge as one of the domains of teacher knowledge and that PCK is a result of transformation of subject matter knowledge, pedagogical knowledge and context knowledge, but that, in turn, these individual domains are also influenced by PCK.

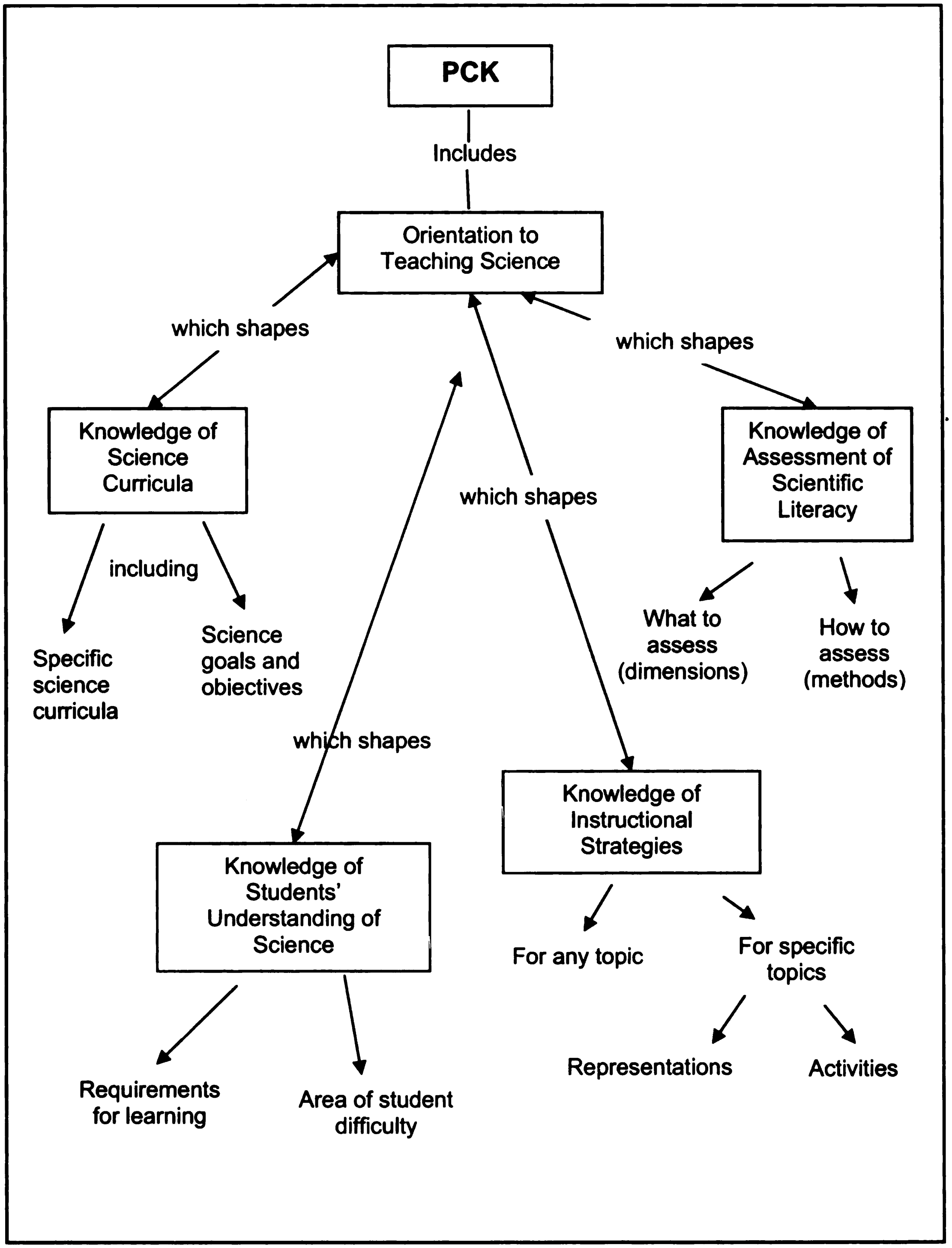

Figure 2.2. Components of Pedagogical Content Knowledge for Science Teaching Adapted from Magnusson *et al.* (1999)

A second issue is the lack of clarity on how PCK develops, although there seems to be an agreement that PCK is developed through an integrative process rooted in classroom and professional development experiences (Baxter & Lederman, 1999; Bransford *et al.,* 2000; Gess-Newsome, 1999; Grossman, 1990; Lee *et al.,* 2007; Magnusson *et al.,* 1999; Van Driel & De Jong, 2001). A third issue is the difficulty in studying PCK because its boundaries are blurry (Loughran *et al.,* 2000), and what exactly comprises it is not always clear and consistent (Lee *et al.*, 2007; Van Dijk & Kattman, 2007).

Much of the research that has been done in education explored individual facets of PCK rather than the whole of a teacher's PCK about a particular topic. Examples of research studies conducted include exploring what teachers know and do not know about some aspect of teaching a particular topic; comparisons of teacher knowledge between different teachers (Magnusson & Krajcik, 1993) and between novice and experienced teachers (Clermont *et al.,* 1994); evaluation of some type of interventions (e.g., workshops, pre-service course) (Smith & Neal, 1989; Van Driel *et al.,* 1998; Veal *et al.,* 1999); and relationship between teachers' subject matter knowledge and PCK about a particular topic (Ebert, 1993; Geddis *et al.,* 1993; Parker & Heywood, 2000 cited in Loughran *et al.*, 2004).

Attempts to study PCK have used methods such as convergent and inferential techniques[9], concept mapping and card sorting[10], and mixed methods

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[9] Likert-type self-report scales, multiple choices, short answers (Baxter & Lederman, 1999)
[10] A teacher is provided with a set of cards; each card has a particular concept, idea, or principle. The teacher is then asked to arrange the cards based on what best illustrates the relationship among the items on the cards (Baxter & Lederman, 1999).

(Haciomeroglu, 2006; Monet, 2006; Van Driel & De Jong, 2001). Mixed methods seem to be most commonly used by researchers because of the inherently complex nature of the PCK construct (Van Driel & De Jong, 2001). Examples of methods used are pre- and post-tests, journals, classroom observations, semi-structured interviews, questionnaires, lesson plan analyses, video-recorded teaching, artifacts, case studies, and cognitive tasks (Dawkins *et al.*, 2003; Haciomeroglu, 2006; Loughran *et al.,* 2001; Mitchell & Mitchell, 1997; Monet, 2006; Shannon, 2006; Shulman, 1992; Woodrow, 2007). Recently, Loughran *et al.* (2001) developed CoRe (Content Representations) and PaPeR (Pedagogical and Professional Experience Repertoire) in an attempt to both study and represent PCK.

Additionally, the number of teachers observed or classrooms studied, duration of observations or study as a whole, and methods of analysis or models or theories used varied greatly. For example, Haciomeroglu (2006) worked with two high school math teachers compared to twenty-four beginning secondary science teachers used by Lee *et al.* (2007). One study lasted for six weeks (Haciomeroglu, 2006) and another lasted for two years (Dawkins *et al.*, 2003). In terms of the analysis, content analysis of curricula, interviews, and observations seem widely adopted (Lee *et al.*, 2007; Woodrow, 2007).

2.3.2.2 My Unique Focus and Contribution to PCK

In my study, I did not measure the teachers' individual knowledge domains per se (e.g., "What or how much do teachers know about an approach, method, or skills?"). Rather, I identified (1) the elements of PCK (goals and beliefs about teaching science, pedagogical approaches, instructional methods and student skills) and (2) manifestations of PCK (see Table D.3) that were used and/or cited to characterize the teachers' overall PCK.

I used the elements of PCK identified in the literature as a guide in examining elements of PCK **and** manifestations of PCK of my teachers (see Table 2.4). I did not examine teachers' knowledge of science per se. Instead, I identified the student skills on which the teachers focused and examined whether those skills aligned with the content that they taught. In contrast to Magnusson *et al.* (1999) and Schwarz & Gwekwerere (2007), I distinguished between goals and beliefs **and** pedagogical approaches and examined these both as elements of PCK (Friedrichsen & Dana, 2005, p. 228) and for manifestations of PCK. I referred to knowledge of instructional representations or strategies as instructional methods and examined it as both a PCK element and for PCK manifestations. I examined context knowledge, knowledge of student understanding, and knowledge of curriculum for PCK manifestations. I did not examine teachers' knowledge of assessment and classroom management. Following from past studies, I used mixed methods (class observations, semi-structured interviews, Content Representations [CoRes], and survey) to study PCK.

In my study, I used PCK to examine how science teachers taught EE and used AC in the classroom. PCK is important because it guides teaching and it provides an opportunity for teachers to be more effective in the classroom

(Bransford *et al.*, 2000), i.e., to successfully achieve the goals that are set out both for the students and for the teacher. Using PCK as my investigative lens allowed me to examine whether teachers' goals and beliefs about teaching science, pedagogical approaches, instructional methods, and their student skills as well as knowledge of student learning, knowledge of curriculum, context knowledge, and other topic-specific knowledge were associated with their use of AC. As with the use of PCK in science education, my study's use of the PCK framework provides insights into science teachers' use of EE and AC in the classroom, and contributes to developing or improving EE and Science curricula in Michigan, especially those aimed at developing students' AC. My study contributes to teacher training programs for EE in Michigan in terms of suggesting ways to strengthen teachers' PCK and how to integrate AC into the science curriculum and practice.

Table 2.4. PCK Variables Examined in My Study

Other Researchers (e.g., Magnusson *et al.*, 1999; Schwarz & Gwekwerere, 2007; Shulman, 1986; Lee *et al.*, 2007; Grossman, 1990; Cochran, 1997; Carlsen, 1999)	**MY STUDY**	
PCK Element	Examined as PCK element	Examined as manifestation of PCK (area where actual PCK was observed)
1) Knowledge of Science/Subject Matter Knowledge	Examined "student skills" as a component of knowledge of science/subject matter knowledge	
2) Orientations toward Teaching Science	Distinguished between (1) goals and beliefs and (2) pedagogical approaches	Goals and beliefs: (1) *reasons/purposes of selecting and emphasizing particular concepts* and (2) *reasons/purposes of selecting and emphasizing particular skills.* Pedagogical Approaches: (1) *reasons/purposes of using particular approaches, methods, or instructional strategies*; (2) *reasons/purposes of using particular activities (e.g., problems, demonstrations, simulations, investigations, and experiments)*; and (3) *activities or examples that connected well with students.*
3) Knowledge of student understanding or learning of science		Knowledge of student learning or understanding
4) Knowledge of Assessment	Not examined	Not examined
5) Knowledge of Instructional Representations or Strategies	Instructional method	Embodied in three PCK manifestations: (1) *reasons/purposes of using particular approaches, methods, or instructional strategies*; (2) *reasons/purposes of using particular activities (e.g., problems, demonstrations, simulations, investigations, and experiments)*; and (3) *activities or examples that connected well with students.*
6) Context Knowledge		Context Knowledge: (1) *ways [that teachers] used to overcome barriers/constraints in teaching context;* (2) *community resources used and why;* and (3) *school resources used and why*.
7) Classroom Management	Not examined	Not examined
8) Knowledge of Science Curriculum		Knowledge of Curriculum

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CHAPTER 3

MICHIGAN ENVIRONMENTAL EDUCATION CURRICULUM SUPPORT (MEECS): PEDAGOGICAL APPROACHES, INSTRUCTIONAL METHODS, STUDENT SKILLS, AND ACTION COMPETENCE

ABSTRACT

The Water Quality Unit of the MEECS, an environmental education curriculum officially sanctioned by the state of Michigan, was examined to identify occurrence of pedagogical approaches, instructional methods, student skills, and action competence. Content analysis of all lessons revealed *activity-driven* (38.5%), *didactic-with-application* (18.3%), *didactic* (14.4%), *conceptual change* (13.5%) and *process-oriented* (12.5%) pedagogical approaches were the most prevalent across the curriculum. The most prevalent instructional methods were *didactic questions* (32%) and *definitions* (15%). The majority of the student skills were process skills, but *critical thinking/think on their own/analytical/evaluation skills* (24.8%) and *inferring/interpreting* (11.5%) were the most prevalent.

Findings showed the curriculum focused more on the *knowledge/insight* AC element (50.4%) and to a lesser extent on *critical thinking and reflection* (20.7%) and *planning and action experiences* (17%). There was lack of attention on two other AC elements – *commitment* and *visions. Knowledge of causes* (12.7%), *knowledge of effects* (11.8%), and *general awareness of environmental issues or problems* (11.2%) were the most prevalent types of *knowledge/insight,* but social structures and cultural practices were weakly addressed. Although *planning and action experiences* was present, much of the experiences suggested was for adults, not for students to do real planning and taking action as part of their learning. Although *knowledge/insight* is considered a prerequisite to developing students' capacity for action, the literature says it is not enough. The overwhelming focus of the curriculum on *knowledge/insight* and the lack of

attention on *commitment* and *visions* may eventually affect the ability of teachers to foster AC in students.

Findings suggest that *knowledge/insight*, *critical thinking and reflection*, and *planning and action experiences* elements of AC may be associated more with *activity-driven*, *didactic-with-application* and *didactic* pedagogical approaches than others. This may suggest that, to increase occurrence of *commitment* and *visions*, the curriculum needs to strengthen its use of approaches other than the top five listed above. Moreover, *didactic questions* and *definitions* (instructional methods) seemed congruent with *didactic* and *didactic-with-application* pedagogical approaches. These findings also possibly suggest that the curriculum needs to expand the range of methods and approaches it suggests for teachers to use. Although most of the student skills were congruent with the *process-oriented* approach, these may also be fostered by *activity-driven, didactic-with-application*, and *didactic* approaches. Finally, findings showed the extent of use of individual elements of AC varied across lessons in the curriculum, which possibly suggests that, to increase teachers' likelihood of developing AC in students using the curriculum, they (teachers) would need to teach all of its lessons.

3.1 INTRODUCTION

In the last two decades we have seen an increase in various types of Environmental Education (EE) programs in different education settings, including schools (Athman & Monroe, 2001; Hammond, 1997; Palmer, 1998; Tilbury, 1995). Along with the increase of EE programs are the recurrent questions: How do teachers go about teaching EE? What does effective EE involve? Are we making an impact? (Hart, 2003; Jensen, 2002; Jensen & Schnack, 1997; Palmer, 1998) Indeed, there is a growing research base in investigating the impacts of EE on students, particularly their knowledge, attitudes, behaviors, and/or skills (Dimopoulos & Pantis, 2003; Hungerford & Volk, 1990; Leeming *et al.*, 1997; Roth, 1992). But another question begs to be answered: What are the characteristics of an effective curriculum? What are its objectives, content, focus, pedagogical approaches, instructional methods, or what student skills are fostered? As Hart (2003) observed, only a few studies have looked directly at EE curricula and what their use in classrooms entails. My study is an attempt to fill this gap.

In this chapter I address my first research question: "To what extent do the science and environmental education curricula used by science teachers represent elements of action competence?" I examine the pedagogical approaches, instructional methods, student skills, and elements of action competence (AC) that were included in the Water Quality Unit of the Michigan Environmental Education Curriculum Support (MEECS) and identify possible associations among the variables. I also discuss implications for future development of EE curricula, teacher education, professional development, and future research.

3.1.1 Michigan Environmental Education Curriculum Support (MEECS)

"MEECS is a set of EE curriculum lessons and support materials, carefully designed to help teachers integrate environmental materials into their classrooms – materials that are Michigan-specific, balanced, science-based, and critically correlated to the Michigan science and social studies' curriculum framework standards and benchmarks" (Michigan Department of Environmental Quality, 2005, p. i) for 4th through 9th grade established by the Michigan Department of Education. In July 2008, the Units also were aligned to the Grade Level Content Expectations (GLCEs) for 4th through 8th grade and high school science and social studies. The materials were developed with broad-based technical and teacher review and teacher-tested in at least 200 Michigan classrooms (web description of the MEECS, accessed 4/4/2010; MEECS brochure).

The five curriculum Units are Ecosystems & Biodiversity, Land Use, Water Quality, Energy Resources, and Air Quality. The Ecosystems and Land Use Units were designed for 4th and 5th grade, the Water Quality Unit was targeted for 6th through 8th grade, and both Air Quality and Energy Resources were targeted for 7th through 9th grade. These Units may be taught separately, or may be used together as an entire EE curriculum for a school or school district. The Request for Proposal issued in 2002, and later the brochure that was disseminated to users of the curriculum described MEECS as consisting of hands-on, *inquiry*-oriented, and data-based lessons, designed (1) to help students gain a basic understanding about Michigan's economy, how the environment functions, and how humans affect the environment, and (2) to help students use science concepts, principles, and data to make informed decisions about "how harmony between human activity and the natural environment can be achieved" (p. 2 of the RFP). The Units were designed also to increase student achievement in the Michigan Education Assessment Program (MEAP) assessment (MEECS brochure, 2006; RFP issued in 2002). The curriculum was designed based on the belief that "a greater understanding of our environment will lead to greater care and stewardship" (vision statement, accessed online on 4/4/2010).

I chose to examine the Water Quality Unit because, according to the survey of MEECS participants which I conducted prior to curriculum analysis (see Chapter 4), this Unit was the most often used by teachers and it had the largest percentage of Unit-trained individuals of all the survey respondents who were trained in the use of MEECS.

The MEECS Water Quality Unit's primary goal is to provide students with a solid understanding of the critical importance of having adequate and clean freshwater supplies for the environment, Michigan's economy, and our quality of life. "The Unit provides a national and international perspective on water availability, an appreciation for Michigan's "dirty" water history, and an understanding of the challenges that Michigan faces in addressing water quality and quantity issues related to groundwater, streams and rivers, wetlands, inland lakes, and the Great Lakes" (Michigan Department of Environmental Quality, 2005, p. 1). The Water Quality Unit consists of nine core lessons and five extension lessons, which are all correlated to the Michigan middle and high school benchmarks and GLCEs for science and social studies (see Table 3.1).

Table 3.1. MEECS Water Quality Unit: Essential Questions and Core Lessons

ESSENTIAL QUESTIONS	CORE LESSON
Where is water found on Earth? How does water move on Earth? Is there enough water on Earth for everyone? Why are the Great Lakes unique?	**1. Where Is All the Water in the World? –** Students describe how water moves through the water cycle, where water is located on Earth, and how much fresh water is available for human use.
Why is clean, fresh, available water so important to humans? What are direct and indirect uses of water? How would having less water or more expensive water affect Michigan residents?	**2. How We Use Water –** Students identify the many ways we use water, both directly for household activities and indirectly in everything we consume. Students calculate their weekly water use and its cost compared to gasoline, and consider how water is an essential component of Michigan's economy and environment.
What is a watershed? Why care about watersheds? How does water in your watershed reach the Great Lakes? Why does the amount of streamflow differ between Michigan streams and for different months of the year?	**3. Do You Know Your Watershed? –** Students define watershed and the parts of a river; compare watershed size and stream flow in Michigan; examine their watersheds' relationship to the Great Lakes.
How does what we do on the land affect water quality? How does pollution get from one place to another? How can I learn about water pollution in my watershed?	**4. How Do Land Uses Affect Water Quality? –** Students build a simple watershed model to observe point & non-point pollution from different land uses; identify the types of pollution resulting from different land uses; give examples of best management practices to reduce pollution; and identify potential sources of water pollution in their watersheds.
How is groundwater connected to surface water? How does groundwater move? How can groundwater become polluted? Is there enough groundwater for all Michigan uses?	**5. Why Care About Groundwater? –** Students explore groundwater movement, how groundwater interacts with surface water, and groundwater uses in Michigan. Students build a model to see how groundwater can be pumped and recharged, and use Michigan data to explore how groundwater can be contaminated.

Table 3.1 Continued:

How do we know our water is safe to drink? What Units are used to measure water pollution? Has our water always been clean? Who is responsible for protecting our drinking water?	**6. Would You Drink This Water? –** Students consider whether the 'look' and 'smell' of water is enough to indicate its quality; conduct a serial dilution to observe the tiny quantities that can be harmful to humans and aquatic organisms; and become familiar with who protects Michigan's water quality.
What is stream monitoring, and how is it done? How do you know if a stream is healthy? What are bioindicators? What makes good habitat for fish?	**7. How Healthy Is This Stream?** – Students identify characteristics of healthy streams and use real Michigan data to evaluate four streams for the presence of pollution-sensitive bioindicator organisms, appropriate habitat, and good water quality to select the best stream for planting brook trout.
Where does storm water come from and where does it go? What are potential contaminants in runoff? How do people affect the quantity and quality of runoff? How can communities grow without impacting aquatic ecosystems? How is storm water runoff different in urban areas versus rural areas?	**8. How Can We Stop Storm Water? –** Students identify pollutants in storm water; use aerial photos to compare changes in land use and runoff quantity; identify best management practices to reduce storm water impacts.
Are the Great Lakes really great? Can I eat fish from the Great Lakes? What types of contaminants are found in the Great Lakes? How can I help protect the Great Lakes?	**9. Bioaccumulation and the Great Lakes Ecosystem –** Students investigate the source and pathways for bioaccumulation of contaminants in Great Lakes food chains; identify locally contaminated rivers using the Michigan Family Fish Consumption Guide; and answer the question, "How can I help the Great Lakes?"

Table 3.2. "Big Ideas or Enduring Understandings" of the MEECS Water Quality Unit

The Water Quality Unit addresses the following "Big Ideas" or "Enduring Understandings:" Upon completion of the Unit, students will understand that:

1. (Awareness) Good quality water and an adequate supply of water are essential to Michigan's communities and to our quality of life.

2. (Connections) All Michigan residents live in a watershed that is part of the Great Lakes watershed, a unique global resource of unprecedented importance to Michigan, the United States and the world.

3. (Concern) Our activities have past, present, and future impacts on Michigan's water resources.

4. (Knowledge) Water quality standards have been established to protect the many uses of Michigan's water.

5. (Knowledge) We can assess the health and water quality of Michigan's streams, rivers, lakes, and groundwater by collecting and analyzing appropriate data.

6. (Knowledge) We need to know where our drinking water comes from and where our wastewater goes.

7. (Decision-making) We need data to make decisions about protecting and restoring Michigan's water resources.

8. (Stewardship and sustainability) It is up to every citizen to be a steward of Michigan's water resources.

Source: MEECS Water Quality Unit Introduction, p. 13

3.2 METHODS

3.2.1 Data Sources and Data Analysis

Each lesson in the Unit has the following main components or sections: Lesson Overview, Objectives, Michigan Curriculum Framework Content Standards and Benchmarks, Advanced Preparation, Background Information, Procedure, Assessment Option, Extensions, and Additional Resources. Each lesson also is accompanied with transparency masters of activity sheets, visuals, answer keys, and other supplemental class materials. On the first page of each lesson is information on the target subjects and grade levels, expected duration of the lesson, and materials needed to complete the lesson. For purposes of this study, I analyzed only five sections of each lesson: (1) Objectives, (2) Standards and Benchmarks, (3) Background Information, (4) Procedures, and (5) Assessment Option, because these comprise the core of a lesson. I also included as data sources any activity sheets, visuals, or other supplemental materials that comprised each of the five sections.

I used Atlas.ti version 5.2 for the coding and analysis of the texts of the five sections of all nine lessons. I analyzed the Unit one lesson at a time. I coded any occurrences of the four variables of interest – pedagogical approaches, instructional methods, student skills, and elements of action competence – in each of the five sections of each lesson into categories under each variable of interest. Before coding the lessons, I read each lesson without doing any coding to identify the organization of each lesson and the topics or concepts covered in each lesson. During the second reading, I started coding.

3.2.1.1 *Coding for Pedagogical Approaches*

Approaches encompass the general structure, organization, and process of instruction that a teacher takes when teaching a lesson, including the purpose of employing such approaches and what the teacher wants students to achieve at the end of class (Eames *et al.,* 2006; Magnusson *et al.,* 1999). In this study, I adapted nine pedagogical approaches from Magnusson *et al.* (1999, pp. 100-101) and Schwarz & Gwekwerere (2007, pp. 182-184). I added *didactic-with-application*, which emerged from the data, as a tenth category. Descriptions of the approaches are below. These approaches comprised the rubric that I used for analyzing the Water Quality Unit of MEECS.

1) *Academic Rigor* – Students are challenged with difficult problems or activities. The teacher uses laboratory work and demonstrations to verify science concepts by demonstrating the relationship between particular concepts and phenomena. The activity often poses a challenge to students. Students may try to solve the problems after they have seen an example from the teacher or using their previous knowledge or experience.

2) *Activity-Driven* – Students participate in a *hands-on activity* or, if not, are given a task to work individually or in groups to help them verify or discover a concept. Hands-on activities require students to be actively involved and engaged with objects, materials, technology, or laboratory equipment/tools and manipulate these for the purpose of learning through experience instead of being passive learners (Flick, 1993; Meinhard,

1992). The teacher gives students equipment/materials and directions/ procedures to complete an activity. In most cases, the teacher tells students what they are supposed to see or learn. It must be noted here that Schwarz & Gwekwerere (2007) and Magnusson *et al.* (1999) only included "hands-on" activities in their *activity-driven* category, but I included non-hands-on activities (e.g., the whole class classifying a list of items found in kitchen cupboard; a pre-reading activity) in this category as well.

3) *Conceptual Change* – Students are pressed for their views about the world and consider the adequacy of alternative explanations. The teacher facilitates dialogue, discussion, or debate necessary to establish valid knowledge claims. The teacher draws out and assesses prior knowledge of students before presenting a new concept. An activity is then used to help students change their naïve conceptions. The teacher compares students' ideas before and after the activity or lesson.
4) *Didactic* – The teacher presents information generally through lecture, discussion, demonstration, or films. Scientific models may be used for demonstration, illustration, or verification. Questions are directed to students to hold them accountable for knowing facts. The focus is on delivery/transmission of content/facts.
5) *Discovery/Exploration* – This approach is student-centered. Students explore the world following their own interests and discover patterns of how the world works during their explorations. A teacher might scaffold

students' explorations depending on students' abilities (or lack thereof), and might ask students to share their "discoveries" later in class.

6) Guided *Inquiry* – This learning is community-centered. Teacher and students work together 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.

7) *Inquiry* – This approach is investigation-centered. The teacher supports students in defining and investigating problems, drawing conclusions, and assessing the validity of knowledge from their conclusions. Questions or problems for investigation come either from the teacher or students. Students do most of the thinking and figure out how to investigate the problem with the teacher's support and help with correcting explanations or applications. Usually, students follow the traditional scientific method when attempting to solve a problem (ask a question, do background research, make a hypothesis, create an experiment to test a hypothesis, collect and analyze data, draw conclusions, and report findings).

8) *Project-Based* – This approach is project-centered. Teacher and student activity centers on a "driving question" that organizes concepts and principles and drives activities within a topic of study. Students then do a project (their choice or from a selection of ideas/options from the teacher) individually or collectively in which they need to do an investigation or

research/collect information and develop artifacts or products (e.g., brochures, reference books, posters, or dioramas) that demonstrate their emerging understanding. Students might present their product to the class or their work might get posted on the wall.

9) *Process-Oriented* – The teacher introduces students to the thinking processes adopted by scientists to acquire new knowledge. Students engage in activities (e.g., laboratory experiments, *problem solving*) to develop integrated thinking skills. Examples of these process skills include observing, classifying, measuring, inferring, and *predicting*.

10) *Didactic-With-Application* – I considered this approach differently from a *didactic* approach. In addition to the features of a *didactic* approach, the teacher provides real world examples or applications of a concept or asks students to identify real world scenarios in which they could apply what they learn.

Following the descriptions of each approach outlined above, I counted each time an approach occurred in the five sections of each lesson in all nine lessons. If the same approach occurred in the same section more than once, I counted it separately if used for a different purpose, activity, or topic. In some cases, I assigned multiple codes to groups of words, phrases, or sentences when they encompassed multiple approaches, as shown below.

> *"Working in small groups, ask students to brainstorm a list of products made in Michigan that require water to grow, process, or manufacture. Compare students' lists to those products shown on the overhead*

transparencies Made in Michigan Wood Products and Grown in Michigan Products, as well as those described in the Background Information. Who has the most Michigan products correctly listed?" was coded as ACTIVITY-DRIVEN (not hands-on) and CONCEPTUAL CHANGE [From Lesson 2, p. 22]

3.2.1.2 Coding for Instructional Methods

Instructional methods are specific ways or means that teachers use to create learning environments and to specify the nature of a lesson or an activity in which the teacher and the students will be involved during class. Particular methods often are associated with certain pedagogical approaches or strategies; many are found within a variety of approaches or strategies (Saskatchewan Education, 1991; Lang & Evans, 2006). Examples of instructional methods include compare and contrast, discussion, *hands-on activity*, and cooperative learning.

Unlike coding for pedagogical approaches, I did not use a pre-determined list of instructional methods for coding because I anticipated seeing a broad array of methods used in the curriculum. Consequently, I let the categories emerge from the data. I counted each time an instructional method occurred in the five sections of each lesson. For example, in the Objectives component of Lesson 1 (Where is all the water in the world?), one of the objectives was to "Discuss the importance of living next to the Great Lakes" (see Figure 3.1). Then in the Procedures section, discussion occurred four times (see highlighted text in yellow in Figure 3.1). If the same method occurred in the same section more than once, I counted it separately if used for a different purpose, activity, or topic. Thus, in lesson 1, I counted "discussion" five times total because this instructional method occurred once in the Objectives and four times in the Procedures section. As in coding for pedagogical approaches, some texts received multiple codes for instructional methods, as shown below.

> *"Think of your bathtub as a watershed. Imagine a stream flowing down the middle of the tub. The drain is the mouth of the stream as it empties into a river, lake, or the ocean. The rim of the tub is the drainage divide. Water that falls on the outside of the tub does not flow down the drain. The water that falls on the inside of the tub runs into the drain (mouth) at the bottom of the tub."* was coded as <u>USE IMAGINATION and GIVE/USE REAL WORLD EXAMPLES</u> [From Lesson 3, p. 44]

Lesson 1 Objectives [p. 1]

1. Define basic terms and processes associated with the hydrologic cycle.
2. Describe the distribution and availability of freshwater and saltwater on Earth.
3. Discuss *the importance and responsibility of living next to the Great Lakes.*

PROCEDURE

1. Anticipatory set [p. 3]

As students enter the room, tell them to answer the question, "*Where would you most like to take a family vacation?*" by placing 10 ml of water into a 100-ml graduated cylinder representing their destination choice of ocean, lake or snow/ice. Discuss students' responses after doing the activity *Where Is Water On Earth?* Compare where students would like to go on vacation to the percentage of water found in that location on the Earth.

5. How is water distributed on Earth and how much water is available for human use? [p. 5-6]

The teacher may ask student groups to report on their predicted distributions of water on Earth, or have each group record their predictions on the board or on an overhead transparency. Discuss the similarities and differences between the groups' predictions.

Display the overhead transparency of the student activity page *Where Is Water on Earth?* with the correct percentages and quantities. Have the class compare the actual percentages with their predictions. While the correct quantities are displayed, ask students to answer the questions at the bottom of the student activity page. Discuss their responses.

6. Tying it all together [p. 6]

Discuss these difficult questions that have yet to be answered:
How might water shortages in the United States or the world affect the Great Lakes? [Many people, businesses, states, and countries will want to divert some of the Great Lakes freshwater.]

Figure 3.1. Coding of Five Instances of "discussion" as an Instructional Method in Lesson 1 of the Water Quality Unit

3.2.1.3 Coding for Student Skills

A skill is procedural knowledge, that is, knowledge and ability to do something. In other words, it is a learned ability to carry out or perform a task. Skills can be cognitive, affective, or psychomotor, or a combination of these (Lang & Evans, 2006). Examples of skills include reading, writing, communicating, interpersonal skills, using the computer, *problem solving*, and *critical thinking*.

As in coding for instructional methods, I let the data direct the coding process; that is, categories of student skills emerged from the data. I counted each time a skill occurred in the five sections of each lesson in all nine lessons. If the same skill occurred in the same section more than once, I counted it separately if it occurred in a different activity or topic. As in coding for pedagogical approaches and instructional methods, I assigned multiple codes to some texts that encompassed multiple skills.

3.2.1.4 Coding for Action Competence (AC)

Studies in the past 30 years predominantly focused on the impacts of EE curricula on students' knowledge, attitudes, and behaviors as indicators of environmental stewardship, environmental literacy, or responsible environmental behaviors. My study, however, moved beyond these behavioral indicators and examined the extent that an EE curriculum shows characteristics of action competence. My study used AC as an alternative framework because I believe there is a need to go beyond behavioral indicators when assessing an EE curriculum, although I agree with others (Dimopoulos & Pantis, 2003; Hockett, *et al.,* 2004; Hsu, 2004; Orams, 1997) that these are important outcomes.

Action competence describes a person's ability to act on an environmental problem or issue, or a person's ability to change his/her living condition (Jensen & Schnack, 1997). According to researchers, multiple aspects contribute to developing AC, but they agree that (1) *knowledge/insight*, (2) *commitment*, (3) *critical thinking and reflection*, (4) *visions*, and (5) *planning and action experiences* are central to AC's development (Breiting & Mogensen, 1999; Eames *et al.,* 2006; Jensen, 2000a; Jensen & Schnack, 1997). The descriptions of each element below emerge from Jensen and Schnack, (1997), Jensen (2000a), Mogensen (1997), Eames *et al.,* (2006), and Breiting & Mogensen (1999).

1) *Knowledge/Insight* – the literature suggested four types, but I added an emergent type (see item "e" below).
    a) *Effects* – what kind of problem is it?
    b) *Causes* – why do we have this problem?
    c) *Change Strategies* – how can we change things (personal, societal levels)?
    d) *Alternatives and Visions* – what can be done about the problem and where do we want to go?
    e) *General Awareness of Environmental Problems or Issues, or Importance of Environmental Resources* – I referred to this is as simply knowing that an environmental problem or issue exists, but

not knowing more (the causes, effects, the depth and range of a problem or issue, etc.)

2) *Commitment* – relates to promoting students' motivation, *commitment*, and drive to get involved in solving environmental problems; extent that students are ready to act to realize their vision; includes understanding their own and others' attitudes and values toward issues.
3) *Critical Thinking and Reflection* – includes thinking about and assessing complex and multiple causes of problems; social and political contexts of a problem, and possible solutions; weighing pros and cons of an environmental issue; recognizing different points of view and challenging current practices and beliefs; and questioning values, perceptions, conditions, and opinions (also by Kyburz-Graber, 1999, p. 416).
4) *Visions* – developing students' ideas, dreams, and/or perceptions about how they can improve their future lives and society.
5) *Planning and Action Experiences* – providing students with concrete, real-life experiences in planning and acting on environmental issues or problems; giving students opportunities to develop skills and confidence to identify and solve problems, set goals, gather information, communicate, and manage time and logistics to take action.

Using a rubric adapted from the works of Jensen & Schnack (1997) Jensen (2000a, 2000b), Mogensen (1997), Eames *et al.* (2006), and Breiting & Mogensen (1999) and the guiding question "Which elements of AC are in the curriculum and to what degree?," I coded for any occurrences of the five elements of AC (*knowledge/insight*, *commitment*, *critical thinking and reflection*, *visions*, and *planning and action experiences*) in the five sections of each lesson in all nine lessons. As in previous coding processes described above, I assigned multiple codes to some texts when they encompassed more than one AC element. As well, I counted any occurrence of a similar AC element in the same section separately if it occurred in a different part/item, activity, or topic.

After the first round of coding for pedagogical approaches, instructional methods, student skills, and elements of AC, I reread each lesson and coded again to check for errors or inconsistencies from the first round of coding. At the end of the second round of coding, I found six inconsistencies (unmatched coding) of 104 coded occurrences of pedagogical approaches, 10 inconsistencies of 707 coded occurrences of instructional methods, nine inconsistencies of 226 coded occurrences of student skills, and 19 inconsistencies of 552 coded occurrences of AC in all nine lessons. I reread the texts where I found the inconsistencies and recoded until the first and second round of codes matched. After coding, I calculated total frequencies and percent occurrences per lesson and across nine lessons for each approach, method, skills, and individual elements of AC.

3.3 RESULTS

3.3.1 Pedagogical Approaches

Of the 104 instances of pedagogical approaches found across all lessons in the Unit, the most prevalent were *activity-driven* (38.5%), *didactic-with-application* (18.3%), *didactic* (14.4%), *conceptual change* (13.5%), and *process-oriented* (12.5%) approaches (see Table 3.3). *Activity-driven* was consistently the most prevalent approach in each lesson, except in Lesson 2 where it tied with *conceptual change* (44.4%), Lesson 3 where it tied with *didactic* (25%) and *didactic-with-application* (25%), and Lesson 4 where it tied with *didactic-with-application* (33.3%). I did not find evidence for use of *academic rigor*, *discovery/exploration*, *guided inquiry*, and *inquiry* approaches in any lessons in the Unit.

3.3.2 Instructional Methods and Student Skills

Fifty different instructional methods were found in the Unit, and of the 707 instances of all these methods, the most prevalent were *didactic questions* (32%) and *definitions* (15%) (see Table 3.3). *In-class activity* comprised 10% and *hands-on activity* comprised only 2% of all the methods used. Twenty different student skills were found in the Unit and 12 of those were science process skills. Of the 226 instances of all the student skills found across all lessons, the most prevalent were *critical thinking/think on their own/analytical/evaluation skills* (24.8%) and *inferring/interpreting* (11.5%), which also represent process skills.

3.3.3 Action Competence (AC)

Of the 552 total instances of AC across all lessons in the Unit, 50.4%, 20.7%, and 17% represented *knowledge/insight*, *critical thinking and reflection*, and *planning and action experiences*, respectively. *Commitment* and *visions* each occurred less than 10% of the overall occurrence of AC in the Unit. *Knowledge/Insight* was the most prevalent AC element in all lessons, except in lesson 1, in which percent of *knowledge/insight* tied with percent of *critical thinking and reflection* at 32.1% (see Table 3.3). *Knowledge/Insight* also was the most prevalent in all five sections of each lesson (see Table 3.4). Of the 50.4% *knowledge/insight* characteristics, 12.7% represented *knowledge of causes*, 11.8% identified *knowledge of effects*, and 11.2% fostered *general awareness of environmental issues/problems* (see Table 3.3). Of all the AC occurrences found in the Unit, 15.9% occurred in Lesson 8 (How can we stop storm water?), 13.9% in lesson 5 (Why care about groundwater?), 13.8% in lesson 7 (How healthy is this stream?), and 13.8% in lesson 9 (Bioaccumulation and the Great Lakes ecosystem) (see Table 3.3). Lessons 1 and 3 had the lowest occurrence of AC across nine lessons.

Table 3.3. Prevalent Pedagogical Approaches, Instructional Methods, Student Skills, and Elements of Action Competence in the Water Quality Unit

	PERCENT OCCURRENCE IN EACH LESSON									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**% Total Occurrence**
PEDAGOGICAL APPROACHES										n=104
Activity-Driven	45.5	44.4	25.0	33.3	50.0	38.5	35.7	30.8	40.0	**38.5**
Conceptual Change	36.4	44.4	-	-	7.1	7.7	14.3	-	20.0	**13.5**
Didactic	9.1	-	25.0	16.7	14.3	7.7	21.4	23.1	10.0	**14.4**
Didactic-With-Application	9.1	11.1	25.0	33.3	28.6	15.4	-	15.4	30.0	**18.3**
Process-Oriented	-	-	12.5	8.3	-	30.8	28.6	23.1	-	**12.5**
INSTRUCTIONAL METHODS										n=707
Didactic Questions	38.2	24.1	22.9	17.4	33.0	40.9	32.1	37.1	37.3	**32.0**
Definitions	19.1	6.9	34.3	14.5	10.0	11.4	11.9	20.0	10.7	**15.0**
STUDENT SKILLS										n=226
Critical Thinking/Think on their own/Analytical/Evaluation skills	46.7	35.3	16.7	25.8	37.0	25.0	10.0	12.1	31.0	**24.8**
Inferring/Interpreting	-	-	33.3	6.5	7.4	32.1	7.5	18.2	6.9	**11.5**
ACTION COMPETENCE										n=552
A) *Knowledge/Insight*	**32.1**	**40.4**	**66.7**	**58.7**	**61.0**	**42.4**	**43.4**	**58.0**	**47.4**	**50.4**
1. Change Strategies	*3.6*	*7.0*	*4.8*	*11.1*	*10.4*	*13.6*	*7.9*	*11.4*	*6.6*	*9.2*
2. Awareness of Environmental Issues/Problems, Importance of Resources	*14.3*	*15.8*	*28.6*	*6.3*	*14.3*	*9.1*	*13.2*	*4.5*	*10.5*	*11.2*
3. Alternatives and Visions	*7.1*	*3.5*	-	*6.3*	*5.2*	*6.1*	*3.9*	*6.8*	*6.6*	*5.4*
4. Effects	*7.1*	*8.8*	*14.3*	*15.9*	*11.7*	*6.1*	*9.2*	*19.3*	*10.5*	*11.8*
5. Root Causes	-	*5.3*	*19.0*	*19.0*	*19.5*	*7.6*	*9.2*	*15.9*	*13.2*	*12.7*
B) *Commitment*	**17.9**	**10.5**	**4.8**	-	**5.2**	**7.6**	**9.2**	**2.3**	**9.2**	**6.7**
C) *Visions*	**7.1**	**3.5**	-	**4.8**	**5.2**	**6.1**	**3.9**	**6.8**	**6.6**	**5.3**
D) *Planning and Action Experiences*	**10.7**	**12.3**	**14.3**	**20.6**	**14.3**	**22.7**	**17.1**	**17.0**	**18.4**	**17.0**
E) *Critical Thinking and Reflection*	**32.1**	**33.3**	**14.3**	**15.9**	**14.3**	**21.2**	**26.3**	**15.9**	**18.4**	**20.7**
Total percent of AC per lesson	5.1	10.3	3.8	11.4	13.9	12.0	13.8	15.9	13.8	**100.0**

- = No occurrences observed   n = total number of instances

Table 3.4. Action Competence Occurrences in the MEECS Water Quality Unit by Lesson Section						
	PERCENT OCCURRENCE OF AC IN EACH SECTION OF THE LESSON					
Elements of Action Competence	**BI**	**P**	**AO**	**O**	**SB**	**TOTAL % OCCURRENCE**
A) *Knowledge/Insight*	76.6	42.3	38.0	46.3	55.5	**50.4** (n=278)
1. Change Strategies	*23.4*	*10.7*	*8.0*	*4.9*	*1.6*	*9.2*
2. Awareness of Environmental Issues/Problems, Importance of Resources	*13.0*	*6.0*	*8.0*	*15.9*	*17.2*	*11.2*
3. Alternatives and Visions	-	*7.0*	*12.0*	*6.1*	*3.1*	*5.4*
4. Effects	*20.8*	*9.8*	*6.0*	*9.8*	*13.3*	*11.8*
5. Root Causes	*19.5*	*8.8*	*4.0*	*9.8*	*20.3*	*12.7*
B) *Commitment*	5.2	7.0	16.0	6.1	3.9	**6.7** (n=37)
C) *Visions*	-	6.5	12.0	6.1	3.1	**5.3** (n=29)
D) *Planning and Action Experiences*	18.2	17.2	14.0	24.4	12.5	**17.0** (n=94)
E) *Critical Thinking and Reflection*	-	27.0	20.0	17.1	25.0	**20.7** (n=114)
Total frequency per section	n=77	n=215	n=50	n=82	n=128	**100.0** (n=552)

\- = No occurrences observed   n = number of instances
Lesson sections: (1) BI = Background Information; (2) P = Procedures; (3) AO = Assessment Options; (4) O = Objectives and (5) SB = Standards and Benchmarks

3.4 DISCUSSION

3.4.1 Pedagogical Approaches

Findings in pedagogical approaches suggest some mismatch between what the Unit purported it does – to engage students in "hands-on lessons that encourage student participation and *inquiry*" (MEECS brochure, 2006) – and the kinds of lessons the Unit actually included. First, although *activity-driven* was the most prevalent approach across the Unit, much of this approach consisted of non-hands-on activities. This is related to the relatively strong combined occurrences of *didactic* and *didactic-with-application* approaches, which suggests that the curriculum continues to use a less engaging and less participatory approach to teaching and learning. Furthermore, although MEECS purported to provide students with *inquiry*-oriented lessons and activities, no *inquiry* or *guided inquiry* approach was found in the Water Quality Unit.

In particular, the lessons failed to include opportunities for students to a) initiate an investigation of a problem identified by themselves or suggested to them by their teacher, or b) draw conclusions and assess the validity of their knowledge from their conclusions (*Inquiry*). No plans required teachers and their students to identify a problem, test explanations, and evaluate their data to find a specific discovery or make a generalization (*Guided Inquiry*) (Brendzel, 2005; Lang & Evans, 2006; Magnusson *et al.,* 1999; Schwarz & Gwekwerere, 2007). Instead, the lessons provided all of the problems or topics that students investigated, as well as the procedures they had to follow. For example, in the activity in which students evaluate four streams and then decide which stream has the best habitat for brook trout (Lesson 7), students receive established data about the streams, such as macro-invertebrate data, water quality data (dissolved oxygen, pH, temperature, and turbidity), and photographs. They then compare the given data to determine the better stream for brook trout.

A truly *inquiry*-based approach requires students to conduct most of the thinking and figuring out how to investigate the problem with the teacher's support and help by correcting explanations or applications (Brendzel, 2005; Lang & Evans, 2006; Magnusson *et al.,* 1999; Schwarz & Gwekwerere, 2007). One way to make it more *inquiry*-based would be to let students identify a problem, collect and analyze the data themselves, and compare results against their hypotheses. To use a *guided inquiry* approach, the teacher should carefully guide students toward a discovery or generalization by working with students in identifying a problem, writing hypotheses, identifying objectives, planning for data collection, interpreting results, and making conclusions (Lang & Evans, 2006).

The target lesson time of 50 minutes/period might explain the limited level of involvement of the students observed in the Unit due to the difficulty of conducting a full blown *inquiry*-based lesson in that amount of time. It should be noted here that I did not examine or analyze the sections after the Assessment Options in each lesson. Perhaps other sections of each lesson (e.g., Extensions and Additional Resources) suggest more *inquiry*-oriented activities, giving teachers an option to do more than the activities suggested in the main body of each lesson.

3.4.2 Instructional Methods and Student Skills

Didactic questions and *definitions* as instructional methods were congruent with *didactic* and *didactic-with-application* pedagogical approaches. The infrequent use of *hands-on lessons* and *experiments* relative to the other methods used in the Unit suggests a need to strengthen use of these instructional methods if the Unit purports to provide such experiences to students. Similarly, despite the Unit's aim to help students investigate the links between human activities and water quality, *investigation/research* comprised only 1.3% of all the methods used in the Unit. Again this points to some mismatch between the objectives of the Unit and its content and instructional methods, and implies a need to increase the use of *investigation/research* methods in teaching the lessons.

The two most prevalent student skills seemed congruent with the Unit's intent to develop students' ability to use scientific knowledge and data to decide, investigate, and explore possible solutions to environmental problems or issues. Prevalence of *critical thinking skills* also seemed to match with *didactic* questions because asking questions (especially the why and the how) provides a common way to encourage *critical thinking* in the classroom. The strong prevalence of process skills despite an infrequent use of the *process-oriented* pedagogical approach may be attributed partially to the dominance of the *activity-driven* approach and, to some extent, the *conceptual change* approach, both of which use and/or address *process-oriented* skills.

3.4.3 Action Competence (AC)

In general, the prevalence of *knowledge/insight* matched expectations because four of the eight "big ideas" or "enduring understandings" that the Unit addresses focus on knowledge and awareness (Michigan Department of Environmental Quality and Central Michigan University 2005) (see Table 3.2). These four are:

1) Good quality water and an adequate supply of water are essential to Michigan's communities and to our quality of life. (Awareness)

2) Water quality standards have been established to protect the many uses of Michigan's waters. (Knowledge)
3) We can assess the health and quality of Michigan's streams, rivers, lakes, and groundwater by collecting and analyzing appropriate data. (Knowledge)
4) We need to know where our drinking water comes from and where our wastewater goes. (Knowledge)

I expected to observe percent of *knowledge/insight* as highest in Background Information (see Table 3.4) because this section provides mostly facts. The lowest occurrence of *knowledge/insight* in the Assessment Option may be because this section also targeted other aspects of learning (e.g., *critical thinking and reflection* – what are the ecological, social, and economic benefits that water provides for Michigan residents?) in addition to assessing knowledge (e.g., what is the distribution of water on earth?).

The Unit met one of AC's *knowledge/insight* requirements in that *knowledge of effects* (ranked second within the *knowledge/insight* component, 11.8%) and *knowledge of causes* (ranked first within the *knowledge/insight* component, 12.7%) comprised significant parts of the *knowledge/insight* component in the entire Unit. According to Jensen (2000a), *knowledge of effects* constitutes an important part of action-oriented knowledge because it awakens people's concerns and attention, and it provides the starting point for their willingness to act. The focus of the Water Quality Unit on *general awareness* (ranked third within the *knowledge/insight* component, 11.2%) also helps to motivate learners.

Jensen (2000a) cautioned, however, that *knowledge/insight* must not stop at the effects of a problem. Rather, learners should understand causes of and ways to solve problems or produce change (change strategies and alternatives and *visions*). Otherwise, Jensen argued, *knowledge of effects* will only generate concerns or worry, will weaken *commitment*, and will contribute to action paralysis. The Water Quality Unit addressed relatively strongly *knowledge of effects and causes*. Compared to the three other types of knowledge, *knowledge of change strategies* (9.2%) and especially *knowledge of alternatives and visions* (5.4%) did not appear frequently. This poses some concern, according to Jensen (2000a), because *knowledge of effects and causes* cannot stand alone. If curriculum designers strive to fully provide action-oriented knowledge, which is a key ingredient in developing AC, then they must insist on including ways of creating social change and finding solutions.

Although *knowledge of causes* occurred highest within the *knowledge/insight* component, it largely comprised only ecological or economic causes of environmental problems or issues. It included minimal discussion regarding how other more diverse social and cultural factors influence people's behaviors or actions toward the environment. Proponents of AC argue that *knowledge of causes* needs to include knowledge of how social structures and cultural practices contribute to environmental problems because environmental problems or issues result from both individual and societal influences (Jensen, 2000a, 2000b; Jensen & Schnack, 1997).

In general, the overall prevalence of *knowledge/insight* may suggest easier inclusion of this element in a curriculum compared to other elements of AC, because *knowledge acquisition* tends to be a common goal of EE programs and is supported by many teachers and educators. In addition, critical pedagogy is not always welcome in schools or by some sectors which are critical of EE as an agent of social change. This may result in some challenges to promote AC in schools or in the community as a whole.

With MEECS, this prevalence matched expectations because, as expressed in the MEECS vision statement, curriculum developers viewed knowledge as a precursor to developing stewardship. This might explain the lack of focus on *commitment* and *visions* in the Unit. Jensen (2000b, p. 234) stresses the importance of *visions* and *commitment* besides *knowledge/insight*: "If there is no *commitment* to fight for *visions*, one cannot speak of action competence." This may imply that, to strengthen focus on AC elements other than *knowledge/insight*, there is a need to revisit the conceptualization of the Unit and perhaps go beyond the "big ideas" or "enduring understandings" that it aims to address.

Based on the essential questions intended from each lesson, it seems that each lesson included the *critical thinking and reflection* element, as shown in the relatively high percent occurrence of *critical thinking and reflection* across nine lessons. It ranked first once, second five times, and third in three lessons compared to other elements of AC (see Table 3.3).

Contrary to my expectation, *planning and action experiences* occurred highest in lesson 6 and in the Objectives and Background Information sections of the Unit. This suggests that *planning and action experiences* remained largely as an objective and less as actually giving students opportunities to plan and take action. Table 3.4 shows *planning and action experiences* appear less frequently in the Procedures and Assessment Option where I expected to see more occurrences of *planning and action experiences*. It is also important to mention here that, although *planning and action experiences* occurred strongly in the Background Information section, these occurrences actually mostly provided suggestions for people in general. This means the Unit lacked specific ideas or opportunities through which students could actually plan and develop an action strategy toward an environmental problem or issue of interest.

Although the text below from Lesson 3: "Do you know your watershed?" indicated *planning and action experiences*, the question does not help identify specific planning activities and actions for students; it provides only general planning and action items.

> *Discuss the following questions to encourage students to carefully examine the hydrographs and the varying streamflow for the different rivers.*
>
> *Why do we need to know how much water is flowing in a stream or river?*
>
> *By knowing streamflow, we can:*
>
> - *Predict flooding and potential threats to human health, property, and safety*
> - *Identify streams with adequate year-round streamflow to support different species of fish*
> - *Identify appropriate building sites that won't be damaged by flooding*
> - *Aid navigation*
> - *Determine potential for different forms of recreation*
> - *Predict potential for pollution impacts*

Across the lessons, I found two noteworthy things. First, the overall percent of AC occurrence (not individual AC elements) occurred lower in lessons 1 through 4 compared to lessons 5 through 9. Second, the overall percent occurrence of AC occurred significantly less in lessons 3 (3.8%) and 1 (5.1%) compared to the other lessons. There are two possible explanations for the first observation. First, the complexity of the lessons increased from beginning to end, so one might expect more use of AC toward the end of the curriculum than in the beginning. Based on the essential questions in each lesson, it appears that the earlier lessons (1 through 4) focused more on knowledge and understanding whereas lessons toward the end (5 through 9) focused more on skill development, application of knowledge, analysis, and/or synthesis.

The length of the lessons provides a second possible reason for the variability in the overall percent occurrences of AC, particularly the number of pages from Objectives → Standards and Benchmarks → Background Information → Procedures → to Assessment Option. Perhaps the longer the lesson, the greater the opportunity to include AC, although admittedly, this did not seem to hold true for all lessons. Lessons 1 through 4 all had seven pages and they had lower percent occurrence of AC than Lessons 5 and 7, which each had ten pages, and lessons 6 and 8, which each had eight pages. Number of pages did not seem to influence percent occurrence of AC in Lesson 9, which despite having only seven pages, had virtually the same percent occurrence of AC as in lessons 5 and 7. It is not clear whether the fact that lesson 9 is essentially an integration of all the learning that students gained from the previous lessons influenced the relatively higher percent occurrence of AC in this lesson compared to lessons 1 through 4.

The considerably lower percent occurrence of AC in lessons 1 and 3 may be attributed to the nature of the topics within the lessons and the objectives of the lessons, aside from being the earlier lessons in the Unit (discussed above). As shown in Table 3.1, lessons 1 and 3 occurred to focus primarily on facts and *definitions* compared to the other lessons. A similar pattern emerges in the objectives of the lessons below. Except Objective #3 in Lesson 1, all the other objectives focus on providing students with *definitions* and facts, which, I would argue, does not provide strong applications of AC.

Lesson 1

1. *Define basic terms and processes associated with the hydrologic cycle.*
2. *Describe the distribution and availability of freshwater and saltwater on Earth.*
3. *Discuss the importance and responsibility of living next to the Great Lakes.*

Lesson 3

1. *Define and apply the following terms: watershed, sub-watershed, headwaters, mouth, drainage divide, streambanks, runoff, floodplain, meander, streamflow/stream discharge, main channel, and tributary.*
2. *Locate their local watershed and identify the Great Lake into which it flows.*
3. *Describe how the size of a watershed and the local weather affect the quantity of water in a stream, river, or lake.*

Other than *knowledge/insight*, it is difficult to identify any patterns of findings from the individual elements of AC; they occurred high in some lessons and low in others. Examples are: percent *commitment* (17.9%) and percent *visions* (7.1%) were highest in lesson 1, but percent *planning and action experiences* (10.7%) was lowest in lesson 1; percent *knowledge/insight* (66.7%)

was highest in lesson 3, but percent *visions* was lowest in lesson 3 (no occurrence) and percent *critical thinking and reflection* was lowest in lesson 3 (14.3%). This may suggest that individual elements of AC are difficult to develop equally in just one lesson.

The distribution of individual elements of AC also varied in strength across different sections of the Unit, as shown in Table 3.4. For example, although *knowledge/insight* consistently occurred the most compared to the other AC elements in each of the five sections, it was highest in the Background Information. *Visions* and *commitment* occurred the most in the Assessment Option; *planning and action experiences* occurred the most in the Objectives; and *critical thinking and reflection* occurred the most in the Procedures. The variability in extent of occurrence of individual elements of AC in each lesson as well as in each section of the curriculum suggests that, to increase the likelihood of using the curriculum as a tool to help foster AC in students, one needs to use all lessons in the curriculum and not only select a few to teach, which is what many teachers do. This might prove critical as, according to Jensen (2000b), one cannot talk of action competence if one individual element is not present. In other words, a synergy of individual elements needs to happen to develop AC. This implies a need to revisit the curriculum to incorporate and strengthen the elements of AC, as well as a need to inform professional development and teacher education programs of the need to use the curriculum entirely – holistically – to maximize the possibility of fostering students' AC.

3.5 ASSOCIATIONS AMONG PEDAGOGICAL APPROACHES, INSTRUCTIONAL METHODS, AND STUDENT SKILLS

The three most prevalent pedagogical approaches were *activity-driven*, *didactic*, and *didactic-with-application*. These approaches occurred alongside the three most prevalent elements of AC, namely *knowledge/insight*, *critical thinking and reflection*, and *planning and action experiences*. In terms of instructional methods, *didactic questions* and *definitions* accompanied the approaches and AC elements listed above. Finally, *critical thinking* and *inferring/interpreting* occurred as two most prevalent student skills.

Findings above may suggest the following:

1) *Activity-driven*, *didactic*, and *didactic-with-application* approaches are associated more with the occurrence of *knowledge/insight*, *critical thinking and reflection*, and *planning and action experiences*, and therefore, may likely explain the weak distribution of *commitment* and *visions* across nine lessons in the Water Quality Unit.
2) The two instructional methods listed above occurred to be more coherent with *didactic* and *didactic-with-application* approaches and *knowledge/insight* and *critical thinking and reflection* elements of AC than with the *activity-driven* approach or *planning and action experiences* element of AC. An *activity-driven* approach may be more likely associated with *planning and action experiences*.
3) The two most prevalent student skills were process skills even though a *process-oriented* approach was not the topmost approach used in the Unit. This possibly suggests that these skills may be fostered just

as likely by *activity-driven*, *didactic*, and *didactic-with-application* pedagogical approaches as by a *process-oriented* approach. Presence of these skills may likely influence presence of *knowledge/insight*, *critical thinking and reflection*, and *planning and action experiences* elements of AC.

3.6 CONCLUSIONS AND RECOMMENDATIONS

This study examined the types of and extent that pedagogical approaches, instructional methods, student skills, and elements of AC were used in the Water Quality Unit of MEECS. Additionally, this study also identified associations among approaches, methods, or skills and elements of AC. Findings showed that the Water Quality Unit focused more on *knowledge/insight*, *critical thinking and reflection*, and *planning and action experiences* elements of AC than on *commitment* or *visions*, with *knowledge/insight* receiving the first priority across nine lessons. This study also found that the Unit focused more on *knowledge of effects, knowledge of causes,* and *general awareness of environmental problems* compared to *knowledge of change strategies* and *knowledge of alternatives and visions.*

While *knowledge/insight* is a prerequisite to developing students' capacity for action, proponents of AC say it is not enough. The overwhelming focus on *knowledge/insight* and *knowledge of causes, effects, and general awareness* – and the lack of attention on *commitment, visions, knowledge of change strategies, and knowledge of alternatives and visions* suggest that the Water

Quality Unit is less likely to develop AC in students. To improve its chance of fostering AC, incorporation and use of the less represented elements of AC have to be strengthened. This may require a reexamination of the goals and objectives of the Unit and a reconsideration of the "big ideas" or "enduring understandings" that it aims to address. Additionally, *knowledge of causes* also should include aspects of how social structures and cultural practices contribute to environmental problems around us as these topics were hardly talked about in the Unit. Similarly, the Unit also needs to provide specific ideas or opportunities for students to do real planning and take action, and not only talk about what people in general could do.

Findings also showed that *knowledge/insight*, *critical thinking and reflection*, and *planning and action experiences* are associated more with *activity-driven*, *didactic-with-application,* and *didactic* approaches than others. The lack of or weak use of other pedagogical approaches may have influenced the weak appearance of *commitment* and *visions* elements of AC in the Unit. Consequently, to increase use of *commitment* and *visions*, the Unit may need to strengthen its use of approaches other than the top three listed above.

This study also found that the Unit used a plethora of instructional methods to deliver lessons, but the two most prevalent were *didactic questions* and *definitions*. These methods occurred more coherent with *didactic* and *didactic-with-application* approaches and with the *knowledge/insight* and *critical thinking and reflection* elements of AC than with *activity-driven* approaches and the *planning and action experiences* element of AC. Similarly, these findings suggest that the Unit needs to expand the range of methods used in teaching the lessons to encompass different elements of AC.

The two most prevalent student skills in the Unit were *critical thinking* and *inferring/interpreting*. These skills seemed more coherent with a *process-oriented* approach, but these skills appeared to generally support the occurrence of the *critical thinking and reflection* and *planning and action experiences* elements of AC. Finally, this study found that the extent of use of individual elements of AC varied across the Unit, which suggests that to increase teachers' likelihood of developing AC in students using the Unit, they (teachers) would need to teach all lessons.

These findings and recommendations may help inform future designs of EE and/or Science curricula for K-12 schools in Michigan aimed at developing AC in students as well as improve teacher education programs to better prepare teachers in Michigan how to use AC-oriented EE curricula.

3.7 LIMITATIONS OF THE STUDY

Findings from this study may be unique to the Water Quality Unit and, therefore, cannot be generalized to other EE curricula or to other MEECS Units. Inter-rater reliability could not be calculated because I was the sole coder of data and there was no other person that checked for consistency of coding.

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CHAPTER 4

SURVEY OF MICHIGAN ENVIRONMENTAL EDUCATION CURRICULUM SUPPORT (MEECS) TRAINING PARTICIPANTS: PCK AND ACTION COMPETENCE

ABSTRACT

Self-administered mail and web surveys were conducted to examine pedagogical content knowledge (PCK) and use of action competence (AC) of MEECS training participants. One hundred thirty one participants responded (28.4%); 88.5% were from public schools (n=131), 67.8% were women (n=115), and 36.5% were between 50 and 60 years old (n=115). Seventy eight percent of the respondents taught science (n=131), 87% taught 9th through 12th grade (n=131), and 66.4% were trained in the use of Water Quality Unit. Note that these % values include people who taught other subjects or grade levels, and were trained in other Units.

Elements of PCK (*goals and beliefs about teaching science, pedagogical approaches, instructional methods, and student skills foci*) and use of AC were examined using content analysis. Combining instances from both surveys, the most prevalent categories of goals and beliefs of respondents were *attitude/behavior change* (18%), *skill development* (12.5%), *global/real world connections* (12.5%), and *student development* (12.3%). The most prevalent elements of AC were *commitment* (45.2%) and *planning and action experiences* (39.3%). This unequal use of AC elements in the classroom and the lack of attention to *critical thinking and reflection* and *visions* may ultimately affect the ability of MEECS teachers to develop AC in their students.

AC was not represented by all the goals and beliefs in the surveys. Of all the occurrences of AC, 21.4% was found in *global/real world connections*, 17.4% in *social reform/citizenship*, and 17.4% in *student development*. Combining

instances from both surveys, the most prevalent pedagogical approaches were *activity-driven* (32%), *discovery/exploration* (18.1%), *didactic* (14.1%), *project-based* (12.1%), and *process-oriented* (11.6%); the most prevalent instructional methods were *hands-on activity* (10.9%) and *cooperative learning/group work* (10%); and the most prevalent student skills were *critical thinking* (26.6%), *investigation/research* (15.6%), and *problem solving* (10.2%).

Some goals and beliefs were embodied in more than one pedagogical approach, instructional method, or skill, and vice versa. However, in some instances, these variables appeared incongruent with each another, suggesting that they do not always predict each other's occurrence. *Project-based* and *discovery/exploration* approaches seemed to be associated with the high occurrence of *commitment,* and *activity-driven* approach to *planning and action experiences.* To increase use of AC, EE curricula need to include elements of AC and use approaches and methods that are associated with AC. Teachers need to be open to these kinds of pedagogical approaches and methods, and learn to negotiate for or address barriers or constraints in their teaching context.

4.1 INTRODUCTION

One of the main goals of environmental education (EE) is to cultivate environmental stewardship in students (Wheeler & Thumlet, 2007). Numerous studies have investigated the impact of EE on what researchers consider aspects or elements of stewardship, such as knowledge, attitudes, and behaviors (Dettmann-Easler & Pease, 1999; Dimopoulos & Pantis, 2003; Ferguson *et al.*, 2001; Hsu, 2004; Hungerford *et al.*, 1990; Hwang *et al.*, 2000; Kruse & Card, 2004; Leeming *et al.*, 1997; NEEAC, 2005; Roth, 1992; Volk & Cheak, 2003; Wheeler & Thumlet, 2007). Another important aspect of understanding the effects of EE is to examine the educators, particularly what they teach, how, and why, as this would add to our knowledge about the relationships and processes that occur between educators or teachers and students. But studies that specifically ask such questions are limited (Hart, 2003).

In this chapter, I address my research question #2: "To what extent does teachers' pedagogical content knowledge in using science and environmental education curricula represent elements of action competence?" To address this question, I first determined how representative my surveyed MEECS teachers were of the overall participants of MEECS training in 2006-2007. Then, I examined the "how" and the "why" of teaching of those who participated in the MEECS training between 2006 and 2007. I identified the elements of pedagogical content knowledge (PCK) and action competence (AC) found in the MEECS teachers' goals and beliefs about teaching science and their descriptions of their nature of instruction. I reported on patterns of approaches, methods, and skills that were more prevalent and were associated with certain elements of AC. I also discussed implications for teacher education and professional development.

4.2 METHODS

4.2.1 Selection of Respondents

I chose the MEECS of the many EE curricula because it is Michigan-specific, is aligned with the Michigan science and social studies curriculum framework benchmarks and standards and the Grade Level Content Expectations for 4th grade through high school, and is endorsed by the Michigan Department of Education. I obtained a list of MEECS training participants from the Michigan Department of Environmental Quality (MI-DEQ), which was the agency that sponsored, funded, and guided the development of MEECS. I then verified mailing and email addresses of the participants by checking the staff list from the school's (or any listed affiliation's) website. I excluded all names that did not appear on the staff list or those which could not be traced because the school did not have a website or did not have a staff list online. I also excluded names that were not affiliated primarily with K-12 schools and others that could not be verified or traced. Due to limited resources, I used only 129 names for the mail survey; I used web-based technology to reach an additional 421 individuals who had verifiable email addresses.

4.2.2 Data Collection Tools

I collected data using self-administered mail and web surveys. I chose both methods for their flexibility, versatility, ability to reach large samples of respondents in relatively short periods of time, and relatively low cost compared with interviews or telephone surveys (Alreck & Settle, 2004). Besides reducing the cost and time for data collection and analysis, use of web surveys has gained popularity in recent years because the internet is widely used by different demographic groups (Alreck & Settle, 2004; Hogarty *et al.*, 2003). Some researchers have identified issues in the use of web surveys (or other online modes of delivery), including response compatibility between web survey and mail survey (Arnau *et al.*, 2001 cited in Hogarty *et al.*, 2003), representativeness of sample (Dillman, 2000; Dillman *et al.*, 1998), variation in computer literacy of respondents, and individual access to computers (Dillman *et al.*, 1998). However, Alreck & Settle (2004) suggested that web surveys are particularly effective for individuals who hold educational and scientific occupations and those who will be reached at work, both of which were characteristics of my sample.

4.2.3 Survey Instruments

Prior to its final printing and use, the survey instrument was reviewed and piloted by 12 individuals having teaching experience and/or expertise in environmental education, assessment, or survey research, including university faculty (3 from Michigan State University and one from North Carolina State University), graduate students (4), elementary school science teachers (2), and environmental educators (2). Before I finalized the survey, I used their suggestions and feedback to make the survey more teacher-friendly (i.e., used language that teachers would use), to check the clarity of the survey, and to check whether questions actually asked what I had intended.

Both versions of the survey consisted of 22 items that included: demographic information (e.g., age, gender, highest education level), school context (e.g., name of school, district, type of school, community where school is located), other background information about the participants (including grade levels and subjects taught, and number of years teaching), and MEECS training participation and classroom use (units trained, past and current use, date of start of use).

In addition to demographics and participant use information, I also asked respondents about their goals for teaching science ("What is/are your primary goal/s as a teacher?"), beliefs about teaching science ("What do you think teaching should be about?") and the nature of their instruction ("How would you describe or characterize the nature of your instruction?") to examine their teaching orientations. I developed these questions based on the works of Magnusson *et al.* (1999), Loughran *et al.* (2004), Lee *et al.* (2007), and Mulhall *et al.* (2003). See Appendices D.1 and D.2 for details of the mail and the web surveys.

4.2.3.1 Mail Survey

Altogether, I mailed 129 surveys in October and November, 2007. I sent the mail surveys in two batches, 98 in the first batch and 31 in the second batch (see Table 4.5). Modifying Dillman's (2000) suggestion to mail a pre-notice, I emailed a pre-notice letter to MEECS participants three days prior to survey mailing. The pre-notice letter asked for participation and included the purpose of the survey, number of items in the survey, and why respondents' participation was important for the study. The survey mailing included a cover letter, the questionnaire, and a self-addressed return envelope. The cover letter reiterated the purpose of the survey, how respondents were selected, informed consent language for human subjects research requirements, number of survey items, and instructions for completing the survey. The cover letter also mentioned that, at the end of the survey, respondents would be asked to provide their contact information if they would be interested in participating in the next phase of the study (classroom observations). Due to lack of funds, I did not send follow-up mailings. I sent reminder emails two, three, and four weeks after the mailing. I also sent thank you emails to all mail survey respondents.

4.2.3.2 Web Survey

I created the web survey through the online tool called Survey Monkey. I sent 421 web links via email between February and April, 2008 (see Table 4.5). This contact included individuals who did not respond to the mail surveys <u>and</u> had verifiable email addresses. I also emailed MEECS training participants a pre-notice letter three days prior to emailing a cover letter and the web link to complete the survey. I used the same language as in the pre-notice letter and cover letter for mail survey respondents. Using Survey Monkey, I tracked who had responded and when. I sent reminder emails to those who had not responded up to four times after the first email invitation. Those who opted out or those who had undeliverable emails (due to wrong or invalid address or full inboxes) did not get further reminders. I also sent thank you emails to all web survey respondents.

4.2.4 Variables of Interest

4.2.4.1 Pedagogical Content Knowledge (PCK)

Pedagogical content knowledge is the integration of individual knowledge domains (e.g., subject matter knowledge, pedagogical knowledge, and knowledge of student learning) that enable a teacher to teach a topic to a particular group of students in a way that helps students relate to the topic and helps them understand and learn effectively (Cochran, 1997; Gess-Newsome, 1999; Loughran *et al.*, 2001; Loughran *et al.*, 2004). In this portion of my study, I examined these elements of PCK: 1) teaching orientations, 2) instructional methods, and 3) subject matter knowledge.

4.2.4.1.1 Orientations Toward Teaching Science

Schwarz & Gwekwerere (2007) used "teaching orientations" interchangeably with "pedagogical approaches," but I divided orientations toward teaching science into (a) goals and beliefs for teaching science at a particular grade level (Magnusson *et al.,* 1999) and (b) pedagogical approaches. This is similar to what Friedrichsen & Dana (2005, p. 225) did, where they looked at the goals as well as the *means* (teachers' purposefully selected and visible use of curricula and instructional and assessment strategies) to characterize teaching orientations. Goals and beliefs serve as a conceptual map for teachers' instructional *decision making* (Grossman, 1990).

1) Goals and Beliefs

Various terms are used to define goals (e.g., aims, objectives, principles, and standards) and beliefs (e.g., conceptions, implicit theories, and orientations), and the terms have been used interchangeably. I referred to teaching goals as teachers' purpose for teaching science, or what they expect to accomplish, thereby providing direction for them (Ornstein & Sinatra, 2005, p. 113). I referred to beliefs as teachers' conceptions or views about teaching science and what it means to teach. Beliefs may be thought of as a broader concept than goals (Cox, 2004, p. 4; Lam & Kember, 2006; Pratt, 1992). Together, goals and beliefs are believed to guide teachers' day-to-day decisions about what and how to teach (Grossman, 1990; Lam & Kember, 2006). Table 4.1 lists the goals and beliefs that I used for coding.

Table 4.1. Categories of Goals and Beliefs of Teachers about Teaching Science

Final list of goals and beliefs categories (categories with asterisks were *a priori* categories, which I adapted from Magnusson *et al.* (1999, pp. 100-101); those without asterisks emerged from the data)

1) Academic Rigor* - represents a particular body of knowledge; challenges students with difficult problems and activities to verify science concepts

2) Activity-Driven* - engages students in hands-on activities, or gives them a task to work individually or in groups

3) *Attitude/Behavior Change** - influences students' attitudes or behavior; helps students identify their own and other people's attitudes, values, feelings, or views toward environmental issues or problems

4) Conceptual Change* - facilitates the development of scientific knowledge by confronting students with contexts that challenge their naïve conceptions

5) Discovery/Exploration* - provides opportunities for students to discover targeted science concepts on their own

6) Guided Inquiry* - establishes a community of learners (e.g., students and teacher) in understanding the physical world using the tools of science; teacher and students define and investigate a problem, testing explanations, evaluating validity and utility of data and adequacy of conclusions

7) Inquiry* -represents science as *inquiry*; engage students in defining and investigating problems, drawing conclusions, and assessing the validity of knowledge from their conclusions

8) Knowledge Acquisition* – I called this "knowledge/awareness" in my initial list; also found by Trigwell & Prosser (1996); helps students acquire knowledge or increase awareness of environmental issues or problems, or activities and events around them

9) Project-Based* - involves students in investigating solutions to authentic problems

10) *Skill Development**[1] – develops of skills

11) Didactic* - transmits the facts of science, content, benchmarks/standards

12) Career benefits/Teacher Development – obtains professional development or growth

13) Content/Subject Matter - considers content beyond/other than what is required in the curriculum

14) Education of Students – educates students in general

15) Global/Real World Connections - provides students with meaningful, relevant experiences to help understand connectedness, interrelationships, and interdependence between people, the world, and the environment

16) Humanistic - serves students, helps students meet their needs besides academic needs

Table 4.1 Continued:

17) Improvement of pedagogy - increases/develops knowledge of teaching strategies/methods and increase subject knowledge to improve instruction

18) Learning - provides a stimulating, fun, engaging, safe, and respectful learning environment; shows different ways to learn

19) Modeling ways of being – serves as a positive influence to students; shows students appropriate behaviors; the teacher exemplifies the values and knowledge to be learned (Pratt, 1992)

20) Social Reform/Citizenship – focuses on a macro perspective of seeking a better society, and acknowledging that everyone is responsible to help improve society [also found in Pratt (1992)]

21) Student Development - develops students' capacity to become active participants in society, in addition to developing specific skills

22) Teacher-Student/Student-Student Relationships - fosters relationships with students and encourages students to make good relationships with others

23) Visioning - provides students with opportunities to think about what they want their future to look like and to set goals

[1] *Science Process Skills are a part of Magnusson et al.'s (1999) nine teaching orientations for science. To put all skills into one category, I combined Science Process Skills with other skills in the Skill Development category instead of treating process skills as a separate category.*

2) Pedagogical Approaches

Approaches are beliefs put into practice (Lam & Kember, 2006, p. 694). Friedrichsen & Dana (2005, p. 228) used a related term called "means," which is the purposeful selection and use of curricula and instructional and assessment strategies. They argued that means are an essential component of representing teaching orientations because they provide a more complete picture of an individual's science teaching orientation. In this study, I adapted the nine pedagogical approaches described by Magnusson *et al.* (1999, pp. 100-101) and Schwarz & Gwekwerere (2006, pp. 182-184), namely, 1) academic rigor, 2) *activity-driven*, 3) *conceptual change*, 4) *didactic*, 5) *discovery/exploration*, 6) *guided inquiry*, 7) *inquiry*, 8) *project-based*, and 9) *process-oriented*. I added 10) *didactic-with-application*. Table 4.2 lists the pedagogical approaches I used for coding.

4.2.4.1.2 Instructional Methods, Representations, or Strategies

This element of PCK includes subject-specific or topic-specific strategies (Magnusson *et al.,* 1999), or the most useful forms of representation of topics, analogies, examples, illustrations, explanations, and demonstrations used in teaching (Shulman, 1986). Instructional methods are specific ways that teachers use to create learning environments and to specify the nature of a lesson or an activity in which the teacher and the students will be involved during class.

Table 4.2. Pedagogical Approaches

1) *Academic Rigor* – Students are challenged with difficult problems or activities. The teacher uses laboratory work and demonstrations to verify science concepts by demonstrating the relationship between particular concepts and phenomena. The activity often poses a challenge to students. Students may try to solve the problems after they have seen an example from the teacher or using their previous knowledge or experience.

2) *Activity-Driven* – Students participate in a *hands-on activity* or, if not, are given a task to work individually or in groups to help them verify or discover a concept. Hands-on activities require students to be actively involved and engaged with objects, materials, technology, or laboratory equipment/tools and manipulate these for the purpose of learning by experience instead of being passive learners (Flick, 1993; Meinhard, 1992). The teacher gives students equipment/materials and directions/ procedures to complete an activity. In most cases, the teacher tells students what they are supposed to see or learn. It must be noted here that Schwarz & Gwekwerere (2007) and Magnusson *et al.*, (1999) included only "hands-on" activities in their *activity-driven* category, but I included non-hands-on activities (e.g., the whole class classifying a list of items found in kitchen cupboard; a pre-reading activity) in this category as well.

3) *Conceptual Change* – Students are pressed for their views about the world and consider the adequacy of alternative explanations. The teacher facilitates dialogue, discussion, or debate necessary to establish valid knowledge claims. The teacher draws out and assesses prior knowledge of students before presenting a new concept. An activity is then used to help students change their naïve conceptions. The teacher compares students' ideas before and after the activity or lesson.

4) *Didactic* – The teacher presents information generally through lecture, discussion, demonstration, or films. Scientific models may be used for demonstration, illustration, or verification. Questions are directed to students to hold them accountable for knowing facts. The focus is on delivery/transmission of content/facts.

5) *Discovery/Exploration* – This approach is student-centered. Students explore the world following their own interests and discover patterns of how the world works during their explorations. A teacher might scaffold students' explorations depending on students' abilities (or lack thereof), and might ask students to share their "discoveries" later in class.

6) *Guided Inquiry* – This learning is community-centered. Teacher and students work together 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.

7) *Inquiry* – This approach is investigation-centered. The teacher supports students in defining and investigating problems, drawing conclusions, and assessing the validity of knowledge from their conclusions. Questions or problems for investigation come either from the teacher or students. Students do most of the thinking and figure out how to investigate the problem with the teacher's support and help with correcting explanations or applications. Usually, students follow the traditional scientific method when attempting to solve a problem (ask a question, do background research, make a hypothesis, create an experiment to test a hypothesis, collect and analyze data, draw conclusions, and report findings).

Table 4.2 Continued:

8) *Project-Based* – This approach is project-centered. Teacher and student activity centers on a "driving question" that organizes concepts and principles and drives activities within a topic of study. Students then do a project (their choice or from a selection of ideas/options from the teacher) individually or collectively in which they need to do an investigation or research/collect information and develop artifacts or products (e.g., brochures, reference books, posters, or dioramas) that demonstrate their emerging understanding. Students might present their product to the class or their work might get posted on the wall.

9) *Process* – The teacher introduces students to the thinking processes adopted by scientists to acquire new knowledge. Students engage in activities (e.g., laboratory experiments, *problem solving*) to develop integrated thinking skills. Examples of these process skills include observing, classifying, measuring, inferring, and *predicting.*

10) *Didactic-With-Application* – I considered this approach differently from a *didactic* approach. In addition to the features of a *didactic* approach, the teacher provides real world examples or applications of a concept or asks students to identify real world scenarios in which they could apply what they learn.

Adapted from Magnusson et al., 1999, pp. 100-101

4.2.4.1.3 Subject Matter Knowledge

This element of PCK includes knowledge of the nature of science, scientific processes, and relationships among various areas in science (Lee *et al.,* 2007). My study did not actually attempt to measure respondents' knowledge of subject matter (or approaches or methods). Instead, I asked respondents to describe or identify the skills to which they sought to expose their students. I wanted to determine whether any pattern existed between and/or among pedagogical approaches, methods, goals, and beliefs about teaching science. I assumed that student skills were directly related to or appropriate for the content being taught.

4.2.4.2 Action Competence (AC)

Although studies in the past 30 years predominantly focused on the impacts of EE curricula on students' knowledge, attitudes, and behaviors as indicators of environmental stewardship, environmental literacy, or responsible environmental behaviors, I looked beyond these variables and examined the extent to which an EE curriculum shows characteristics of AC. This study used the AC concept as an alternative framework because I believe there is a need to go beyond knowledge, attitudes, and behaviors when assessing an EE curriculum, albeit these are important impact variables (Dimopoulos & Pantis, 2003; Hockett *et al.,* 2004; Hsu, 2004; Orams, 1997). Table 4.3 lists the elements of AC I used for coding.

Table 4.3. Elements of Action Competence

1) *Knowledge/Insight* – the literature suggested four types, but I added an emergent type (see item "e" below).
    a) *Effects* – what kind of problem is it?
    b) *Causes* – why do we have this problem?
    c) *Change Strategies* – how can we change things (personal, societal levels)?
    d) *Alternatives and Visions* – what can be done about the problem and where do we want to go?
    e) *General Awareness of Environmental Problems or Issues, or Importance of Environmental Resources* – I referred to this is as simply knowing that an environmental problem or issue exists, but not knowing more (the causes, effects, the depth and range of a problem or issue, etc.)

2) *Commitment* – relates to promoting students' motivation, *commitment*, and drive to get involved in solving environmental problems; extent that students are ready to act to realize their vision; includes understanding their own and others' attitudes and values toward issues.

3) *Critical Thinking and Reflection* – includes thinking about and assessing complex and multiple causes of problems; social and political contexts of a problem, and possible solutions; weighing pros and cons of an environmental issue; recognizing different points of view and challenging current practices and beliefs; and questioning values, perceptions, conditions, and opinions (also by Kyburz-Graber, 1999, p. 416).

4) *Visions* – developing students' ideas, dreams, and/or perceptions about how they can improve their future lives and society.

5) Planning and Action Experiences – providing students with concrete, real- life experiences in planning and acting on environmental issues or problems; students are given opportunities to develop skills and confidence to identify and solve problems, set goals, gather information, communicate, and manage time and logistics to take action.

Adapted from Jensen & Schnack, (1997), Jensen (2000a), Mogensen (1997), Eames et al. (2006), and Breiting & Mogensen (1999)

4.2.5 Data Analysis

4.2.5.1 Quantitative Analysis

I used SPSS version 15.0 for all quantitative analyses. See Table B.1 for a summary of Chi Square results. To test for non-response bias – the extent to which those non-responding to surveys are systematically different from the whole population (Fowler Jr., 2002, p. 41) – I compared percent occurrences in age group, gender, education level, primary goals and beliefs about teaching science, and instructional methods of those who did not respond to the mail survey but responded to the web survey AND those who responded to the mail survey. I also used Chi Square statistics to test for significant differences ($p \leq 0.05$) in age group, gender, and education level between respondents and non-respondents.

I faced significant challenges when I attempted to determine the representativeness of my survey respondents of the 2006-2007 population of MEECS training participants. No general data regarding characteristics of the general MEECS population exist. Thus, I did not conduct any statistical tests to compare my survey respondents' results with MEECS training participants.

4.2.5.2 Qualitative Analysis

I used Atlas.ti version 5.2 for content analysis to code the goals and beliefs of survey respondents as well as their pedagogical approaches, instructional methods, and student skills. This technique involved coding and categorizing qualitative responses based on explicit rules of coding (Krippendorff, 1980; Strauss & Corbin, 1998; Weber, 1990). Survey respondents were the units of analysis and they were characterized through their goals and beliefs and nature of instruction, which were the units of observations. Recording units, or the texts that were assigned a category label (GAO, 1996), consisted of words, phrases, or sentences.

Coding Process

To code for pedagogical approaches, instructional methods, student skills, and elements of AC, I used the *definitions* shown in Tables 4.2 (approaches) and 4.3 (AC). For instructional methods and skills, I also added new categories as they emerged. Prior to coding for goals and beliefs, I developed categories (groups of words having similar meanings or connotations (Weber, 1990, p. 37)) from the works of Magnusson *et al.* (1999) and Schwarz & Gwekwerere's (2007) (see Table 4.1). Subsequently, I added *knowledge/awareness*, *attitude/behavior change*, and *critical thinking skills* to the list of categories because these are some of the more common measures of impacts of environmental education on students. These twelve categories served as my initial list for coding.

During the rounds of coding, new categories emerged, and I added these to the initial list (emergent coding). For example, *skill development* was one of the most commonly cited goals and beliefs, so I made this into a separate category. Also, I combined all types of *skill development* such that, in the revised list of goals and beliefs categories (see below), "science process skills" and "*critical thinking skills*" were a part of *skill development* category instead of being separate categories. I treated several other emergent categories as separate categories. After reorganizing and regrouping categories, I developed a final list of goals and beliefs categories, which I used in the final coding and analysis of responses in both mail and web surveys. The categories with asterisks were from Magnusson *et al.* (1999).

For the first round of coding, I read responses twice, and on the third time, I started coding recording units (word, phrase, sentence, or groups of these) by examining both manifest and latent contents of goals/beliefs, pedagogical approaches, instructional methods, and student skills of web survey respondents and then of mail survey respondents. Manifest content is the visible, surface content, and latent content is the underlying meaning (Babbie, 1992). According to Babbie (1992), coding for both increases reliability and validity. Moreover, repeating the coding process three times for each question allowed for checking mistakes and to ensure that data were coded the same way in all three rounds, thereby increasing intra-rater reliability (Weber, 1990). Then I read responses again twice and coded for emergent categories, that is, those not previously on the list. I added any new categories to the growing list until no new categories were identified.

After coding for goals and beliefs, I assigned them to the five elements of AC, namely, *knowledge/insight, commitment, visions, critical thinking and reflection,* and *planning and action experiences*, using a set of criteria (see Appendix C.1) that I developed based on the works of Breiting & Mogensen (1999), Jensen & Schnack (1997), Jensen (2000), Mogensen (1997), Eames *et al.* (2006), Barrett (2006), Fien & Skoien (2002), and Wals (1994). Thus, when coding I asked, "What elements of AC does each of the goals and beliefs represent or embody?" The decision on whether a primary goal or belief represents or embodies AC depended on how strongly it matched, represented, or embodied the characteristics of AC that I compiled from the literature (see Appendix C.1).

I assigned multiple codes to some responses because they had multiple meanings. For example,

> Respondent #9, Water Quality web group:
>
> *"To provide a safe inclusive environment that inspires lifelong learners"* was coded as both <u>develop/instill positive attitudes toward learning/education (ATTITUDE/BEHAVIOR CHANGE)</u> and <u>provide/create fun/safe learning environment (LEARNING).</u>

For responses in which more than one goal/belief, approach, method, skill, or AC element was described, I counted each goal/belief, approach, method, skill, or AC element separately if each had a different context, even if, in some instances, I assigned them the same code; if the goal/belief, approach, method, skill, or AC element was in the same context, I counted them as one instance. For example,

> Respondent #7, Ecosystem and Biodiversity web group:
>
> *"I want children to be equipped to understand the world they live in, to have knowledge and resources that will help them to make responsible life choices, and to understand how interdependent we are - to each other, and to our environment. I want to help them acquire the tools they need - reading, writing, math concepts, knowledge of the world and environment they live in."*

Coding:

"I want children to be equipped to understand the world they live in..." = Facilitate understanding *of the world in general* (one context) → counted as one instance

"...to understand how interdependent we are - to each other, and to our environment." = Facilitate understanding *of connection/interdependence between people and between people and the environment* (another context) → counted as another instance

"...to have knowledge and resources... knowledge of the world and environment they live in." = Help students to acquire knowledge or awareness → counted as one instance because they had the same context (knowledge of the world and environment)

that will help them to make responsible life choices = help students make responsible/good/informed choices → counted as one instance

I want to help them acquire the tools they need - reading, writing, math concepts = develop academic skills → counted as one instance

Thus, from this single response, I assigned 4 different codes, but I counted 5 instances.

<u>Specific Nuances in Coding</u>

In coding for goals and beliefs, I did not make any distinction between what I call "primary" goal and "secondary" or the "recipient" goal, as described in the example below.

"...to have knowledge and resources that will help them to make responsible life choices..."

I call “to have knowledge and resources…” as the primary goal because the respondent thought knowledge and resources could help students “make responsible life choices,” a goal in itself but presumably could not be achieved without the primary goal. In the analysis, however, I coded both goals and counted them separately no matter their “order of importance.” I followed the same rule throughout the coding process.

In many cases, I based my coding for pedagogical approaches on the methods that the respondent provided, with very little or no description about how or why the method was used. Consequently, I went with what the literature said were methods more commonly associated with certain pedagogical approaches. Additionally, I used multi-coding to make sure that not one particular pedagogical approach was “favored.”

Table 4.4 shows the data sources I used for coding goals and beliefs, approaches, methods, student skills, and AC as well as the total number of instances and inconsistencies coded. During the last round of coding, I went back and reread the parts where I found the inconsistencies and recoded until all of my coding matched. After coding, I calculated the total frequencies and percent occurrences for each goal/belief, approach, method, skill, and element of AC in the mail and in the web surveys.

Table 4.4. Data Sources for Coding Variables of Interest, Number of Instances, and Inconsistencies in Coding

Variable of Interest	**Survey Question**	**Number of Instances Coded**	**Number of Inconsistencies in Coding**
Goals and Beliefs	What is/are your primary goal as a teacher? What do you think teaching should be about (your beliefs)?	472	7 (1.5%)
Pedagogical Approaches	How would you describe or characterize the nature of your instruction?	481	8 (1.7%)
Instructional Methods	How would you describe or characterize the nature of your instruction?	588	5 (0.9%)
Student Skills	What is/are your primary goal as a teacher? What do you think teaching should be about (your beliefs)? How would you describe or characterize the nature of your instruction?	128	2 (1.6%)
Action Competence	What is/are your primary goal as a teacher? What do you think teaching should be about (your beliefs)?	529	9 (1.7%)

Note: Some questions were used to capture multiple variables

4.3 RESULTS

4.3.1 Characteristics of Survey Respondents

One hundred thirty one MEECS training participants responded to the survey (28.4%) (see Table 4.5). Water Quality had the highest number of combined respondents (47.3%), even though this Unit had only the third largest number of trained individuals across Units in 2006-2007. The difference in distribution of respondents across Units between mail and web surveys was significant X^2 (4, N = 131) = 25.53, $p < 0.05$.

Comparison between respondents and non-respondents showed significant differences in age group (X^2 (4, N = 52) =18.96, $p < 0.05$), gender (X^2 (1, N = 52) = 6.23, $p < 0.05$), and education level (X^2 (2, N = 52) = 22.90, $p < 0.05$) (see Table A.1). Non-respondents had 19.4% more individuals younger than 40 years old, 32% fewer individuals 40 through 59 years old, and 13% more individuals 60 years old or older. In other words, respondents consisted more of middle-aged individuals (40 through 59 years old) whereas non-respondents consisted more of younger (up to 39 years old) and older (60 years and beyond). There were 7% more male non-respondents. Non-respondents had 9% fewer graduate degree holders compared to respondents.

Comparison between respondents and non-respondents' primary goals or beliefs about teaching showed percent differences between respondents and non-respondents ranged from 0.2 to 8.7 (see Table A.2). As with other comparisons in this chapter, I considered a 10% difference as substantial in cases where a statistical test was not performed. I concluded that there is no substantive difference between respondents and non-respondents in terms of primary goals or beliefs. In terms of instructional methods between respondents and non-respondents, percent differences ranged from 0.6 to 6.8, also less than 10% difference and therefore not considered substantial (see Table A.3). Thus, findings revealed that even though respondents and non-respondents were different in terms of age, gender and education level, the differences in their primary goals or beliefs about teaching and their instructional methods were not substantial enough (less than 10% difference) to conclude that they were systematically different. Thus, I concluded that the respondents were representative of the MEECS training participants of 2006-2007.

About 90% of respondents taught at public schools. As with other variables above, no data were available for school type where MEECS participants taught, but these findings were consistent with Michigan K-12 schools data; that is, a majority of Michigan's K-12 schools are also public (91.4%). The difference in distribution of school type among respondents in the mail and the web surveys was not significant X^2 (6, N = 131) = 2.65, $p > 0.05$.

About 68% of combined respondents were women. Difference in distribution of women and men between the mail and the web surveys was not significant X^2 (1, N = 115) = 0.06, $p > 0.05$. About 37% of combined respondents were 50 through 59 years old (n=115). Difference in age distribution of respondents between the mail and the web surveys was not significant X^2 (5, N = 115) = 6.75, $p > 0.05$. About 92% of combined respondents had a graduate degree (n=111). Difference in distribution of education level among respondents in the mail and the web surveys was not significant X^2 (2, N = 111) = 3.34, $p > 0.05$.

Seventy-eight percent of combined respondents (n=131) taught Science, but this percentage also includes those who taught other subjects. Difference in distribution of respondents teaching science in the mail and the web surveys was not significant X^2 (1, N = 131) = 3.50, $p > 0.05$. Eighty-seven percent of combined respondents taught 9th through 12th grade, but this percentage also includes those who taught also in other grade levels. Differences in distribution of respondents teaching at different grade levels between the mail and the web surveys were not significant, except in the 9th grade level X^2 (1, N = 131) = 4.51, $p < 0.05$. About 66% of combined respondents were trained in the Water Quality Unit, but this percentage also includes those who were trained in other units. Difference in distribution of respondents trained in Water Quality Unit between the mail and web surveys was not significant X^2 (1, N = 131) = 2.86, $p > 0.05$.

Table 4.5. Survey Response Rates

Mail Survey	Sent	Received	Response Rate (%)	
1st batch (10/23/07)	98	29	29.6	
2nd batch (11/10/07)	31	7	22.6	
Total	129	36	27.9	
Web Survey	Sent	Received (partial/complete)	Undeliverable	Response Rate (%)
WATER group	98	33 (4/29)	15	(33/83)*100 = 39.8%
AIR group	40	9 (3/6)	10	(9/30)*100 = 30%
ECO and BIO group	173	33 (5/28)	44	(33/129)*100 = 25.6%
LAND USE group	27	3 (0/3)	5	(3/22)*100 = 13.6%
ENERGY group	83	17 (3/14)	15	(17/68)*100 = 25%
Total	421	95 (15/80)	89	(95/332)*100 = 28.6%
Combined	Sent	Received		Response Rate (%)
Mail Survey	129	36	27.5	27.9
Web Survey	332	95	72.5	28.6
Total	461	131	100	28.4

4.3.2 Primary Goals and Beliefs about Teaching Science

Among web survey respondents, the most prevalent categories of goals and beliefs about teaching science were *attitude/behavior change* (18.5%, 67 instances), *student development* (15.5%, 56 instances), *skill development* (13%, 47 instances), and *global/real world connections* (11.9%, 43 instances) (see Table 4.6). In the mail survey, the most prevalent categories of goals and beliefs were *attitude/behavior change* (16.4%, 18 instances), *global/real world connections* (14.5%, 16 instances), *social reform/good citizenship* (11.8%, 13 instances), and *skill development* (10.9%, 12 instances). *Student development* gathered only 1.8% of instances in the mail survey. Combining instances from mail and web surveys, the four most prevalent goals and beliefs categories were *attitude/behavior change* (18%), *skill development* (12.5%), *global/real world connections* (12.5%), and *student development* (12.2%). Project-based goals and beliefs did not appear in any of the responses to either survey.

4.3.3 Action Competence

Of the 472 instances of primary goals and beliefs in the surveys (mail and web combined), 350 (74.2%) represented AC as a whole (not looking at individual elements of AC) (see Table 4.7). Of the 74.2%, the top five highest appearances of AC were the following: 21.4% of AC instances were found in the *global/real world connections* category of goals and beliefs, 17.4% in the *social reform/good citizenship* category, 17.4% in the *student development* category, and 12.7% in the *learning* category. In terms of occurrence of individual elements of AC, *commitment* was mentioned the most (45.2%), followed by *planning and action experiences* (39.3%), *critical thinking and reflection* (8.7%), *knowledge/ insight* (5.9%), and *visions* (0.9%) (see Table 4.8).

Table 4.6. Teachers' Goals and Beliefs about Teaching Science in the Mail and Web Surveys

	Mail Survey (n_1=36)		Web Survey (n_2=95)		Mail and Web Combined (n_3=131)	
Categories of teachers' goals and beliefs about teaching science	**Number of Instances**	**Frequency of Use (%)**	**Number of Instances**	**Frequency of Use (%)**	**Number of Instances**	**Frequency of Use (%)**
Attitude/Behavior Change	18	16.4	67	18.5	85	**18.0**
Global/Real World Connections	16	14.5	43	11.9	59	**12.5**
Improvement of Pedagogy	8	7.3	12	3.3	20	4.2
Knowledge Acquisition	7	6.4	11	3.0	18	3.8
Learning	7	6.4	27	7.5	34	7.2
Skill Development	12	10.9	47	13.0	59	**12.5**
Social Reform/Good Citizenship	13	11.8	33	9.1	46	9.7
Student Development	2	1.8	56	15.5	58	**12.3**
Didactic	8	7.3	13	3.6	21	4.4
Total number of instances of goals and beliefs	110		362		472	

n = number of respondents

Table 4.7. Teachers' Goals and Beliefs about Teaching Science Representing Action Competence

	Mail Survey (n_1=36)		Web Survey (n_2=95)		Mail and Web Combined (n_3=131)	
Categories of teachers' goals and beliefs about teaching science	**Number of Instances**	**% AC**	**Number of Instances**	**% AC**	**Number of Instances**	**% AC**
Activity-Driven	2	2.6	2	0.7	4	1.1
Attitude/Behavior Change	11	14.3	38	13.9	49	14.0
Conceptual Change	1	1.3	1	0.4	2	0.6
Content/Subject Matter	-	-	2	0.7	2	0.6
Discovery/Explanation	1	1.3	4	1.5	5	1.4
Global/Real World Connections	16	20.8	43	15.8	59	16.9
Guided Inquiry/Learning Communities	-	-	4	1.5	4	1.1
Inquiry	4	5.2	5	1.8	9	2.6
Knowledge Acquisition	7	9.1	11	4.0	18	5.1
Learning	7	9.1	27	9.9	34	9.7
Skill Development	10	13.0	42	15.4	52	14.9
Social Reform/Citizenship	13	16.9	33	12.1	46	13.1
Student Development	2	2.6	55	20.1	57	16.3
Teacher-Student/ Student-Student Relationships	1	1.3	3	1.1	4	1.1
Visioning	2	2.6	3	1.1	5	1.4
Total number of instances of goals and beliefs	77	100.0	273	100.0	350	100.0
TOTAL %	(77/110)*100 = 70.0		(273/362)*100 =75.4		(350/472)*100=74.2	

n = number of respondents

Table 4.8. Teachers' Goals and Beliefs about Teaching Science Representing Individual Elements of Action Competence

Elements of Action Competence	**Knowledge/ Insight**		***Commitment***		***Visions***		**Critical Thinking and Reflection**		**Planning and Action**			
Categories of teachers' goals and beliefs about teaching science	**Mail**	**Web**	**Mail**	**Web**	**Mail**	**Web**	**Mail**	**Web**	**Mail**	**Web**		
	Number of Instances										**TOTAL Number of AC Instances**	**TOTAL % of AC Instances**
Activity-Driven			2	2					2	2	8	1.5
Attitude/Behavior Change			10	38					1		49	9.3
Conceptual Change	1	1	1	1			1	1	1	1	8	1.5
Content/Subject Matter		1		1				1			3	0.6
Discovery/Exploration			1	4							5	0.9
Global/Real World Connections			7	28			2	17	16	43	113	**21.4**
Guided Inquiry										4	4	0.8
Inquiry									4	5	9	1.7
Knowledge Acquisition	7	11									18	3.4
Learning	3	7	7	27					3	20	67	**12.7**
Skill Development			1	2			4	20	5	20	52	**9.8**
Social Reform/Good Citizenship			13	33					13	33	92	**17.4**
Student Development			2	55					1	34	92	**17.4**
Teacher-Student Relationship			1	3							4	0.8
Visioning					2	3					5	0.9
TOTAL number of instances of AC element per survey	11	20	45	194	2	3	7	39	46	162	529	
TOTAL % of instances of AC element per survey	9.9	4.8	40.5	46.4	1.8	0.7	6.3	9.3	41.4	38.8		
% of AC in combined surveys	5.9		**45.2**		0.9		8.7		**39.3**			

Total # of AC instances in the mail survey: 111 Total # of AC instances in the web survey: 418

4.3.4 Pedagogical Approaches

The most prevalent pedagogical approaches of combined mail and web respondents were *activity-driven* (32%), *discovery/exploration* (18.1%), *didactic* (14.1%), *project-based* (12.1%), and *process-oriented* (11.6%) (see Table 4.9, 4th column in bold text). Percent occurrence for each approach was similar between the mail and web survey respondents.

Table 4.9. Pedagogical Approaches Cited by Teachers

Pedagogical Approaches	**Mail % of instances**	**Web % of instances**	**M+W combined % of instances**
Academic Rigor	-	0.6	0.4
Activity-Driven	30.9	32.5	**32.0**
Conceptual Change	0.7	2.6	2.1
Didactic	13.7	14.3	**14.1**
Didactic-With-Application	0.7	1.5	1.2
Discovery/Exploration	17.3	18.4	**18.1**
Guided Inquiry	2.2	2.0	2.1
Inquiry	7.2	5.8	6.2
Process-Oriented	13.7	10.8	**11.6**
Project-Based	13.7	11.4	**12.1**
TOTAL %	100.0	100.0	100.0

4.3.5 Instructional Methods

The most prevalent instructional methods of combined mail and web respondents were *hands-on activity* (10.9%) and *cooperative learning/group work* (10%) (see Table 4.10, 4th column in bold text). Percent occurrence for each method was similar between the mail and web survey respondents.

Table 4.10. Most Prevalent Instructional Methods of Teachers			
Instructional Methods	**Mail % of instances**	**Web % of instances**	**M+W combined % of instances**
Cooperative Learning/Group Work	10.1	9.8	**10.0**
Experiments and Labs	8.3	6.2	6.8
Field Trips	5.9	5.7	5.8
Hands-on Activity	10.7	11.0	**10.9**
Use of Technology	5.3	6.2	6.0

4.3.6 Student Skills

The most prevalent student skills foci of combined mail and survey respondents were *critical thinking/think on their own/analytical/evaluation* (26.6%), *investigation/research/field data collection* (15.6%), and *problem solving* (10.2%) (see Table 4.11, 4th column in bold text). Mail survey respondents cited *investigation/research/field data collection* considerably more often than web survey respondents, but the latter cited *decision making* and *problem solving skills* considerably more than the former.

Table 4.11. Most Prevalent Student Skills Foci of Teachers			
Student skills	**Mail % of instances**	**Web % of instances**	**M+W combined % of instances**
Critical Thinking/Think On Their Own/ Analytical/Evaluation Skills	22.2	28.3	**26.6**
Decision Making	2.8	12.0	9.4
Problem Solving	5.6	12.0	**10.2**
Investigation/ Research/Field Data Collection	25.0	12.0	**15.6**
Social Skills/Communicating (Ability to Explain, Describe)	8.3	6.5	7.0

4.4 FURTHER INTERPRETATION OF AND REFLECTION ON RESULTS

4.4.1 Survey Respondents

4.4.1.1 Teaching Orientations – Goals and Beliefs

The teaching orientations (goals and beliefs) suggested in the literature (Magnusson *et al.,* 1999) did not exactly correspond with the reported categories of goals and beliefs of respondents; I found fourteen other categories in this study (see Table B.2 for a complete list of categories). This finding is similar to that of Friedrichsen & Dana (2005), who found that teachers' teaching orientations (goals and approaches in this study) were complex, and were broader in scope than those described in the literature.

Four categories of goals and beliefs were most prevalent – *attitude/behavior change*, *skill development*, *global/real world connections*, and *student development* (see Table 4.6). This possibly suggests that teachers held multiple levels of categories of goals and beliefs, which also was found by Magnusson *et al.* (1999) and Friedrichsen & Dana (2000). This hierarchy of goals and beliefs seems consistent with the pivotal position that Grossman (1990) ascribed to goals and beliefs within the PCK domain of teacher knowledge. Grossman suggested that "conceptions of purposes for teaching subject matter" – which I call "goals and beliefs" – influence the other components of PCK and, in turn, are being influenced by the other components as well (Grossman, 1990 cited in Friedrichsen & Dana, 2000).

It is not known why these four categories were more prevalent than the others, but I would surmise they may have been associated with the (1) teachers' teaching and learning experiences (past and current) such as the kinds of teachers they worked with in the past, the educational systems orientation of the school they attended, or the professional development exposure; (2) the contexts of the schools where they taught; and (3) their personal background (Van Driel *et al.* 2001), among other things that form the context for the teachers *at the time* of the study. I emphasized *at the time* of the study following Friedrichsen & Dana's (2000) finding that goals and beliefs change over time.

4.4.1.2 Teaching Orientations – Pedagogical Approaches

There also appeared to be a hierarchy in the use of pedagogical approaches by respondents. *Activity-driven, discovery/exploration, didactic, project-based,* and *process-oriented* approaches were more prevalent than others. I examined the congruence between goals and beliefs and pedagogical approaches because goals and beliefs are believed to influence elements of PCK (Grossman, 1990). For example, *project-based* goals and beliefs were not represented when respondents were asked about their goals and beliefs, but in their description of their pedagogical approaches, respondents described *project-based* approaches (12.1%) (see Table 4.12). This suggests that respondents' pedagogical approaches do not always match their goals and beliefs about teaching. Furthermore, this finding implies that, unlike what Grossman (1990) suggested, goals and beliefs do not always guide teachers' decision on teaching approaches. This inconsistency between espoused beliefs and reported teaching approaches also was observed by Lim & Chai (2008) in their study of how pedagogical beliefs of six primary school teachers in Singapore affect the planning and conduct of their computer-mediated lessons.

I also observed weak congruence in the *skill development* category of goals and beliefs (12.5%), which was the second most prevalent category in the surveys. Based on the goals within this category (see Table B.2) and the nature of *guided inquiry* and *inquiry* pedagogical approaches, as referred to in this study, it appears that *skill development* probably was embodied to a certain extent in the *guided inquiry, inquiry,* and/or *process-oriented* pedagogical approaches. However, findings showed that *guided inquiry* and *inquiry* approaches did not receive mention as frequently as *process-oriented* (11.6%) or the other approaches (see Table 4.12). Similarly, weak congruence was observed in the *didactic* category of goals and beliefs and the *didactic* pedagogical approach. The *didactic* pedagogical approach was the third most prevalent (14.1%), but *didactic* goals and beliefs were much less prevalent (4.4%) (see Table 4.12).

Table 4.12. Incongruence Between Pedagogical Approaches and Goals and Beliefs			
Pedagogical Approaches	**M+W combined % of instances**	**Goals and beliefs**	**% of instances**
Academic Rigor	0.4	*Attitude/Behavior Change*	**18.0 1st**
Activity-Driven	32.0 **1st**	Global/Real World Connections	**12.5 2nd**
Conceptual Change	2.1	Improvement of Pedagogy	4.2
Didactic	14.1 **3rd**	Knowledge Acquisition	3.8
Didactic-With-Application	1.2	Learning	7.2
Discovery/Exploration	18.1 **2nd**	*Skill Development*	**12.5 2nd**
Guided Inquiry	2.1 weak	Social Reform/Good Citizenship	9.7
Inquiry	6.2 weak	Student Development	**12.3 3rd**
Process-Oriented	**11.6 5th**	Didactic	4.4 weak
Project-Based	**12.1 4th**	**No Project-based goals and beliefs**	

Notes on congruence/incongruence:

1) Project-based goals and beliefs were absent, but *project-based* approaches were present, therefore there was incongruence
2) Skill development goal and belief was strong (second most prevalent), but *guided inquiry* and *inquiry* approaches, which may embody skill development, were weak.
3) Didactic goal and belief was weak, but *didactic* approach was strong (third most prevalent)

In contrast to the cases of incongruence above, it appears that *global/real world connections* (second most represented category of goals and beliefs) may be embodied to some extent in the *activity-driven, discovery/exploration,* and *process-oriented* pedagogical approaches. These three approaches occurred in the five most prevalent approaches of respondents. This appears consistent with Grossman *et al.* (1989) and Richardson's (1996) suggestion that teachers' beliefs about subject matter influence how they think about their content and their classroom practice.

The variability in congruence of pedagogical approaches to goals and beliefs and vice versa indicates that factors other than goals and beliefs affect the approaches that teachers use for instruction. This was also suggested by Lim & Chai (2008) and Friedrichsen & Dana (2005). Furthermore, these factors may be related to immediate needs in the classroom, such as MEAP test preparation and lack of time, lack of resources (e.g., funding, content materials, lab equipment and tools), curriculum requirements, skills and abilities of students and how they learn, and political and/or structural barriers in the school (see Table 4.13).

Table 4.13. Factors That May Influence Teachers' Goals and Beliefs about Teaching
Respondent 106, Mail survey group: *"Lack of time in classes - execute and evaluation - often short; lack of time to fully prepare; "not on the high stakes test"...why bother (thoughts of others I have heard)."* **Respondent 174, Mail survey group:** *"Right now I am using water quality and land use units in my classroom. Next year* [meaning in 2008], *when the Michigan GLCEs for fifth grade science change, I don't know if I'll be able to teach environmental education anymore. I feel very strongly about educators' responsibility to teach children to love the Earth and take care of it. I feel environmental education should begin at the early elementary level. Unfortunately, unless it is mandated by the state, it won't happen. Teachers (those who believe in it) cannot possibly go above their already bloated curriculum to teach "extra" topics. Environmental education should not be extra! It should be core. How can I help make this happen?"* **Respondent 124, Mail survey group:** *"My students have difficulty reading. Also funding (a lack thereof) is at a critical point. Field trips have been cut, hands-on disposable items are difficult to replace."* **Respondent 166, Mail survey group:** *"I hate to admit it, but with 30+ students in a class, and 5-7 of them special ed, I do lots of notes, review, and small group work. I do less labs than I would like, but materials, time, and patience are in short supply."*

In Lam & Kember's (2006) examination of the relationship between conceptions (beliefs) of teaching and approaches to teaching, they found that when there is limited contextual influence on the way teachers teach, their approaches to teaching follow logically from their conceptions of teaching. However, as the contextual influence increases, this starts to influence the ways in which teachers teach; hence, we see that the approaches do not follow the beliefs. It appears that, in my study, contextual influences may play a role in the survey respondents' pedagogical approaches. Lim & Chai's (2008) findings support Lam & Kember's (2006); they also found that teachers' mindset of teaching for tests (e.g., MEAP tests) hinders them from teaching based on their beliefs.

4.4.1.3 Instructional Methods

Looking at specific individual instructional methods, it could be argued that the five most prevalent methods of respondents (*hands-on activity, cooperative learning/group work, experiments and labs, use of technology,* and *field trips*) (see Table 4.16) are congruent with the *activity-driven* pedagogical approach, which was their most prevalent approach. *Field trips* also could be seen as congruent with the *discovery/exploration* pedagogical approach, along with instructional methods such as nature walks, hikes, and use of the outside as the classroom. The latter method, however, was not one of the most prevalent methods of respondents (4.4%).

Experiments and labs usually are employed in a *process-oriented* approach (fifth most prevalent in the surveys), but it may also be used for *discovery/exploration* approach (second most prevalent in the surveys) (Ormrod, 1995). In addition to being used in an *activity-driven* approach, *cooperative* *learning/group work* is also typically used in a *project-based* approach (fourth most prevalent in the surveys). Interestingly, there was very little occurrence of the *didactic questions* instructional method in the surveys (only 1%), even though *didactic* learning was the third most prevalent pedagogical approach. This may be because *didactic questions* are just one of a few other methods that could be used in conjunction with a *didactic* approach; *lectures* and *demonstrations* can be used as well (Magnusson *et al.*, 1999).

These findings provide evidence that an instructional method can be used in more than one pedagogical approach, and that an approach can use instructional methods that other approaches also use. Similarly, a pedagogical approach can represent more than one category of goals and beliefs, or a category of goals and beliefs can be embodied in more than one pedagogical approach. Magnusson *et al.* (1999) noted similar patterns and explained that it is not the use of a particular strategy but the purpose of employing it that distinguishes a teacher's orientation to teaching science (Magnusson *et al.,* 1999, p. 97).

4.4.1.4 Student Skills

Some of the skills cited by respondents appear to be associated with particular pedagogical approaches. For example, it may be argued that *critical thinking, decision making, problem solving, investigation/research skills* (see Table 4.17) are related to a *process-oriented* approach, which was one of the five most prevalent pedagogical approaches of survey respondents (see Table 4.9).

Investigation/research and problem solving skills also may be related to *guided inquiry, inquiry,* and/or *project-based* approaches. *Critical thinking skills* may be associated with *conceptual change, guided inquiry,* and/or *inquiry* approaches.

Some skills may be associated with certain methods. For example, *social skills* may be related to *cooperative learning/group work* methods, or *investigation/research* and *problem solving skills* may be related to *experiments and labs* instructional method. As with pedagogical approaches and instructional methods, some skills are associated with more than one instructional method or pedagogical approach. This is not surprising because experience tells us that there are teachers who use different approaches or methods to develop a particular skill in students.

The five most prevalent student skills foci found in this study all were found by Eames *et al.* (2006) to be important in enhancing AC; *critical thinking, problem solving,* and *decision making* occurred repeatedly in Eames *et al.'s* (2006) identification of factors that influence development or enhancement of AC in students. Thus, in my study, respondents' attempts at exposing their students to these skills may increase teachers' capacity to develop students' AC.

4.4.1.5 Elements of Action Competence (AC)

Results of AC from surveys revealed an uneven distribution of occurrence of individual elements of AC – 45.2% was *commitment* and 39.3% was *planning and action experiences*, while the other elements appeared less than 10% of all the instances of AC (see Table 4.8). This finding may imply that there is uneven use of AC elements in the classroom. In addition, this uneven distribution was expected, because it was clear during the analysis that not all of the goals and beliefs of respondents about teaching espoused AC. Consequently, not all categories of goals and beliefs were congruent with characteristics of AC.

4.4.2 Survey Respondents versus Water Quality Unit

4.4.2.1 Pedagogical Approaches

I compared pedagogical approaches cited by respondents to those found in the Water Quality Unit. An example of similarity was that *activity-driven* (most prevalent), *didactic* (third most prevalent), and *process-oriented* (fifth most prevalent) pedagogical approaches were mentioned in the same frequency as both data sources (see Table 4.15). *Academic rigor*, *guided inquiry* and *inquiry* were cited in the surveys, but they were less prevalent compared with the other approaches; these three approaches were absent in the Water Quality Unit.

In terms of the differences observed, *didactic-with-application* and *conceptual change* approaches were mentioned less frequently in the surveys than in the Water Quality Unit; *discovery/exploration* was the second most prevalent approach in the surveys but was absent in the Water Quality Unit. These similarities and differences suggest that teachers adopt approaches other than those used or suggested in the EE curriculum (Water Quality Unit), probably based on their students' needs, available resources, and curriculum requirements, among many other factors (see Table 4.14).

Table 4.14. Factors That May Influence Teachers' Selection and Use of Pedagogical Approaches
Respondent 128, Mail Group: *"My teaching style is a mixture of all you mentioned above. I believe hands-on and visual things are more important than notes/facts. It needs to be fun for students to learn. Major things I do include: "Comprehension Coaches" to encourage kids to know how to read informational texts, hands-on mini-labs and full labs to get kids excited about the material and immersed in deep thinking/questioning of what is really happening with each concept; outdoor explorations in our own community to further connect lessons to their personal lives; group projects to encourage team work and further analysis of lessons and big ideas; lots of visual aides to help students better understand Earth's processes..."* **Respondent 157, Mail Group:** *"I believe that I show a balance of hands-on experiences as well as teaching students facts about the subject. As budgets get tighter it has been more difficult to get students outdoors."* **Respondent 166, Mail Group:** *"I hate to admit it, but with 30+ students in a class, and 5-7 of them special ed, I do lots of notes, review, and small group work. I do less labs than I would like, but materials, time, and patience are in short supply. I use PowerPoint projects, flip books, group studying, small labs, lots of personal experience sharing (both from me and the students)."* **Respondent 155, Mail Group:** *"...too many standards/requirements to give students a strong base. Basically, I would like to have our current GLCEs identified and remain consistent. Many gaps in curriculum can occur when these are constantly changing."*

In the Water Quality Unit, a connection was found between *activity-driven* and *planning and action experiences*. A similar connection was found in the surveys – the *activity-driven* approach was the most prevalent approach and *planning and action experiences* were the second most prevalent element of AC, a close second to *commitment*.

Table 4.15. Comparing Pedagogical Approaches of Survey Respondents and the Approaches Included in the Water Quality Unit		
Pedagogical Approaches	**MEECS participants' survey % of instances**	**MEECS Water Quality Unit % of instances**
Academic Rigor	0.4	-
Process-Oriented	**11.6 5th**	**12.5 5th**
Activity-Driven	**32.0 1st**	**38.5 1st**
Discovery/Exploration	**18.1 2nd**	-
Project-Based	12.1 **4th**	2.9
Conceptual Change	2.1	13.5 **4th**
Inquiry	6.2	-
Guided Inquiry	2.1	-
Didactic	**14.1 3rd**	**14.4 3rd**
Didactic-With-Application	1.2	**18.3 2nd**
TOTAL	100.0	100.0

4.4.2.2 Instructional Methods

The distribution of instructional methods in the surveys was very different from what was found in the Water Quality Unit. *Didactic questions* was proportionately less prevalent (only 1%) of all the methods that were cited by survey respondents, but this method clearly dominated the Water Quality Unit (32%) (see Table 4.16). *Hands-on activity* was the most prevalent method cited by the respondents (10.9%), but it appeared below the five most prevalent methods (only 2%) in the Water Quality Unit. *Cooperative learning/group work* was the second most prevalent (10%) of all the methods cited by respondents, but it appeared below the five most prevalent methods (2.5%) in the Water Quality Unit. *Definitions* was not mentioned by respondents, but this method was the second most prevalent in the Water Quality Unit.

The findings above might be attributed to many factors, such as those that may have been associated with the types of teaching approaches that were cited (or used) by survey respondents, which include MEAP test preparation requirements, lack of time, lack of resources (e.g., funding, content materials, lab equipment and tools), curriculum requirements, target audiences (age groups, socio-economic factors skills and abilities of students), and political and/or structural barriers in the school. Differences in content focus between what the respondents teach and the lessons in the Water Quality Unit, and goals and beliefs of respondents and the objectives of the unit may also have influenced these findings.

Table 4.16. Comparing Instructional Methods of Survey Respondents and Methods Included in the Water Quality Unit

	MEECS participants' survey % of instances	**MEECS Water Quality Unit % of instances**
Instructional Methods		
Compare and Contrast	-	3.4 5th
Cooperative Learning/Group Work	**10.0 2nd**	2.5
Definitions	-	**15.0 2nd**
Didactic questions	-	**32.0 1st**
Discussion	-	4.0 4th
Experiments and Labs	6.8 3rd	-
Field Trips	5.8 5th	-
Hands-on Activity	**10.9 1st**	2.0
Use of Technology	6.0 4th	9.8 3rd

4.4.2.3 Student Skills

As in the Water Quality Unit, *critical thinking* and *problem solving skills* were the most and third most prevalent student skills, respectively, in the surveys. *Inferring/interpreting* (11.5%) was the second most prevalent and *predicting* (6.6%) was the fifth most prevalent in the Water Quality Unit, but *inferring/interpreting* was absent and *predicting* was not in the five most prevalent student skills in the surveys. Nonetheless, process skills were mentioned more frequently in both data sources when compared to other skills (see Table 4.17).

It is important to mention here that, in addition to considering all the other factors that may have influenced the findings observed in this part of the study, findings on AC, goals and beliefs, pedagogical approaches, instructional methods, and student skills should be interpreted in the context of the characteristics of the survey respondents. For example, even though the majority of respondents were science teachers (32.2%), there were many others who taught other subjects (e.g., Math – 14.2%, Social Science – 12.3%, Language Arts – 12%). This composition may strongly influence the types of approaches, methods, or student skills that were observed in the surveys, and may have played a role in the differences that were observed between results from the Water Quality Unit and those found in the surveys. The Water Quality Unit was developed with science and social science teachers in mind, so, expectedly, the approaches, methods, and student skills are designed for use by science and social science teachers, even though teachers of subjects other than science and social science also were invited to use MEECS. Among the respondents, there were those who taught subjects other than science or social science, which may or do use different approaches or methods or focus on different skills.

Teaching experience also may have influenced the results found in pedagogical approaches, methods, or student skills. Some respondents had more teaching experience than others (15.6% had 0-5 years experience, and 43.8% had more than 16 years experience). Other researchers have found that teaching experience influences teachers' decisions related to classroom instruction (Lee *et al.,* 2007, Friedrichsen & Dana, 2005).

Table 4.17. Comparing Student Skills of Survey Respondents and the Water Quality Unit		
	MEECS participants' survey % of instances	**MEECS Water Quality unit % of instances**
Student skills		
Ability to Apply Knowledge Learned to Real World Situations	2.3	7.1 4th
Critical Thinking/Think on Their Own/Analytical/Evaluation Skills	**26.6 1st**	**24.8 1st**
Decision Making	9.4 4th	
Inferring/Interpreting	-	**11.5 2nd**
Investigation/ Research/ Field Data Collection	**15.6 2nd**	5.8
Predicting	0.8	6.6 5th
Problem Solving	**10.2 3rd**	9.3 3rd
Social Skills/Communicating (Ability to Explain, Describe)	7.0	5.3

4.4.2.4 Elements of Action Competence

The distribution of AC in the survey of MEECS teachers was very different from the distribution of AC in the Water Quality Unit of the MEECS. For teachers, *knowledge/insight* was the fourth most prevalent AC element (5.9%), which suggests that it did not appear to be as important for them; but in the Water Quality Unit, knowledge was the first most prevalent AC element (50.4%) (see Table 4.18). *Commitment* (45.2%) and *planning and action experiences* (39.3%) were the two most prevalent AC elements of teachers, but *commitment* (6.7%) was the fourth most prevalent and *planning and action experiences* (17%) was the third most prevalent AC elements in the Water Quality Unit.

Although exact difference in percent occurrences of variables between teachers and the Water Quality Unit cannot be compared because surveys and curriculum are different data sources and because of the difference in data analysis, findings showed that *commitment* and *planning and action experiences* were more prevalent in the teachers than in the curriculum. The only thing that matched between the teachers and the Water Quality Unit was the occurrence of *visions*, which appeared last in both (5.3% in Water Quality and 0.9% in the surveys). These findings possibly suggest that there is incongruence between the focus of the curriculum (Water Quality Unit) and of the teachers, which further implies that elements of AC will be utilized in varying extents depending on whether the teachers use the curriculum, use a different one, or teach without it.

Table 4.18. Comparing Elements of Action Competence Mentioned by Survey Respondents and AC Elements Included in the Water Quality Unit

	MEECS participants' survey % of instances	**MEECS Water Quality unit % of instances**
Elements of Action Competence		
Knowledge/Insight	5.9	**50.4 1st**
Commitment	**45.2 1st**	6.7
Visions	0.9	5.3
Planning and Action Experiences	**39.3 2nd**	**17 3rd**
Critical Thinking and Reflection	8.7	**20.7 2nd**

In the Water Quality Unit analysis, there was evidence that the increasing complexity of the lessons (from lesson 1 to lesson 9) played a factor in the extent that AC occurred in the individual lessons. In the surveys, the higher occurrence of AC in the five categories of goals and beliefs listed in Table B.4 may be attributed to two factors – the nature of the goals and beliefs of respondents and the number of goals and beliefs that could possibly be classified within each category that represented AC. For example, the *global/real world connections* category consisted of goals and beliefs that related to providing students with meaningful, relevant experiences to help understand connectedness, interrelationships, and/or interdependence between people, the world, and the environment. Specifically, goals and beliefs within the *global/real world connections* category that embodied AC included facilitating understanding of interdependence/connections between people and the world/environment (see statements from Respondents 588060766, 575846006, and 576358637 in Table 4.19), teaching application of knowledge and skills in real life (see statements from Respondents 574056487and 583875054 in Table 4.19), and using authentic situations to provide real world experiences (see statements from Respondents 178, 584472434, and 574025764 in Table 4.19).

Arguably, *global/real world connections* category lends itself more to use of AC-oriented activities and experiences compared to the *knowledge acquisition* category of goals and beliefs, which usually focuses more on helping students access or acquire knowledge/information from various sources or on developing student awareness. It seems that finding meaningful experiences for students that will help them grasp how people and the environment are connected encompasses more aspects of instruction, such as content/topic, teaching methods, and, probably, *knowledge acquisition* (see statements by Respondents 574056487 and 57635863 in Table 4.20) than *knowledge acquisition* alone.

Table 4.19. Teachers' Goals and Beliefs within the Global/Real World Connections Category that Embodied AC
Respondent 588060766, Web Group: *"I want children to be equipped to understand the world they live in, to have knowledge and resources that will help them to make responsible life choices, and to understand how interdependent we are - to each other, and to our environment."* **Respondent 575846006, Web Group:** *"To foster a better understanding of our natural world so that individuals become informed stewards of our natural resources."* **Respondent 576358637, Web Group:** *"Help students understand the connection between human activity and the environment - mainly as it pertains to water use, conservation, treatment, protection."* **Respondent 574056487, Web Group:** *"I think teaching should be about educating students on an individual basis not only about your specific content area, but about life and real world applications/situations. I try to prepare my students for not only the next grade level but for situations and life outside of the classroom."* **Respondent 583875054, Web Group:** *"I want my students to learn the required information and gain skills to make good decisions about using resources in their personal lives."* **Respondent 178, Mail Group:** *"To make real life examples so the students aren't just reading out of a book, they will be able to see how it is used."* **Respondent 584472434, Web Group:** *"I like to do as many hands-on activities as possible. My classes have monitored a nearby stream for about 7 years I think it is. We collect, sort and identify the macro-invertebrates to determine the health of our stream. We also do water quality chemical testing."* **Respondent 574025764, Web Group:** *"... introducing them to the process and practice of a specific discipline, i.e., geography. I want learners to experience becoming a geographer rather than learning a few geographic facts and concepts."*

Although *knowledge acquisition* may encompass *knowledge of effects* and *causes* of environmental issues or problems, it usually only includes helping students to access or obtain ecological scientific information (Jensen, 2000). Although AC was embodied more in the *global/real world connections* category, Eames *et al.* (2006) found goals and beliefs within *global/real world connections* and *knowledge acquisition* (e.g., (a) providing wide experiences, using authentic situations to provide real world experiences, and (b) increasing knowledge) to be important in developing students' AC. This implies the need to have both categories of goals and beliefs to enhance teachers' development of students' AC.

Table 4.20. Knowledge Acquisition Goals and Beliefs of Teachers
Respondent 574056487, Water Quality web survey group: *"I think teaching should be about educating students on an individual basis not only about your specific content area, but about life and real world applications/situations."* **Respondent 57635863, Water Quality web survey group:** *"Help students understand the connection between human activity and the environment - mainly as it pertains to water use, conservation, treatment, protection."* Both teachers above spoke about expanding content area into real world connections between people and the environment, not just focus on scientific or ecological facts, which is usually the focus of *knowledge acquisition*.

Another category of goals and beliefs that is probably more compatible with AC than other categories is *social reform/good citizenship*, which consisted of goals and beliefs that related to developing students' understanding of their responsibility to improve society and to encouraging care for the environment. Eames *et al.* (2006) found in one of their case studies involving five New Zealand classrooms (1st through 9th grade) that making children aware of their responsibility to participate in finding solutions to problems of society was important in developing students' AC. As with the *global/real world connections* category, *social reform/good citizenship* speaks directly about AC, particularly with increasing *commitment* and *planning and action experiences*, as exemplified in respondents' comments below (see Table 4.21).

Table 4.21. Social Reform/Good Citizenship Goals and Beliefs of Teachers
Respondent 574302380, Air Quality web survey group: *"Having the students be able to see a problem and think through the possible outcomes and make the best choice with the most favorable outcome for all involved."* **Respondent 128, Mail survey group:** *"My biggest concern is students appreciating the world in which they live. Teaching needs to raise responsible citizens to ensure future generations can prosper and continue to exist on this planet - we need to make some changes."*

Second, the number of goals and beliefs that could possibly comprise a category also may have influenced the distribution of AC across teaching orientations. For example, the *student development* category was composed of eight goals compared to only one for the *visioning* category. Although this is not true for all categories of goals and beliefs, in general, the more goals and beliefs there are for a particular category, the higher the occurrence of that category because of the greater chance that a particular goal or belief was mentioned. See Table B.4 for goals and beliefs that represented AC.

One striking difference in comparing the extent that the elements of AC were mentioned in the survey and those included in the Water Quality Unit was that the *commitment* element was mentioned much less frequently in the Water Quality Unit (4th most frequently mentioned) than in the survey. One prominent difference in the approaches between the respondents and the Water Quality Unit was the occurrence of *project-based* and *discovery/exploration* pedagogical approaches – *project-based* was in the five most prevalent approaches in the surveys, but not in the Water Quality Unit; *discovery/exploration* was the second most prevalent in the surveys, but it was absent in the Water Quality Unit. These two approaches may have a connection to the occurrence of the *commitment* element of AC.

Eames *et al.* (2006) found this similar pattern in one of their case studies involving five classrooms in New Zealand. In particular, they found that providing students with diverse experiences in the environment (embodied in *global/real world connections* in this study), developing students' understanding of their responsibility to help solve problems and improve society (embodied in *social reform/good citizenship* in this study), and helping students make informed decisions (embodied in *attitude/behavior change* in this study) are important to developing or enhancing students' AC. The students who were involved in the case study described that actual connection with the environment was important to the development of their understanding of issues, allowed them to build on their prior experience, and consequently increased their emotional engagement with an issue. Emotional engagement, of which *commitment* is one aspect, is an important factor in developing or enhancing students' AC according to Eames *et al.* (2006).

Another finding from Eames *et al.'s* (2006) study was that making students aware of their responsibility to help solve problems in society helped them realize that their participation was important. This facilitated the development of their ability to solve problems, which is one of the skills repeatedly suggested by

Eames *et al.* (2006) as key to developing or enhancing AC. Furthermore, Eames *et al.* (2006) found in their study that teachers who used pedagogies that had characteristics similar to what this study refers to as *project-based* and *discovery/exploration* approaches (e.g., children visiting an aviary, observations of actual birds visiting school grounds, and bird house building) generated emotional engagement, which is an underlying requirement for AC. This suggests that the respondents, who cited as using *project-based* and *discovery/exploration* pedagogical approaches more frequently than what was included in the Water Quality Unit, may have a better chance of developing *commitment* in their students than the Water Quality Unit, if presented exactly as described.

As I found in the Water Quality Unit, *visions* appeared the least of all the elements of AC in the surveys. *Knowledge/Insight* was mentioned much less frequently in the surveys while it was represented the most in the Water Quality Unit. *Critical Thinking and Reflection* was only the third most prevalent in the surveys although it was the second most prevalent in the Water Quality Unit. The weak occurrence of *knowledge/insight* and *critical thinking and reflection* may be associated with a weaker occurrence of the *didactic-with-application* pedagogical approach in the surveys (occurred below the five most prevalent) compared to the Water Quality Unit (second most prevalent). According to Eames *et al.* (2006), *knowledge/insight* and *critical thinking and reflection* are important elements for our attention because *knowledge/insight* helps students make informed decisions, and asking students to reflect on their prior knowledge or experiences allows students to analyze their state of learning and helps them learn how to make strategic decisions in the future. This suggests a need to help teachers identify pedagogical strategies that can strengthen use of student reflection in their instruction.

4.5 DISCUSSION, SUMMARY, AND IMPLICATIONS FOR RESEARCH AND PROFESSIONAL PRACTICE

Some respondents' teaching goals and beliefs were incongruent with their pedagogical approaches. This implies that goals and beliefs either do not always influence teachers' decisions on how to teach, or factors other than goals and beliefs influence classroom instruction decisions. Moreover, some goals and beliefs were embodied in more than one pedagogical approach, and some pedagogical approaches represented more than one category of goals and beliefs. Magnusson *et al.* (1999) observed the same pattern, and they suggested that it is the purpose of using a particular strategy that distinguishes teaching orientations to science, not the use of it.

Some approaches (e.g., *activity-driven*, *didactic*, and *process-oriented*) cited by respondents matched those found in the Water Quality Unit in terms of order of occurrence, but some appeared lower or higher than they did in the Water Quality Unit (e.g., *conceptual change* and *didactic-with-application*). These similarities and differences indicate that teachers adopt approaches other than those used or suggested in the EE curriculum.

The most prevalent instructional methods were *hands-on activity* and *cooperative learning/group work*. The most prevalent skills-foci were *critical thinking*, *investigation/research*, *problem solving*, and *decision making*. I found that an instructional method was associated with more than one pedagogical approach or skill, and a student skill was associated with more than one approach or method.

The distribution of instructional methods in the surveys was very different from the distribution in the Water Quality Unit. These differences may be attributed to many factors, which include MEAP test preparation requirements, lack of time, lack of resources (e.g., funding, content materials, lab equipment and tools), curriculum requirements, target audiences (age groups, socio-economic factors skills and abilities of students), and political and/or structural barriers in the school. Additionally, differences in content (subjects) focus between what the respondents teach and the lessons in the Water Quality Unit, and goals and beliefs of respondents and the objectives of the unit also may have influenced these findings.

The most prevalent elements of AC were *commitment* and *planning and action experiences*, and an uneven distribution of elements of AC was observed; these two elements appeared substantially more than the others. This finding suggests that there may be uneven use of AC elements in the respondents' classrooms. Moreover, the elements of AC that were prevalent in the surveys appeared differentially in the Water Quality Unit, suggesting that there is an incongruence between the focus of the curriculum (Water Quality Unit) and of the teachers, which may mean elements of AC are or will be used in varying extents depending on whether the teacher uses the curriculum, uses a different one, or teaches without it.

In Chapter 3 I suggested that use of approaches other than *activity-driven*, *didactic*, and *didactic-with-application* may increase the occurrence of the *commitment* and *visions* elements of AC. In this chapter I found that a higher occurrence of *project-based* and *discovery/exploration* approaches and the occurrence of goals and beliefs related to *global/real world connections*, *attitude/behavior change*, and *social reform/good citizenship* may have influenced the stronger appearance of *commitment* in the surveys compared to its appearance in the Water Quality Unit. *Visions* remained the least prevalent element and there were no evident patterns that can help explain this finding other than students setting goals and thinking about what their future can be are not currently a strong component of teaching in the classrooms. Further research is needed to examine what types of pedagogical approaches use and can foster which elements of AC.

I also found that not all of the goals and beliefs of respondents about teaching represented AC. Action competence appeared the most in the *global/real world connections*, *social reform/good citizenship*, *student development*, *learning*, and *skill development* categories of goals and beliefs and that some of these goals and beliefs (e.g., global /real world connections) lend themselves to the use of AC more than others (e.g., *knowledge acquisition*). This finding implies that, along with a reexamination of the goals and objectives and the focus of the curriculum as suggested in Chapter 3, goals and beliefs, pedagogical approaches, and instructional methods of curriculum users as well as their student skills need to be revisited to identify which of these aspects of PCK target which elements of AC. This will help identify the weak points that need to be addressed to ultimately increase teachers' capacity to foster AC in their students. Subsequently, this will help inform future development of AC-oriented EE curricula and guide teachers who attempt to foster AC in their students.

The cases of incongruence between goals and beliefs and pedagogical approaches, instructional methods, and student skills and the reasons behind them imply that, to align these variables of interest, the contextual aspects need to be addressed seriously. As Lim & Chai (2008) pointed out, even though beliefs are important, the socio-cultural conditions in which the teachers are working are very important. Thus, even if teachers' goals and beliefs lend themselves to adopting AC in the classroom, teachers will be less likely to use AC-oriented pedagogical approaches if they are overwhelmed with contextual issues that they need to address that differ from AC. As one respondent said,

> *"...I feel very strongly about educators' responsibility to teach children to love the Earth and take care of it. I feel environmental education should begin at the early elementary level.* ***Unfortunately, unless it is mandated by the state, it won't happen. Teachers (those who believe in it) cannot possibly go above their already bloated curriculum to teach "extra" topics. Environmental education should not be extra! It should be core*** (text in bold is for added emphasis). *How can I help make this happen?"*

The incongruence observed between some of the elements of PCK and the elements of AC that were used and/or cited by teachers and included in the

Water Quality Unit imply a need to close the gap between the rhetoric and reality of EE. This has strong implications for curriculum development and in-service professional development. To increase teachers' use of AC in the classrooms using EE curricula, the curriculum design should be informed by AC theory and research, such as knowledge obtained from this study. In turn, theory and research should be informed by EE practice such that research and practice become an iterative process. In particular, curriculum developers should create a curriculum based on the kinds of pedagogical approaches and instructional methods that teachers prefer to use and that research has deemed as most likely to foster students' AC. Curriculum developers also need to ensure that all elements of AC are included and equally addressed.

To complement the curriculum development process, professional development programs need to focus on helping teachers develop an openness to use of other approaches and methods, particularly the ones that appeared to be associated with the use of AC. In addition, professional development activities need to provide ample opportunities for teachers to observe, learn, and apply AC-oriented approaches and methods in real world classroom settings. Furthermore, contextual factors such as challenges and barriers in school, curriculum requirements, and teachers' previous professional development exposures need to be integrated into the teachers' learning experiences to help make them meaningful and useful for teachers. A good example of this is the apparent importance of preparing students for the MEAP tests. Teachers are more likely to use a curriculum if it can help them meet standards and benchmarks or Grade Level Content Expectations, which can help them prepare their students for the MEAP.

More research is needed to identify factors that influence the presence or absence of AC, and its extent of use in each teacher. For example, do certain pedagogical approaches, methods, and student skills result in greater use of AC? Stratified analysis could determine whether subjects taught influence teachers' pedagogical approaches, methods, or student skills. Similarly, stratified analysis could detect whether teaching experience influences teachers' approaches, methods, and student skills. Future research also should investigate the utility of professional development and/or curriculum in strengthening teachers' use of AC, that is, whether a combination of professional development that targets use of AC and use of an AC-oriented curriculum is needed to maximize teachers' use of AC.

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THE INTERACTION OF MICHIGAN ENVIRONMENTAL EDUCATION CURRICULUM, SCIENCE TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE, AND ENVIRONMENTAL ACTION COMPETENCE

VOLUME II

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CHAPTER 5

PEDAGOGICAL CONTENT KNOWLEDGE AND ACTION COMPETENCE: AN IN-DEPTH EXAMINATION OF FOUR SCIENCE TEACHERS IN MICHIGAN

ABSTRACT

Pedagogical content knowledge (PCK) and use of action competence (AC) of four public school science teachers were examined through manifest and latent content analyses of data collected from class observations, semistructured interviews, Content Representations (CoRes), and surveys. Teachers A and B taught 7th grade, Teacher C taught 6th grade, and Teacher D taught 5th grade.

Although each teacher cited multiple goals and beliefs about teaching science, their most prevalent goal and belief was to *transmit facts, content, knowledge, and/or benchmarks/standards*, possibly suggesting that their main focus was to provide students with knowledge that meet curriculum requirements. Many of the teachers' goals and beliefs appeared to be bound within the content that they had to teach, as opposed to general goals and beliefs related to teaching science.

Prevalence of individual elements of PCK (goals and beliefs, pedagogical approaches, instructional methods, and student skills) did not always predict or indicate prevalence of individual PCK manifestations, or the strength of teachers' overall PCK. Teacher A, the least consistent in terms of use of pedagogical approaches and instructional methods, had the weakest overall PCK. However, Teacher C, the most consistent in terms of use of pedagogical approaches, the most *activity-driven* and *process-oriented*, and focused on student skills the most, was only second to Teacher D, who was the most flexible in terms of what to teach, when, and how, in terms of overall strength of PCK.

Strong overall PCK appeared to be associated with strong AC for some teachers, but not for others. Teacher D had the strongest PCK and was also the most AC-oriented. Teacher A had the weakest PCK and had the weakest AC. However, no evidence of AC was found in Teacher C, despite having the second strongest overall PCK of the four teachers. This suggests that use of AC is influenced by factors other than PCK, including possibly content taught and personal conviction of teachers.

Knowledge/Insight was the most prevalent element of AC across the teachers, and appeared to be associated with the use of *didactic* and *didactic-with-application* pedagogical approaches. Real world *planning and action experiences* appeared to be associated with the use of *activity-driven*, *process-oriented*, and *project-based* approaches, and fewer barriers or constraints in the teaching context of teachers. *Commitment* and *visions* were the least prevalent elements of AC. Teachers need to incorporate all five elements into their teaching to increase their capacity to foster students' AC. To do this, curriculum and assessment need to include the concept of AC. In addition, teachers need to account for barriers or constraints in their teaching context, learn how to use various pedagogical approaches and instructional methods to apply AC in the classroom, and reflect on how their teaching goals and beliefs mesh with AC.

5.1 INTRODUCTION

In this chapter, I continue to address my second research question through an in-depth examination of PCK and use of AC by four science teachers. The research question I address is: “To what extent does teachers’ pedagogical content knowledge in using science education and environmental education curricula and content materials represent elements of action competence?”

5.2 METHODS

5.2.1 Selection of Teachers and Classes

I selected four teachers from the pool of MEECS (Michigan Environmental Education Curriculum Support) survey respondents (Chapter 3) based on their interest to participate, location (proximity to Michigan State University), and subject and grade level taught. My participants consisted of a 7th grade teacher from County X, a 7th grade teacher from County Y, a 6th grade teacher from County Z, and a 5th grade teacher also from County Z. These teachers helped me identify which class group to observe, except for the 5th grade teacher who taught only one class group the entire day. To help me compare results across the four teachers, the teachers and I selected average class groups for observations, i.e., average in terms of students’ cognitive levels. We also considered class dynamics and special needs of students in our *decision making*. For example, the second hour class of County Y teacher had one student who became extremely uncomfortable in the presence of anyone other than the teacher and the classmates in the room. Consequently, the teacher and I decided not to include that particular class in the study.

5.2.2 Consent and Assent Forms

I sought teachers' participation in the study about three months prior to class observations. As part of the Institutional Review Board's requirement for conducting human subjects research, I collected teachers' and parents' consent and students' assent. About one month before conducting class observations, the teacher sent parental consent forms home with students. Following the teachers' suggestion, students were given up to two weeks to return the forms. The teachers were primarily responsible for collecting the consent forms prior to class observations. Some students returned the consent forms during the first week of observations. The consent form described the study to the parents and asked their permission for their child's participation in focus group interviews, access to some of students' class work (e.g., homework, tests, and projects), and photo release.

The assent form contained the same information as the consent form, but I read it to the students and explained the purposes of my study, and the role that they would be playing. I also answered questions before students signed the assent form. I emphasized that student participation in the interviews and other data collection were voluntary, and that they would not be penalized if they did not want to participate. In the 7th grade classroom in County Y, I gave students assent forms one week before class observations started, because the teacher preferred it that way. In the other classrooms, I gave assent forms during the first week of observations. Most assent forms were returned by students the same day the forms were given to them. Other students returned the form several days later.

Students were still part of the class observations even though their parents did not allow them to participate in the study and/or they did not agree to participate, because observations were done for the whole class. But no interviews, collection of class work, and picture taking were done from/of students who were not allowed by their parents and/or when they did not agree to participate in the study.

5.2.3 Data Collection

5.2.3.1 Class Observations

Class observations are a common method of examining AC (Breiting *et al.*, 2009; Eames *et al.*, 2006; Onyango-Ouma *et al.*, 2009) and PCK (Loughran *et al.*, 2001; Mitchell & Mitchell, 1997; Monet, 2006; Shannon, 2006; Woodrow, 2007). In this study, I conducted a total of 38 class observations from December 2007 through April 2008 (see Table 5.1). Each class observation typically lasted from an hour to an hour and a half. Observations were completed when the teacher completed the topic/unit/session that he/she was teaching. The number of class visits per week and the total for each class varied across the four teachers, depending on the number of lessons and activities teachers planned for an entire topic/unit/section, the schedule and availability of the teachers, and school activities and closings due to weather or holidays.

Table 5.1. Class Observations Schedule			
Teacher A	**Teacher B**	**Teacher C**	**Teacher D**
7th grade, 27 students	7th grade, 28 students	6th grade, 23 students	5th grade, 25 students
County X	County Y	County Z	County Z
12/10/2007	1/23/2008	1/11/2008*	2/4/2008
12/11/2007	1/24/2008	1/14/2008*	2/6/2008
12/13/2007	1/29/2008	2/14/2008* (field trip)	2/11/2008
12/14/2007	1/30/2008	2/19/2008	3/13/2008
12/18/2007	1/31/2008	2/21/2008	3/19/2008
12/19/2007	2/15/2008	2/22/2008	3/20/2008
	3/5/2008*	2/26/2008	3/27/2008*
	3/24/2008*	2/27/2008	3/28/2008*
	3/25/2008*	2/29/2008	3/31/2008*
	3/26/2008*		4/16/2008*
	4/2/2008*		
	4/3/2008*		
	4/4/2008*		

Note: * - Not analyzed

I wanted to observe teachers' instruction of an environmental topic or content, but the timing of the study relative to the topics or content the teachers had already covered and had yet to cover, and the availability of the teachers, did not make this possible for Teacher B and Teacher C. So I conducted observations on the weeks that these two teachers were available and within the time frame of the study, regardless of the topic or content taught. At the time of data collection, two teachers covered two major topics or content: Teacher A taught air pollution and water pollution and Teacher D taught agents of erosion and rocks and minerals. Teacher C taught forces and motion. Although forces and motion seem like two separate topics, Teacher C considered them one and, therefore, he combined the two topics and taught them as one. Teacher B taught one topic only (classification of organisms).

I recorded class instruction and activities using digital recorders, which I strategically positioned in three locations in the classroom. I observed each class from the back of the room in a way that did not distract the class. In addition, I did not participate in any part of the class. I also took notes, which I used primarily to cross-check transcripts from audio recordings. I noted teacher-student and student-student interactions, the overall classroom climate, and classroom setting and resources in addition to recording goals and beliefs, types and examples of pedagogical approaches, instructional methods, and student skills as well as manifestations or indications of PCK and AC.

Finally, I noted questions and observations for debriefing with the teacher after class or at a later time, depending on the availability of the teacher. Debriefing was done in person (interview or casual chat) and via email. If debriefing could not be done in person, I emailed the questions to the teacher either on the same day that the observation was conducted or the day after. I included teachers' responses in the transcript of that particular day's class observation.

5.2.3.2 Semi-structured Interviews

In addition to class observations, interviews are also a common data collection method used in studies of AC (Breiting *et al.*, 2009; Eames *et al.*, 2006;

Fien & Skoien, 2002; Onyango-Ouma *et al.*, 2009; Simovska, 2007) and PCK (Boz & Boz, 2008; Dawkins *et al.*, 2003; Loughran *et al.*, 2001; Monet, 2006; Woodrow, 2007). In this study, I interviewed each teacher five times from October 2007 through April 2008 – before, during, and after class observations (see Table D.1 for schedule of interviews). Interview durations varied. Most debriefing interviews lasted only ten to fifteen minutes; other interviews lasted for about an hour. Interview questions included the following: goals and beliefs about teaching; knowledge of curriculum, standards, benchmarks, and content expectations; approaches, strategies, and methods used in the classroom and why; types of activities or projects included and lessons taught; issues, challenges, and barriers in teaching; lessons, activities, and projects the teacher planned to do and why; students' learning styles and preferences; and resources for teaching. See Appendix D.12 for the complete list of interview questions.

I audio-taped each interview using a digital recorder and also took notes during the interview to cross-check with transcripts later. During the interviews, I gave teachers ample time to respond to all questions to encourage them to respond in detail and to provide thoughtful responses.

5.2.3.3 Content Representations (CoRes)

I adapted this method from Loughran *et al.* (2001) and Mulhall *et al.* (2003) who used CoRes to capture **and** portray PCK. These researchers noted that CoRes set out and discussed the aspects of PCK most attached to a particular content taught in a particular context. In my study, I used CoRes (see Table D.2) to capture PCK and to find evidence of teachers' use of AC. Each teacher filled out a CoRes table for every topic he/she taught and that I observed. I gave teachers CoRes tables three weeks before my class observations. I collected the CoRes sheets on the first week of observations. The CoRes sheets asked teachers to list or identify:

1) big ideas for teaching a particular topic;
2) why the topic is important for students to know;
3) what they (teachers) want students to learn about the topic;
4) difficulties or limitations connected with teaching the topic;
5) how they (teachers) considered knowledge of student learning in planning lessons;
6) other factors they (teachers) considered in planning lessons;
7) teaching approaches, strategies, and methods; and
8) specific ways of ascertaining students' understanding or confusion around the topic.

5.2.3.4 Surveys

Surveys are another popular method used to examine AC (Breiting *et al.*, 2009; Eames *et al.*, 2006; Jensen, 2000a, 2000b; Onyango-Ouma *et al.*, 2009; Simovska, 2007) and PCK (Davis & Petish, 2005; Johnston & Ahtee, 2006; Van Driel *et al.*, 2002; Van Driel *et al.*, 1998). The survey completed by the four teachers was the same survey that was sent to the MEECS training participants (Chapter 4) (see Appendix D.1, mail survey instrument). In addition to demographics and participants' use of MEECS, the survey also asked about teachers' goals for teaching science ("What is/are your primary goal/s as a teacher?"), beliefs about teaching science ("What do you think teaching should be about?") and the nature of their instruction ("How would you describe or characterize the nature of your instruction?"). I also used the survey as an additional data source for evidence of teachers' use of AC.

5.3 DATA ANALYSIS

I transcribed audio recordings from class observations and interviews with the help of three people. I reviewed all transcripts and cross-checked the transcripts with my field notes for accuracy. Because the number of observations varied across teachers, I analyzed only the first six observations that were relevant to the topics taught by each teacher to ensure consistency across teachers in the amount of observation data to be analyzed. I used Atlas.ti 5.2 software to code and analyze 24 class observation transcripts (six per teacher), 20 interview transcripts, and CoRes and survey data.

I examined these elements of PCK: teaching orientations (goals and beliefs about teaching science and pedagogical approaches), instructional methods, and student skills. In addition, I also examined manifestations of teachers' PCK and teachers' use of AC. It is important to note here that I did not measure the teachers' individual knowledge domains per se, that is, "what or how much do teachers know about an approach, method, or skills?" because of the inherent challenges in measuring teachers' knowledge accurately (e.g., teachers may be uncomfortable or not willing to participate in the study if their knowledge will be measured). Rather, I identified the goals and beliefs, pedagogical approaches, instructional methods, student skills, and manifestations of PCK, and measured the extent to which they were used and/or cited by the teachers to characterize their overall PCK.

I used content analysis of qualitative data following the works of Krippendorff (1980), Strauss & Corbin (1998), and Weber (1990). The four teachers were the units of analysis and the units of observation were their goals and beliefs about teaching science, pedagogical approaches, instructional methods, student skills, manifestations of PCK, and AC. Recording units, or the texts to which I assigned a category label (GAO, 1996), consisted of words, phrases, or sentences, or groups of these.

I coded each variable (e.g., goals and beliefs, pedagogical approaches, instructional methods) for each teacher one data source at a time (see Table 5.2). I coded goals and beliefs first, followed by pedagogical approaches, instructional methods, student skills, manifestations of PCK, and AC. I coded each of the variables first in class observations, then in interviews, in CoRes, and in surveys. Prior to actual coding, I read the transcripts, and the CoRes and survey responses once to get familiar with the data. On the second reading, I started coding.

Table 5.2. Coding Steps Followed for Each Teacher

	Data Sources			
Variables of Interest	**CO**	**In**	**CoRes**	**Su**
1) Goals and Beliefs about Teaching Science	Step 1	→	→	→
	A, B, C, D	→	→	→
2) Pedagogical Approaches	Step 2	→	→	→
3) Instructional Methods	Step 3	→	→	→
4) Student Skills	Step 4	→	→	→
5) Manifestations of PCK	Step 5	→	→	→
6) Action Competence	Step 6	→	→	→

(CO = Class Observations; In = Interviews: CoRes = Content Representations; Su = Surveys; A, B, C, and D = Teachers)

5.3.1 Coding Process in Detail

5.3.1.1 Pedagogical Content Knowledge (PCK)

<u>5.3.1.1.1 Teaching Orientations – Goals and Beliefs</u>

To code for goals and beliefs, I used the final categories of goals and beliefs about teaching science used in Chapter 4 as a guide (*a priori*), but I added new categories as they emerged. I examined both the manifest and latent contents of recording units to code for occurrences of goals and beliefs. Manifest content is the visible, surface content and latent content indicate the underlying meaning (Babbie, 1992). I counted each time a *unique* goal or belief occurred in the transcript, CoRes, and survey. This means that I counted only once any goals and beliefs that were repeated in a particular transcript. I coded some responses multiple times because they encompassed multiple goals and beliefs.

Example of multiple coding:

Teacher B final interview:

"My primary goal as a teacher is to lead each student to an appreciation for every day science and understand basic principles of science that will affect their daily lives" was coded as DEVELOP/INSTILL POSITIVE ATTITUDES TOWARD SCIENCE and TRANSMIT FACTS, CONTENT, KNOWLEDGE, AND/OR BENCHMARKS/STANDARDS

5.3.1.1.2 Teaching Orientations – Pedagogical Approaches

In this chapter, I used the same rubric for coding as the one I used in Chapters 3 and 4, which was mostly adapted from Magnusson *et al.* (1999, pp. 100-101) and Schwarz & Gwekwerere (2007, pp.182-184). To code for pedagogical approaches from class observation data, I measured the *amount of time* (length, in minutes) a teacher spent on each approach instead of simply counting the *number of times* (frequency) that each approach was displayed because actual usage time was available. To measure the amount of time a teacher spent on each approach, I noted the time when the teacher began using a particular approach and the time when the teacher switched to a different approach.

After the first round of coding, I went back and coded again to check for errors and inconsistencies in my coding. As with coding in Chapters 3 and 4, I assigned multiple codes to some recording units because they represented or encompassed more than one approach. After coding, I added the total times each teacher spent on an approach in each observation and then I converted the total amount of time spent on each approach to percent use for each approach.

The procedures I used in coding for pedagogical approaches seen in class observations were not the same procedures I used in coding for interview, CoRes, and survey data. Instead, I followed the same procedures I used in coding for the Michigan Environmental Education Curriculum Support (MEECS) (Chapter 3) and the MEECS participants' survey data (Chapter 4). I counted each time an approach occurred in the interview transcript, CoRes, and survey responses of the four teachers. If the same approach occurred more than once, I counted it separately if it was used for a different purpose, activity, or topic. In some cases, I coded groups of words, phrases, or sentences more than once.

Examples of coded pedagogical approaches:

Teacher A survey response:

Nature of instruction:
1) "Giving facts" was coded as DIDACTIC

2) "Lab (show them and then let them do it)" was coded as ACTIVITY-DRIVEN

Teacher C interview:

"And, I have a real good flavor for how well they're going to be able to work as a scientist or at least understand science in that last quarter because the whole last quarter is devoted to an in-class project and I call it "super-hero spectrum" where they build a super-hero and then they have to be responsible for one part of the electromagnetic spectrum. They have to be experts….and teach the basic facts of what that part of the spectrum represents to the rest of their classmates, and they have like six weeks or seven weeks to produce this. And, in the end, they have to present it and teach it to the class. And then their classmates have to ask questions of them." was coded as PROJECT-BASED

I determined the most prevalent approaches, i.e., most-used and/or cited in each teacher and across teachers based on two criteria: (1) the occurrence of an approach in all four data sources and (2) the frequency of use of an approach based on percent occurrence within a data source. That is, did the same approach appear in all four data sources, and did the same approach appear at the same frequency (percent wise) in each data source?

Examples:

a) Prevalence of approaches used by each teacher

- I compared occurrences of approaches AND their frequencies of use across data sources. Occurrence is the raw number of occurrences of each approach in each data source. Frequency of use is the raw number of occurrences of each approach in each data source divided by the total raw number of occurrences of ALL approaches in that particular data source. For example, I considered an approach that occurred in all four data sources AND was the most frequently used and/or cited in class observations, third most frequently used and/or cited in interviews, second most in CoRes, and third most in survey was more prevalent overall compared with an approach that occurred in only 3 of 4 data sources (regardless of the frequency of use). I automatically considered less prevalent any approach that did not appear in all four data sources than those that did.

- If more than one approach occurred the same number of times across data sources, I compared their frequencies of use. For example, an approach that occurred in all four data sources AND was the most frequently used and/or cited in class observations, third most frequently used and/or cited in interviews, second most in CoRes, and third most in survey was more prevalent overall compared with an approach that occurred in all four data sources AND was the second most frequently used and/or cited in class observations, second most in interviews, third most in CoRes, and fifth most in survey.
- If frequencies of use of more than one approach were the same across data sources, I compared actual percent values. For example, in Teacher A, *didactic* approach (20%) was the most frequently used and/or cited in class observation, but *activity-driven* approach (30%) was the most frequently used and/or cited in interviews. Therefore, I considered *activity-driven* more prevalent than *didactic* for Teacher A because percent of use for *activity-driven* was greater than percent of use for *didactic*.

b) Prevalence of approaches across teachers

- To determine prevalence of approaches across teachers, I compared occurrences and frequencies of use across data sources. Number of occurrences took precedence over frequency of use.

For example, if frequency of use for *didactic-with-application* were as follows:

Class Observations: Teacher A>Teacher D>Teacher B>Teacher C

Interviews: Teacher D>Teacher A>Teacher C

CoRes: Teacher D>Teacher B>Teacher C

Survey: Teacher C

Teacher C's use and/or citation of *didactic-with-application* occurred in all data sources.

Teacher D occurred in 3 of 4 sources
Teacher A occurred in 2 of 4 sources
Teacher B occurred in 2 of 4 sources
Therefore, C>D>A>B.

Based on my criteria, *didactic-with-application* was most prevalent in Teacher C, even though this approach was not the most frequently used and/or cited in 3 of 4 data sources in Teacher C, because the approach occurred in all four data sources in this teacher. *Didactic-With-Application* was second most prevalent in Teacher D, followed by Teachers A and B. The approach was least prevalent in Teacher B because, in addition to appearing in only 2 of 4 data sources, its frequency of use was not as high as in the other teachers.

5.3.1.1.3 Instructional Methods and Student Skills

To code for instructional methods and student skills, I used the methods/skills found in Chapter 3 and Chapter 5 as a guide, but I added new methods/skills as they emerged from the data. Unlike coding for goals and beliefs, for which *similar* goals and beliefs were counted *only once* in each transcript regardless of the number of times it occurred in the *same* transcript, I counted separately each time a method/skill occurred in a transcript, CoRes, or survey, provided the method was used for a different activity or topic. This means that I counted some methods/skills more than once in the *same* transcript, CoRes, or survey. For skills, I assigned some recording units multiple codes.

Examples of coded instructional methods and student skills:

Teacher C CoRes:

"I always try to include a balance of traditional reading/worksheet lessons with visual/hands-on lessons." was coded as ACTIVITY PACKETS/WORKSHEETS, HANDS-ON ACTIVITY, and READING FOR MEANING

Teacher C interview:

"Then they find the average speed. Then they have to rank it based on who won the race. Well, you'd be surprised, they can't interpret the data when it starts talking about so many minutes, so many meters per minute. And they don't catch on to the fact that if Suzy ran less than 60 minutes and everybody else is more than 60 minutes, Suzy won the race. And that her speed needs to be the first speed. And once they do that, then they could figure it from there" was coded as INFERRING/INTERPRETING SKILLS

5.3.1.1.4 Manifestations of Pedagogical Content Knowledge

In Chapter 4, I noted that some *elements* of PCK were examined, but not *manifestations* of PCK, i.e., specific areas for which there was evidence of PCK use in teachers' instruction. In this chapter, I examined both individual *elements* of PCK and *manifestations* of it. I compiled a list of eleven PCK manifestations (see Table 5.3) adapted from the works of several researchers to be used for coding (Grossman, 1990; Lee *et al.*, 2007; Lee & Luft, 2005; Magnusson *et al.*, 1999; Meijer *et al.*, 1999; Mulhall *et al.*, 2003; Wilson, 2006). I coded and counted unique instances of PCK each time they occurred in a transcript, CoRes, or survey. Subsequently, some PCK manifestations occurred more than once in the *same* transcript, CoRes, or survey. See Table D.3 for descriptions of the following PCK manifestations.

Table 5.3. PCK Manifestations
1) Reasons/purposes of selecting and emphasizing particular concepts
2) Reasons/purposes of selecting and emphasizing particular skills
3) Knowledge of student learning or understanding
4) Ways used to overcome barriers or constraints in teaching context
5) Reasons/purposes of using particular approaches, methods, or instructional strategies
6) Reasons/purposes of using particular activities
7) Knowledge of curriculum
8) Activities or examples that connected well with students
9) Community resources used and why
10) School resources used and why
11) Order of subjects/content to teach

Example of coded manifestation of PCK:

Teacher D classroom observation:

"Teacher (T): Ok, moving on to chemical weathering. So chemical weathering is all the ways rock is broken down and the chemical makeup is changed [teacher is writing on the board]. *Do I need to use the dark and black marker?*
Students: Yeah. Coz I can barely…
T: Ok, so all the ways that rock is broken down and the chemical make-up is changed. So in this case, we got the ***daddy rock*** [emphasized] *being one kind of rock and the* ***baby rock*** [emphasized] *being a different kind of rock. Because for whatever reason, that chemical changed the content or the makeup of the baby rock, ok?"*

I coded this as *PCK: activities and examples that connected well with students*. The teacher used "daddy" and "baby" to show and emphasize the difference between two rocks that have been changed due to chemical weathering. The teacher knew that her fifth grade students related to the words "daddy" and "baby," so she used those words to teach about the impacts of chemical weathering.

I assigned some recording units with multiple codes because they encompassed more than one manifestation of PCK. For example,

Teacher B interview:

"They enjoy labs. Because 7th graders need to get up and move around. They can't sit, they just can't. They're gonna shut down if they just sit. So they enjoy the labs. They, I think, we do a lot in the computer labs as well. In fact I just had a student today say, I really like this, I feel like I'm learning. So I knew that was good. And they like things where they can get up and move around. And really with labs that's a big part of it."

I coded this as *PCK: knowledge of student learning* and *PCK: reasons/purposes of using particular approaches and/or methods*. The teacher recognized one characteristic of her students (they cannot sit still) and consequently chose an instructional method of teaching (conducting labs) that helped facilitate learning of her students.

5.3.1.2 Elements of Action Competence

I used the same set of criteria that I used in Chapter 3 (pp. 11-12) and Chapter 4 (pp. 10-11; 75-77) to code for AC in this chapter. While coding, I was guided with the question "Which elements of AC were displayed in the class observations, interviews, CoRes, and surveys, and to what degree?" I coded for any *unique* occurrences of five elements of AC (*knowledge/insight*, *commitment*, *critical thinking and reflection*, *visions*, and *planning and action experiences*) in each of the four data sources from each teacher. This means that, if another recording unit occurred exactly the same or very close to a previously coded one in the same transcript from which the first one was found, I did not code the succeeding one as separate because it was not a unique occurrence. As with previous coding processes described above, I coded some recording units as representing multiple elements of AC.

Examples of coded elements of AC:

Teacher A CoRes:

What you intend the students to learn about global warming:
1) *"causes"* – was coded as KNOWLEDGE OF CAUSES
2) *"possible consequences"* was coded as KNOWLEDGE OF EFFECTS

Teacher D classroom observation:
"If you're going to take a tree down, you need to replant a tree. The problem is it takes a very long time for those trees to grow…but it's better than doing nothing but it's still not an equal trade. So you guys have to

think about that, that's why when I told you guys to look for the post consumer content when you go to the store, when you're buying tissue, napkins, ummm cereal, looking at the boxes and everything, look for a high amount of post consumer content. That means that a large portion of your stuff is recycled, ok, and that's what you want." was coded as COMMITMENT and CHANGE STRATEGIES

Like my coding procedures in Chapters 3 and 4, I reread the parts for which I found inconsistencies in my coding and recoded until the first and second round of codes matched (see Table E.1). After coding, I calculated total occurrences and percents (frequency of use) for each goal and belief, pedagogical approach, instructional method, student skills, PCK manifestation, and element of AC for each teacher across data sources.

5.4 RESULTS and DISCUSSION

5.4.1 Teacher Profiles

Table 5.4 lists some characteristics of the four teachers. Some notable similarities and differences were the teachers' ages, years of teaching experience, MEECS training, subjects and number of classes taught, and school locations. Teachers A and D were much younger (in their early 30s) than Teachers B and C (in their late 50s). Teacher A had the shortest teaching experience (3 years); Teacher B had been teaching the longest (23.5 years). Teacher D taught several subjects, but in only one class group. The other teachers taught one or two subjects, but in multiple class groups. Teacher B was trained in four MEECS units compared with only one unit for Teachers C and D; Teacher A was not trained in MEECS at all. All four teachers taught at a public, non-magnet school. Teachers B and D's schools were located in a small town, Teacher A's was in a rural community, and Teacher C's was in an urban fringe within a midsize city[11]. Teachers A and B taught older students (7th grade); Teacher C taught 6th grade, and Teacher D taught the youngest group (5th grade). Teachers B, C, and D had master's degrees and Teacher A was pursuing a master's degree at the time of the study. Of the four teachers, Teacher A also appeared to have had the strongest science background based on college majors and minors. See Table D.4 for additional information about the teachers.

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[11] Any territory within a MSA (Metropolitan Statistical Area) or CMSA (Consolidated Metropolitan Statistical Area) of a Large City and defined as urban by the U.S. Census Bureau. An area becomes a CMSA if it meets the requirements to qualify as a metropolitan statistical area, has a population of 1,000,000 or more, if component parts are recognized as primary metropolitan statistical areas, and local opinion favors the designation. Qualification of an MSA requires the presence of a city with 50,000 or more inhabitants, or the presence of an Urbanized Area (UA) and a total population of at least 100,000. Visit http://www.census.gov/population/www/metroareas/metroarea.html for more information.

Table 5.4. Teacher Profiles

Teacher A	Teacher B	Teacher C	Teacher D
▪ Male, 32 years old ▪ School type: Public, non-magnet ▪ School community: metropolitan rural ▪ Topics taught at the time of the study: Air and Water pollution ▪ Teaches 7th grade Science, multiple class groups ▪ Least experienced in teaching (3 years) ▪ Not trained in MEECS ▪ Major/Minor: Cell and Developmental Biology/ Biology and Chemistry Education; pursuing MA in Physical Science	▪ Female, 57 years old ▪ School type: Public, non-magnet ▪ School community: small town ▪ Topic taught at the time of the study: Classification of organisms ▪ Taught 7th grade Science, multiple class groups; also taught 6th grade Reading ▪ Most experienced in teaching (23.5 years) ▪ Most MEECS-trained (Ecosystems and Biodiversity, Water Quality, Air Quality, and Land Use Units) ▪ Major/Minor: Special Education and Early Childhood Education; MA in K-8 Science	▪ Male, 59 years old ▪ School type: Public, non-magnet ▪ School community: urban fringe within a midsize city ▪ Topic taught at the time of the study: Forces and motion ▪ Taught 6th grade Science, multiple class groups ▪ Second most experienced in teaching (22 years) ▪ MEECS-trained – (Water Quality Unit) ▪ Major/Minor: Secondary Physical Education/ History, Social Studies; MA in Science Education	▪ Female, 33 years old ▪ School type: Public, non-magnet ▪ School community: small town ▪ Topics taught at the time of the study: Agents of erosion and rocks and minerals ▪ Taught 5th grade Science, Language Arts/English, Mathematics, Social Studies/Social Science, one class group ▪ Moderately experienced in teaching (8 years) ▪ MEECS-trained – (Land Use Unit) ▪ Major/Minor: Elementary Education/Math, Science, and French; MA (unknown)

5.4.2 Elements of PCK

In this section, I report on results for goals and beliefs, pedagogical approaches, instructional methods, and student skills for each teacher across four data sources (class observations, interviews, CoRes, and surveys). For simplicity purposes, I report only the three most prevalent goals and beliefs across the four teachers because the top three were more distinct than the fourth, fifth, sixth most-cited (and so on), which tended to be comprised of multiple goals and beliefs. For pedagogical approaches, instructional methods, and student skills, I report on the five most prevalent because the prevalence of each approach/method/skill was distinct across teachers. The following notes apply for Tables 5.5 through 5.8:

1) CO = Class Observations; In = Interviews; CoRes = Content Representations; and Su = Surveys
2) Percents (columns 3 through 6) correspond to the frequency of use of each goal and belief within a data source. Frequency is the number of raw occurrences of a goal and belief within a data source divided by the total number of occurrences of ALL goals and beliefs within a data source.
3) Overall Prevalence: 1 = most prevalent, 2 = second most prevalent, and so on.

5.4.2.1 Teaching Orientations – Goals and Beliefs about Teaching Science

5.4.2.1.1 Individual Teachers

Teacher A, County X: taught air and water pollution in 7th grade

Teacher A cited multiple goals and beliefs about teaching science, and his three most prevalent goals and beliefs across data sources were (1) *transmit facts, content, knowledge, and/or benchmarks/standards*, (2) *help students acquire knowledge or awareness*, and (3) *engage students in hands-on activities* (see Table 5.5). No goals and beliefs occurred in all data sources, and *transmit facts, content, knowledge, and/or benchmarks/standards* was the only goal and belief that occurred in more than one data source in Teacher A (33.3% in class observations, 16.7% in interviews, and 25.0% in the survey). In contrast, the three most prevalent goals and beliefs of the three other teachers occurred in at least 2 data sources.

Table 5.5. Three Most Prevalent Goals and Beliefs about Teaching Science: Teacher A

Teacher A		**Data Sources**				
Categories of Goals and Beliefs	**Individual Goals and Beliefs**	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Activity-Driven	*Engage students in hands-on activities*	66.7				3
Knowledge Acquisition	*Help students acquire knowledge or awareness*			100.0		2
Didactic	*Transmit facts, content, knowledge, and/or benchmarks/ standards*	33.3	16.7		25.0	1

Teacher B, County Y: taught classification of organisms in 7th grade

Teacher B also cited multiple goals and beliefs about teaching science, and her most prevalent across data sources were (1) *transmit facts, content, knowledge, and/or benchmarks/standards*, (2) *develop/instill positive attitudes toward science*, and (3) *develop/instill positive attitudes toward education* (see Table 5.6). No goals and beliefs occurred in all data sources.

Table 5.6. Three Most Prevalent Goals and Beliefs about Teaching Science: Teacher B

Teacher B		**Data Sources**				
Categories of Goals and Beliefs	**Individual Goals and Beliefs**	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Attitude/Behavior Change	*Develop/instill positive attitudes toward learning/ education*		12.5		16.7	3
	Develop/instill positive attitudes toward science		25.0		16.7	2
Didactic	*Transmit facts, content, knowledge, and/or benchmarks/ standards*		37.5	66.7		1

Teacher C, County Z: taught forces and motion in 6th grade

Teacher C also cited multiple goals and beliefs, and his most prevalent across data sources were (1) *transmit facts, content, knowledge, and/or benchmarks/ standards*, (2) *prepare students for society/higher education/career/ future*, and (3) *develop/instill positive attitudes toward science* (see Table 5.7). No goals and beliefs occurred in all data sources, but *transmit facts, content,* *knowledge, or benchmarks/standards* occurred in three data sources (9.1% in class observations, 16.7% in interviews, and 33.3% in CoRes).

Table 5.7. Three Most Prevalent Goals and Beliefs about Teaching Science: Teacher C						
Teacher C		**Data Sources**				
Categories of Goals and Beliefs	**Individual Goals and Beliefs**	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Attitude/Behavior Change	*Develop/instill positive attitudes toward science*		6.7		33.3	3
Student Development	*Prepare students for society/higher education/career/ future*		10.0		33.3	2
Didactic	*Transmit facts, content, knowledge, and/or benchmarks/ standards*	9.1	16.7	33.3		1

Teacher D, County Z: taught agents of erosion and rocks and minerals in 5th grade

As the other teachers, Teacher D also cited multiple goals and beliefs, and her most prevalent across data sources were (1) *transmit facts, content, knowledge, and/or benchmarks/standards*, (2) *represent a body of knowledge,* (2) *develop science process skills, and* (3) *reach students* (see Table 5.8). No goals and beliefs occurred in all data sources, but *transmit facts, content, knowledge, and/or benchmarks/standards* occurred in three data sources (33.3% in class observations, 6.7% in interviews, and 83.3% in CoRes).

Table 5.8. Three Most Prevalent Goals and Beliefs about Teaching Science: Teacher D						
Teacher D		**Data Sources**				
Categories of Goals and Beliefs	**Individual Goals and Beliefs**	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Academic Rigor	*Represent a body of knowledge*	33.3	6.7			2
Humanistic	*Reach students*				100.0	3
Skill Development	*Develop science process skills*	33.3	6.7			2
Didactic	*Transmit facts, content, knowledge, and/or benchmarks/ standards*	33.3	6.7	83.3		1

5.4.2.1.2 Combined Results of Four Teachers

All four teachers cited multiple goals and beliefs in their teaching. Combining all occurrences of goals and beliefs from all four teachers, fourteen unique categories occurred across four teachers and four data sources. Of the fourteen, nine categories were different from those suggested by Magnusson *et al.*, 1999: (1) *attitude/behavior change*, (2) *global/real world connections*, (3) *learning*, (4) *student development*, (5) *humanistic*, (6) *improvement of pedagogy*, (7) *social reform/good citizenship*, (8) *knowledge acquisition*, and (9) *modeling ways of being*. The most prevalent categories were (1) *skill development* (24.1%), (2) *didactic* (19.8%), and (3) *attitude/behavior change* (12.1%) (see Table 5.9).

In terms of individual goals and beliefs, the most prevalent across all four teachers was *transmit facts, content, knowledge, and/or benchmarks/standards* (1 in the last column, Table 5.10), which fell within the second most prevalent category – *didactic* (2 in the last column, Table 5.9). The second most prevalent goal and belief was *develop science process skills* (2 in the last column, Table 5.10).

Table 5.9. Three Most Prevalent Categories of Goals and Beliefs of Four Teachers

	Raw Number of Occurrences in Each Data Source						
Categories of Goals and Beliefs	**CO**	**In**	**CoRes**	**Su**	**Total Number of Occurrences**	**Total Frequency (%)**	**Overall Prevalence**
Attitude/Behavior Change	1	9		4	14	**12.1**	**3**
Didactic	3	11	8	1	23	**19.8**	**2**
Skill Development	7	20	1		28	**24.1**	**1**

CO = Class Observations; In = Interviews; CoRes = Content Representations; Su = Surveys

Overall Prevalence: 1 = most prevalent; 2 = second most prevalent, and so on.

Frequency = number of raw occurrences of a goal and belief within a data source divided by the total number of occurrences of ALL goals and beliefs within a data source

Table 5.10. Summary of Five Most Prevalent <u>Individual</u> Goals and Beliefs of Four Teachers

Individual Goals and Beliefs	A	B	C	D	Frequency of Use of Each Goal and Belief Across Teachers	Overall Prevalence of Goals and Beliefs
Represent a body of knowledge	-	-	2	2	D2 > C	
Engage students in hands-on activities	1	1	2	-	C > A3 > B	4
Develop/instill positive attitudes toward learning/education	-	2	1	-	B3 > C	
Develop/instill positive attitudes toward science	1	2	2	-	B2 > C3 > A	3
Transmit facts, content, knowledge, and/or benchmarks/ standards	3	2	3	3	D1 > A1 > C1 > B1	1
Reach students	-	-	-	1	D3	
Help students acquire knowledge or awareness	1	-	-	1	A2 > D	
Develop science process skills	1	1	2	2	D2 > C > A > B	2
Prepare students for society/higher education/career/future	1	-	2	-	C2 > A	5
Number of goals and beliefs that occurred in 3 out 4 data sources (shaded areas)	1	0	1	1		

A, B, C, and D = Teachers; numbers in columns 2 through 5 correspond to the number of times a goal and belief occurred across data sources, e.g., 3 means that particular goal and belief occurred in only 3 of 4 data sources (e.g., class observations, interviews, and content representations). In column 6, the number following A, B, C, or D is the frequency of use of that particular goal and belief within a teacher, e.g., A1 means *transmit facts, content, knowledge, and/or benchmarks/standards* was the most prevalent goal and belief of Teacher A. Note that only the three most prevalent goals and beliefs of the teachers are included here; the letters (teachers) without a number next to them mean that the corresponding goal and belief was not in the top three. The last column indicates the five most prevalent goals and beliefs across the four teachers (1=most prevalent).

Table 5.11. Similarities and Differences of Goals and Beliefs Regarding Teaching Science Among Four Teachers			
Teacher A	**Teacher B**	**Teacher C**	**Teacher D**
Transmit facts, content, knowledge, and/or benchmarks/standards was the most prevalent goal and belief of the four teachers			
Aside from *transmit facts, content, knowledge, and/or benchmarks/ standards*, this teacher wanted to focus most on *knowledge acquisition, i.e.,* teaching students how to/where to find information to increase their knowledge and *engaging students in hands-on activities*.	She also wanted to focus most on *developing/ instilling positive attitudes toward education* and *developing/ instilling positive attitudes toward science*	Like Teacher B, this teacher also wanted to focus most on *developing/instilling positive attitude toward science*, but unlike Teacher B, *preparing students for society/ higher education/ career/ future* appeared more important for Teacher C than for Teacher B.	She wanted to focus most on *representing a body of knowledge, i.e., doing science challenges students with different problems to verify science concepts, developing science process skills*, and at the same time, *reaching students*.

<u>5.4.2.1.3 Discussion: Goals and Beliefs about Teaching Science</u>

5.4.2.1.3.1 Goals and Beliefs of Individual Teachers

The occurrence of multiple goals and beliefs and the prevalence of some in each teacher may suggest that teachers' goals and beliefs may be found on a continuum, and that some goals and beliefs are more important than others (see Table 5.11). For example, in Teacher A, findings may suggest that *transmit facts, content, knowledge, and/or benchmarks/standards* was more important to him than *helping students acquire knowledge or awareness* and *engage students in hands-on activities,* as indicated by the occurrence of *transmit facts, content, knowledge, and/or benchmarks/standards* in 3 of 4 data sources compared with the other goals and beliefs, which occurred only in one data source. This pattern of occurrence also surfaced in Teachers C and D.

It appears in the next quote that Teacher A's most prevalent goal and belief (*transmit facts, content, knowledge, and/or benchmarks/standards*) reflects his desire to cover his school's curriculum requirements to meet Michigan Curriculum Benchmarks and Standards. This possibly means that addressing curriculum requirements was his first priority. The same explanation may be said for the three other teachers who also cited *transmit facts, content, knowledge, and/or benchmarks and standards* as their most prevalent goal and belief.

Teacher A interview:

> *Gel (G): "So how do you choose what to teach...?*
> *Teacher (T): I go through just the things that I do, seventh grade, so I do a little bit of geology, I guess, and earth formation and stuff like that, fossil layers, fossils, rock layers, things like that. So a little bit of earth science I guess if you call that.... I also do any benchmarks I can cover in my environmental science text. They pulled the ones that were...these are just the 7th grade ones that they pulled that I was gonna do in 7th grade. These are the ones that I was going to be responsible for."*

As the next quote illustrates, Teacher A's other goal and belief to *help students acquire knowledge or awareness* occurred to be related to his desire to cover curriculum requirements. In addition, Teacher A's goal and belief to *help students acquire knowledge or awareness* also occurred to be influenced by his other goal to *help students make their own decisions about environmental issues or problems*. The reason that Teacher A ascribed importance to assessing students' scientific knowledge and developing their ability to analyze a situation scientifically, may be because he believed knowledge and evaluation skills are important to *decision making*. Finally, his desire to *engage students in hands-on activities* stemmed from his belief that hands-on activities will help keep his students interested and engaged in his class.

> Teacher A interview:
> *G: "What do you focus on more environmental science?*
> *T: Environmental science, a lot of the big pro…a lot of the things, as I said before, you have to relate cause and effect. I think being able to analyze a situation scientifically is a big thing. Not only the way to…not only scientific fact but also the way to approach things scientifically too. What I would mostly want to get of the kids is having them make decisions on their own about the environment. If you are talking about environmental science specifically…*
> *G: So more informed because now they know…*
> *T: Yeah, and now they've been exposed to some of these stuff at a young age and they've all heard of it. I mean there's buzz words out there that they can ask me about that probably ten years ago kids I don't know if they are asking a 7th grade teacher or even certain things like global warming are big ideas now, holes in the ozone layer, they really want to talk about this. They probably hear about this whether it's debate, another one is natural selection, coz then you got parents arguing over it. So I definitely want to give them the tools to make their own decisions on these."*

In Teacher B, although her three most prevalent goals and beliefs each occurred in two data sources, the extent in which they occurred differed. In both interviews and CoRes, *transmit facts, content, knowledge, and/or benchmarks/ standards* occurred as her most prevalent goal and belief. In contrast, *develop/ instill positive attitudes toward science* occurred as the most prevalent goal and belief in the survey, but only her second most prevalent goal and belief in the interviews. Similarly, *develop/instill positive attitudes toward learning/education* occurred as her most prevalent goal and belief in the survey, but only her third most prevalent goal and belief in the interviews. Thus, despite appearing the same number of times across data sources, the frequency of use of goals and beliefs in each data source may be indicative of their overall importance for each teacher.

Teacher B's focus on *developing/instilling positive attitudes toward science* and *developing/instilling positive attitudes toward learning/education* more than the other goals and beliefs possibly resulted from her concern over students' lack of interest in science and in learning or education in general (see next quote). This concern was also expressed by Teacher C, which explains the occurrence of *develop/instill positive attitudes toward science* as one of his three most prevalent goals and beliefs.

Teacher B interview:

> *T: "What I want them to get is an appreciation for science, and I want them to think of it as more than just a class, but sort of a lifetime commitment. I want them to always be interested. I want them to know that their actions can change the way things work in our world.*
> *G: Like empowering them too?*
> *T: Yes, exactly. I guess I was rather shocked my first year here that many students don't like science, and it just surprised me. It really surprised me, because in elementary school, you know, you do a little experiment or something, and everybody is there. They love it. They can't get enough of it. And here I noticed that there's a sense of apathy."*

As the next quote illustrates, Teacher C focused on *preparing his students for society/higher education/career/future* in addition to *transmitting facts, content, knowledge, and/or benchmarks/standards,* because he believed that science teaching is more than just teaching facts; it is about allowing students to experience science and providing them with opportunities to develop skills and knowledge and to practice and apply them to prepare them for a successful career in science.

Teacher C interview:

"A lot of people, especially people that are higher up that are used to dealing with upper level kids, a lot of them are putting a whole lot more importance on the facts and the fact that a kid needs to be able to actually calculate density and understand why they're doing it. My feeling is this: I need to turn kids onto science. If I can turn them onto science to the possibility that they can make a living at this and the possibility that this is fun and it's really not learning because that's where the key is at middle school. So, my goal and the thing that drives my teaching is I want these kids to be able to physically experience science. not just…I do expect them to know it. I do give them multiple-choice tests. I just believe that in order for someone to really consider seriously that science is a way to go or an avenue to go to be successful in this day and age and get a job. They have to first of all, believe that they can do it. And, the only way they're going to believe that they can do it is if they actually tried it. The main reason is to get them to practice. And that's my driving force."

Teacher D's desire to *represent a body of knowledge* and to *develop science process skills* in addition to *transmit facts, content, knowledge, and/or benchmarks/standards* may indicate a need that she wants to address in her class instruction, e.g., students' mastery of science concepts (illustrated in the next quote) and the development and application of students' science process skills in their learning, which in turn may reflect her desire to cover school curriculum requirements to meet Michigan Curriculum Benchmarks and Standards.

Teacher D interview:
"Well we have, umm, I mean we have the, the you know Michigan standards and benchmarks and all that basically that we're supposed to follow. I am not uhhh you know probably as familiar with them all as I should be. But basically what I look at are the big ideas for each unit. And

umm, I try to think about how you know I can get the kids to understand those concepts and then the little concepts that go along with them."

In addition, Teacher D's goal and belief to reach students is likely influenced by her personal experience working with at-risk and special education learners as shown in the quotes below.

> Teacher D survey response:
> *"Personally, I feel we're too concerned as a society, about "covering everything" so we don't really "cover" anything. I'd rather teach fewer topics and go into more detail so the kids will actually remember studying the topic. My goal is to "reach" as many kids as I can."*

> Teacher D interview:
> *"As a teacher, you really do, you have to have your bag of tricks. Yeah, and you know we've got all the students with special needs and I worked with the cognitively impaired kids, I've worked with the autistic kids although I haven't worked with them as frequently umm I've worked with the learning disabled kids, I've worked with the emotionally impaired kids. You name it, any group that we have in our building, I worked with. I try to be compassionate and try to understand how hard it is for them. I prefer to work with the students with learning disabilities because umm I have more experience in that. I'm more familiar with what accommodations to make, you know what is an accommodation versus a modification."*

5.4.2.1.3.2 Most Prevalent Goals and Beliefs Across Teachers

The occurrence of categories other than those identified in the literature supports my conclusion in Chapter 4 that categories suggested by Magnusson *et al.* (1999) were limited and did not encompass all the reported goals and beliefs of teachers. My findings are also consistent with findings of Friedrichsen & Dana (2005).

In terms of individual goals and beliefs, the prevalence of some goals and beliefs point to contextual and personal factors that possibly explain these goals and beliefs. Contextual factors may be structural, e.g., school curriculum requirements, Michigan Curriculum Benchmarks and Standards, and content, or those related to student characteristics. Personal factors may include teachers' educational backgrounds, professional development experiences, and their own beliefs or values (Van Driel *et al.*, 2001).

The predominance of *transmit facts, content, knowledge, and/or benchmarks/standards* goal and belief may be an indication of the teachers' conventional view or belief about education, a personal factor, that (1) it is still predominantly transmission of knowledge (e.g., Teacher A on assessment: "Yeah, I think learning…is some sort of way that they've gained any sort of scientific knowledge…") and (2) it is *their* responsibility to teach facts and to increase knowledge of students about a particular content (Hungerford & Volk, 1990). This predominance also possibly suggests what other teachers call "teaching for the test," that is, teachers' primary goal is to teach what will be assessed in the standardized tests like the Michigan Educational Assessment Program (MEAP) – a contextual (structural) factor.

Although this is not a universal occurrence, "teaching for the test" appears to be the case for the four teachers examined in this study who, despite having different content foci (see Table 5.4), all considered *transmit facts, content, knowledge, and/or benchmarks/standards* as their number one goal and belief about teaching science. The next quote illustrates the emphasis that Teacher B's school placed on teaching what is being assessed. Many similar quotes can be found in the interviews and the teacher surveys.

> Teacher B Interview:
> *"Now our goal is to do scope and sequence and to do the curriculum and the assessments. I asked my principal the other day, ok, 'Where do we start with this?' We start with the assessments. Because when you know what's being assessed, then you'll know what you have to teach."*

The relatively stronger occurrence of *develop science process skills* and *develop/instill positive attitudes toward science* (see Table 5.10) compared with other goals and beliefs may be seen as a reflection of increasing school-wide, district-wide, or state-wide attention on integrating science processes (in Grade Level Content Expectations or GLCEs) or constructing and reflecting on new scientific knowledge (in the Michigan Curriculum Benchmarks and Standards) – a contextual (structural) factor – to improve students' MEAP scores. It also may be a result of teachers' knowledge that many of their students lack interest in science – a contextual factor (student characteristics) – as illustrated by the quote below.

> Teacher C interview:
> *You got to kind of trick the kids into being enthusiastic about something and the fact that they're going to learn even though they pretty much have an idea that it's not cool. I run into this, especially with girls, a lot. Girls get into middle school and they start thinking that it's not cool to be smarter than the boys. And that attitude still exists although it's not as pervasive as it was. It's still there. So, my thoughts are, I want kids to look at science with more of an open mind and I want them to be enthusiastic about it.*

Moreover, in the interviews of the four teachers, it was evident that the content they taught was largely dictated by the GLCEs or the Michigan

Curriculum Benchmarks and Standards. Subsequently, most of their goals and beliefs about teaching science appeared to be bound within the content that they (had to) teach – contextual (structural) factor; only a few were more general or not tied to a particular content or topic (see quote from Teacher B below). As Grossman (1990) and Lam & Kember (2006) suggested, the teachers' goals and beliefs may still in fact have guided their day-to-day decisions about what and how they taught. But findings in this study seem to show that teachers' goals and beliefs and their day-to-day decisions about what and how to teach were influenced by content, in addition to other factors.

> A more general goal and belief from Teacher B interview:
> "*What I'm looking for is for them to establish attitude and an understanding for how science works. And a willingness to investigate it. Everything else beyond that I guess is bonus.*"

As quoted from Teacher D's interview on page 212, her primary focus on knowledge and understanding of science concepts was influenced by her desire to follow the Michigan Curriculum Benchmarks and Standards. In the quote from Teacher B above, she not only wanted to focus on understanding of science, but also on developing her students' positive attitudes toward science, including their willingness to conduct investigations. The huge contrast in these two teachers' goals and beliefs about teaching science may possibly result in their use of very different pedagogical approaches (see Tables 5.13 and 5.15) and instructional methods (see Tables 5.19 and 5.21).

Finally, findings showed that some goals and beliefs occurred more than others across data sources, which could imply that some data sources (e.g., interviews and surveys) were better tools to examine goals and beliefs compared with others (e.g., class observations and CoRes). I found goals and beliefs more visible in the interviews and in the survey than in the CoRes and in the class observations. This was expected, because the teachers were asked directly about their goals and beliefs in the interviews and the survey, but not in the other data sources. In the CoRes, goals and beliefs about teaching science occurred primarily in teachers' explanations of the importance of teaching a topic and/or what they want their students to learn about a topic or in a lesson. Appearance of goals and beliefs in class observations was least expected, because I did not ask the teachers to talk about their goals and beliefs while they taught.

5.4.2.2 Teaching Orientations – Pedagogical Approaches

The following notes apply for Tables 5.12 through 5.15, 5.18 through 5.21, 5.24 through 5.27, and 5.31 through 5.34:

a) CO = Class Observations; In = Interviews; CoRes = Content Representations; and Su = Surveys
b) Percents (columns 2 through 5) correspond to the frequency of use of each pedagogical approach within a data source. Frequency is the number of raw occurrences of a pedagogical approach/instructional method/student skill within a data source divided by the total number of occurrences of ALL approaches within a data source.
c) Overall Prevalence: 1 = most prevalent, 2 = second most prevalent, and so on.

5.4.2.2.1 Individual Teachers

Teacher A, County X: taught air and water pollution in 7th grade

Teacher A cited and/or used multiple pedagogical approaches, and his most prevalent approaches across data sources were (1) *activity-driven*, (2) *didactic*, (3) *didactic-with-application*, (4) *process-oriented*, and (5) *project-based* (see Table 5.12). *Activity-driven* was the only approach that occurred in all data sources (22.2% in interviews, 50% in the survey, 36.4% in class observations, and 16.7% in CoRes).

Table 5.12. Five Most Prevalent Pedagogical Approaches of Teacher A

Teacher A	**Data Sources**				
Pedagogical Approaches	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Process-Oriented	8.0	15.9			4
Activity-Driven	36.5	22.2	16.7	50.0	1
Project-Based		14.3			5
Didactic		12.7	83.3	50.0	2
Didactic-With-Application	55.5	11.1			3

Teacher B, County Y: taught classification of organisms in 7th grade

Teacher B cited and/or used multiple pedagogical approaches, and her most prevalent approaches across data sources were (1) *activity-driven*, (2) *didactic*, (3) *process-oriented*, (4) *project-based*, and (5) *didactic-with-application* (see Table 5.13). *Activity-driven* (46.2% in interviews, 33.3% in the survey, 37.2% in class observations, and 18.8% in CoRes), *didactic* (43.8% CoRes, 20.5% in interviews, and 11% in class observations, and 8.3% in the survey), and *process-oriented* (18.8% in CoRes, 16.7% in the survey, 10.4% in class observations, and 12.8% in interviews) approaches occurred in all data sources.

Table 5.13. Five Most Prevalent Pedagogical Approaches of Teacher B					
Teacher B	**Data Sources**				
Pedagogical Approaches	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Process-Oriented	10.4	12.8	18.8	16.7	3
Activity-Driven	37.2	46.2	18.8	33.3	1
Project-Based	3.7	15.4		33.3	4
Didactic	11.0	20.5	43.8	8.3	2
Didactic-With-Application	37.6		18.8		5

Teacher C, County Z: taught forces and motion in 6th grade

Teacher C cited and/or used multiple pedagogical approaches, and his most prevalent approaches across data sources were (1) *activity-driven*, (2) *process-oriented*, (3) *didactic*, (4) *didactic-with-application*, and (5) *discovery/exploration* (see Table 5.14). *Activity-driven* (45.7% in class observations, 36.4% in CoRes, 33.3% in the survey, and 26.7% in interviews), *process-oriented* (45.7% in class observations, 38.3% in interviews, 16.7% in the survey, and 18.2% in CoRes), *didactic* (27.3% in CoRes, 16.7% in the survey, 20.3% in interviews, and 0.8% in class observations), and *didactic-with-application* (7.8% in class observations,16.7% in the survey, 9.1% in CoRes, and 1.7% in interviews) occurred in all data sources.

Table 5.14. Five Most Prevalent Pedagogical Approaches of Teacher C					
Teacher C	**Data Sources**				
Pedagogical Approaches	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Process-Oriented	45.7	38.3	18.2	16.7	2
Activity-Driven	45.7	26.7	36.4	33.3	1
Discovery/Exploration		1.7		16.7	5
Didactic	0.8	20.0	27.3	16.7	3
Didactic-With-Application	7.8	1.7	9.1	16.7	4

<u>Teacher D, County Z: taught agents of erosion and rocks and minerals in 5th grade</u>

As the other teachers, Teacher D also cited and/or used multiple pedagogical approaches, and her most prevalent approaches across data sources were (1) *didactic*, (2) *activity-driven*, (3) *project-based*, (4) *didactic-with-application*, and (5) *conceptual change* (see Table 5.15). *Didactic* (42.9% in the survey, 22% in interviews, 15.9% in CoRes, and 11.7% in class observations), *activity-driven* (22% in interviews, 31.3% in class observations, 28.6% in the survey, and9.5% in CoRes), and *project-based* (18% in interviews, 14.6% in class observations, 14.3% in the survey, and 7.9% in CoRes) approaches occurred in all data sources.

Table 5.15. Five Most Prevalent Pedagogical Approaches of Teacher D					
Teacher D	**Data Sources**				
Pedagogical Approaches	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Activity-Driven	31.3	22.0	9.5	28.6	2
Project-Based	14.6	18.0	7.9	14.3	3
Conceptual Change	0.6	18.0			5
Didactic	11.7	22.0	15.9	42.9	1
Didactic-With-Application	41.8	12.0	58.7		4

5.4.2.2.2 Combined Results of Four Teachers

The four teachers had similarities and differences in their most prevalent pedagogical approaches across data sources (see Tables 5.16 and 5.17). Overall, *activity-driven* and *didactic* were the most prevalent pedagogical approaches across teachers (1 and 2 in the last column, Table 5.16). Of the four teachers, Teacher C was the most *activity-driven* and most *process-oriented* and he also had the most representations of pedagogical approaches across data sources (see shaded areas in column 4, Table 5.16). Teacher D was the most *didactic*. *Inquiry* and *guided inquiry* were the least prevalent of all approaches (see column 6, Table 5.16).

Table 5.16. Summary of Five Most Prevalent Pedagogical Approaches of Four Teachers

Pedagogical Approaches	**A**	**B**	**C**	**D**	**Frequency of Use of Each Approach Across Teachers**	**Overall Prevalence of Approaches**
Academic Rigor	1	0	2	1	C > D > A	
Process-Oriented	2	4	4	2	C2 > B3 > A4 > D	3
Activity-Driven	4	4	4	4	C1 > B1 > A1 > D2	1
Discovery/Exploration	1	2	2	2	C5 > D > B > A	
Project-Based	1	3	1	4	D3 > B4 > A5 > C	5
Conceptual Change	1	1	0	2	D5 > A > B	
Inquiry	1	0	0	0	A	
Guided Inquiry	0	0	0	0	No Occurrences	
Didactic	3	4	4	4	D1 > B2 > C3 > A2	2
Didactic-With-Application	2	2	4	3	C4 > D4> B5 > A3	4
Number of approaches that occurred in 4 of 4 data sources	1	3	4	3		
Teacher who used and/or cited the most diverse pedagogical approaches across data sources	**C > D > B > A**					

Table 5.16 Continued:

A, B, C, and D = Teachers; numbers in columns 2 to 5 correspond to number of times an approach occurred across data sources, e.g., 4 means that particular approach occurred in all four data sources (class observations, interviews, content representations, and survey). In column 6, the number following A, B, C, or D is the frequency of use of that particular approach within a teacher. For example, C2 means that *process-oriented* approach was the second most prevalent approach in Teacher C. Note that only the five most prevalent approaches are included here; the letters (teachers) without a number next to them mean that the corresponding approach was not in the top five. The last column identifies the five most prevalent approaches across the four teachers (1 = most prevalent).

Table 5.17. Similarities and Differences of Pedagogical Approaches of Four Teachers

Teacher A	Teacher B	Teacher C	Teacher D
Across the four teachers, the most prevalent approaches were *activity-driven* and *didactic* approaches			
Least *didactic*	Also *didactic*, like Teacher D		Most *didactic*
		Most *activity-driven*	Least *activity-driven*
	Also *process-oriented*, like Teacher C	Most *process-oriented*	Least *process-oriented*
Least consistent with use of approaches – only one approach (*activity-driven*) occurred in all data sources		Most consistent with use of approaches – four approaches occurred in all data sources	
		Least *project-based*	Most *project-based*
	Least *didactic-with-application*	Most *didactic-with-application*	
Didactic approach was congruent with his goals and beliefs to *transmit facts* and *teach students how to acquire knowledge*. *Activity-Driven* was congruent with *engage students in hands-on activities* goal and belief.	*Didactic* approach was congruent with her goal and belief to *transmit facts* and her use of *activity-driven*, *process-oriented*, and *project-based* approaches were congruent with her goal and belief to develop students' positive attitudes toward science.	*Activity-driven* and *process-oriented* approaches were congruent with his goals and beliefs to *prepare students for society/future* and to develop students' positive attitudes toward science.	*Didactic* approach was congruent with her goal and belief to *transmit facts*. Some approaches were incongruent with her goals and beliefs, e.g., one of her three most prevalent goals and beliefs was to *represent body of knowledge* yet she is the least *process-oriented* and *activity-driven* of all teachers.

5.4.2.2.3 Discussion: Pedagogical Approaches

5.4.2.2.3.1 Pedagogical Approaches of Individual Teachers

The occurrence of *activity-driven* pedagogical approach as the most prevalent approach in Teacher A may be influenced by his goal and belief to *engage students in hands-on activities* (third most prevalent) to keep them interested and engaged in class (see Table 5.17). Similarly, the strong prevalence of *didactic* and *didactic-with-application* approaches in Teacher A, which are primarily used for disseminating information or providing scientific facts, may be explained by his goals and beliefs to *transmit facts, content, knowledge, and/or benchmarks/standards* and to *help students acquire knowledge or awareness.* In turn, this may be associated with Teacher A's lack of tenure and his need to meet curriculum requirements. This congruence between *didactic* and *didactic-with-application* approaches and the goal and belief to *transmit facts, content, knowledge, and/or benchmarks/standards* also occurred in Teachers B, C, and D – *transmit facts, content, knowledge, and/or benchmarks/standards* was their most prevalent goal and belief and *didactic* and *didactic-with-application* was in their five most prevalent approaches.

The occurrence of *activity-driven* pedagogical approach as the most prevalent approach and the prevalence of *process-oriented* approach (third most-used and/or cited) in Teacher B may be influenced by her goals and beliefs to *develop/instill positive attitudes toward science* and *develop/instill positive attitudes toward learning/education* in general. As with Teacher A, Teacher B believed that using approaches such as *activity-driven* and *process-oriented* that allow students to "get up and do things," e.g., experiment, manipulate objects, or collect and examine real data, instead of sitting down and listening to *lectures*, could improve their liking or appreciation of science and education in general (see quote below).

Teacher B interview:

> *"I try to pull in as many labs and hands-on activities as we can. I try, sometimes I just throw something that is completely of the area, like I - I haven't done this yet, I forgot all about it - but I have a little thing where it looks like two identical bases and you put ice cubes on and one melts almost instantly and the other doesn't melt at all. And so little things like that can get them thinking and having, just spark their interest a little bit."*

As shown earlier, Teacher C also shared this view (see next quote), which helps explain the strong prevalence of *activity-driven*, *process-oriented*, and *discovery/exploration* approaches in his teaching. In addition, the strong prevalence of *activity-driven* and especially *process-oriented* approaches in Teacher C also may be explained by his desire to *prepare his students for society/higher education/career/future*. A *process-oriented* approach consists primarily of learning about and developing process skills, which Teacher C believed are some of the skills his students need to be competitive in the global economy.

Teacher C interview:

> *"And the thing that they like about it is that I do a lot of hands-on stuff. They are of their seats, we go outside, they shoot rubber bands. One of the fun things that we do is we go outside and we have two or three different types of rubber bands and we're shooting them. The main reason is to get them to practice metrically measuring, gathering data and then bringing it back and making a graph. That's the whole purpose of the activity. But, in the meantime, they're learning a whole lot more about scientific*

method; they're learning about lab methods, they're learning about what is proper lab procedure, what is not and so forth. I have many, many different activities that are focused in that direction and they come in and they're enthusiastic, they're saying, 'hey what are we going to do today?' So, they come into my class with their eyes open and their minds open and they're willing and ready to do what they have to do."

Teacher D's goal and belief to *reach her students* seemed to be associated with the prevalence of *project-based* approach in her teaching, where, as a quote from her interview below illustrates, she used this approach mostly as an assessment method that she adjusted based on the abilities of her students. According to her, this approach also allowed her to meet the different learning styles of her students, thus "reaching" or accommodating their different learning needs. In contrast, the noticeably weaker prevalence of a *process-oriented* approach in Teacher D (not in her five most used and/or cited approaches), despite her goals and beliefs to *develop science process skills* and to *represent body of knowledge* (her second most-cited), possibly suggests that, to some extent, her use of pedagogical approaches is not always explained by her goals and beliefs as a science teacher.

Teacher D interview:

"I try to do differentiating, I try to do the things that will meet their you know their different learning styles. I try to do things, like when we do the solar system, you know, they can do a diorama, so if they are very hands on. They can do that or if they are more of, you know of uh, uh a writer, you know more visual, they can do the ABC book. And umm the pamphlets, you know so I like to have those, those options when we do projects and things like that. So that it can meet their, you know their different learning needs. And I will also make different rubrics so that I have pretty much the same expectations. You know like instead of having, you know, five facts about the planet, maybe the special ed kids have to have three. So they still have to come up with you know facts about the planet.

Uhhhm, maybe they have to tell me the color of the planet and the rotation and the revolution time. But they don't have to tell me extra facts. So you know I try to take in their, you know what they are able to do. And then you know the kids that are capable of doing more projects like that allow them to do more."

5.4.2.2.3.2 Most Prevalent Pedagogical Approaches Across Teachers

Findings showed that, although teachers employed multiple pedagogical approaches in their teaching, they used and/or cited only a few of them (no more than three) more extensively than others. In addition, although the exact extent of use is variable across teachers, two approaches were used consistently throughout – *activity-driven* and *didactic*. The dominance of these two approaches appeared to be largely connected to the teachers' primary goals and beliefs, even though the teachers did not entirely share the same goals and beliefs. Although congruence between goals and beliefs and pedagogical approaches appeared to exist, there also was some incongruence that may indicate a complex relationship between the two PCK variables.

As the teacher with the most representations of pedagogical approaches across data sources (4 approaches occurred in all 4 data sources – see shaded areas in column 4, Table 5.16), this may suggest that Teacher C was the most consistent in terms of use of pedagogical approaches. However, based on my class observations and interviews with him, this consistency also appeared to indicate that he was the least flexible or adaptable of the four teachers in terms of exploring other pedagogical approaches. Teacher C's consistency may be attributed to his long teaching experience (22 years). The same may be said of

Teacher B, who has taught for 23.5 years and was also fairly consistent with her use of pedagogical approaches (3 approaches occurred in all 4 data sources – see shaded areas in column 3, Table 5.16). Many years of teaching experience most probably have developed their knowledge and ability to use a specific set of approaches consistently.

Furthermore, both teachers' lack of flexibility or adaptability in terms of use of pedagogical approaches may be attributed possibly to their years of teaching experience – they have been teaching much longer than Teachers' A and D. It is possible that their belief in their pedagogical strategies is very strong, and that it may be difficult to change or "unlearn" their "old" ways, thereby resulting in a lack of openness to other approaches.

Teacher C's appearance as the most *activity-driven* and most *process-oriented* of all the teachers was expected, because his goals and beliefs appeared the most consistent with his pedagogical approaches. In both approaches, Teacher D was the weakest compared with the other teachers because, as she explained in her interview (see quote below), her inability to use *activity-driven* and *process-oriented* approaches were due to lack of funding, space, and time. This may explain why Teacher D was the most *didactic* of the four teachers.

Teacher D interview:

G: "What factors affect your teaching, and what are some of the things that you emphasize in your teaching?"
T: "Well, a lot of factors influence my teaching. Uhh, you know materials, number one. Like I said before, we don't have a lot of money in the district so when it comes to doing a lot of labs. I can't do a whole lot of lab experiment. Umm, so a lot of times, if I do one, I just do one. Instead of

doing, instead of having all the kids do it, umm, you know so that's one thing. Umm, the amount of space and the lack of time, and the lack of, you know, uh sinks and, and counters and things like that. The students also come into play. The kids' need uh, play a big role in it. I, you know, depending on the year, and you know the reading levels of the kids and umm the maturity levels and, and things like that, that can umm make a big difference as to how I actually teach them because I had kids that we could really go in depth."

The weak prevalence of *inquiry* and *guided inquiry* was surprising, and it appeared in spite of the seemingly increased emphasis on use of these approaches in science education in the United States. This presents an opportunity to continue to conduct studies that examine the prevalence of *inquiry* and *guided inquiry* approaches in environmental education and the factors that influence their use.

5.4.2.3 Instructional Methods

5.4.2.3.1 Individual Teachers

Teacher A, County X: taught air and water pollution in 7th grade

Teacher A used and/or cited a variety of instructional methods, and his most prevalent methods across data sources were (1st) *experiments/labs/computer labs*, (2nd) *discussion*, (3rd) *lecture*, (4th) *in-class activity*, and (5th) *drawings/pictures/posters* (see Table 5.18). None of the methods Teacher A used and/or cited occurred in all data sources, but *experiments/labs/computer labs* and *discussion* occurred in three of four data sources. Use of *didactic questions* was considerably more (45.6%) than any other methods Teacher A used in class observations, but it was absent in the other data sources.

Table 5.18. Five Most Prevalent Instructional Methods of Teacher A					
Teacher A	**Data Sources**				
Instructional Methods	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Didactic Questions	45.6				
Discussion	0.6	4.7	7.7	16.7	2
Drawings, Pictures/ Posters/Visuals/Diagrams	1.5	4.7	15.4		5
Experiments/Labs/ Computer Labs	0.2	4.7	15.4	16.7	1
In-Class Activity	1.1	4.7		33.3	4
Lecture	0.2	2.3	15.4	16.7	3

Teacher B, County Y: taught classification of organisms in 7th grade

As with Teacher A, Teacher B also used and/or cited a variety of methods, and her most prevalent methods across data sources were (1st) *experiments/labs/ computer labs*, (2nd) notes, (3rd) *discussion*, (4th) *student reading textbook aloud*, and (5th) *use of technology* (see Table 5.19). *Experiments/labs/computer labs, notes*, *discussion*, and *student reading textbook aloud* occurred in all four data sources. In class observations, *didactic questions* dominated the methods (53.7%), but as with Teacher A, it did not appear in the other data sources.

Table 5.19. Five Most Prevalent Instructional Methods of Teacher B					
Teacher B	**Data Sources**				
Instructional Methods	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Didactic Questions	53.7				
Discussion	0.7	4.4	6.3	7.7	3
Experiments/Labs/ Computer Labs	0.3	4.4	6.3	23.1	1
Notes	0.4	7.4	6.3	7.7	2
Student Reading Textbook Aloud	0.9	2.9	6.3	7.7	4
Use Of Technology	1.5	17.6		15.4	5

Teacher C, County Z: taught forces and motion in 6th grade

As with Teachers A and B, Teacher C also used and/or cited different methods, and his most prevalent methods across data sources were (1st) *hands-on activity*, (2nd) *lecture*, (3rd) *activity packets/worksheets*, (4th) *experiments/labs/computer labs*, and (5th) *graphs/charts* (see Table 5.20). Only *hands-on activity* occurred in all data sources. As it did in Teachers A and B, *didactic questions* dominated class observations (47.4%) in Teacher C, but this method did not appear anywhere else.

Table 5.20. Five Most Prevalent Instructional Methods of Teacher C

Teacher C	**Data Sources**				
Instructional Methods	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Activity Packets/ Worksheets	4.6	4.2	13.3		3
Didactic Questions	47.4				
Experiments/Labs/ Computer Labs	2.9	13.7	6.7		4
Graphs/Charts	4.0	3.2	6.7		5
Hands-On Activity	2.3	20.0	13.3	16.7	1
Lecture	0.6	4.2	13.3	16.7	2

Teacher D, County Z: taught agents of erosion and rocks and minerals in 5th grade

As with the other teachers, Teacher D used and/or cited different methods, and her most prevalent methods across data sources were (1st) *individual work/project*, (2nd) *field trips*, (3rd) *ask for/use examples*, (4th) *discussion*, and (5th) *drawings/pictures/posters* (see Table 5.21). *Individual work/project* and *field trips* occurred in all data sources. Unlike the other teachers, for who *didactic questions* only occurred in class observations, this m

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method occurred in Teacher D's class observations (55.6%) and interviews (20.5%).

Table 5.21. Five Most Prevalent Instructional Methods of Teacher D					
Teacher D	**Data Sources**				
Instructional Methods	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Ask For/Use Examples	7.3	2.6	22.1		3
Didactic Questions	55.6	20.5			
Discussion	2.6	6.4	15.8		4
Drawings, Pictures/ Posters/Visuals/ Diagrams	2.6	11.5	7.4		5
Field Trips	0.2	1.3	1.1	9.1	2
Individual Work/Project	0.2	7.7	5.3	9.1	1

5.4.2.3.2 Combined Results of Four Teachers

The four teachers had similarities and differences in their most prevalent instructional methods across data sources. Overall, *experiments/labs/computer labs* and *discussion* were the most prevalent methods across teachers and across data sources (1 and 2 in the last column, Table 5.22). Of the four teachers, Teacher B used the most diverse in use of instructional methods, as observed across data sources (4 methods occurred in all 4 data sources – see shaded areas in column 3, Table 5.22).

Table 5.22. Summary of Five Most Prevalent Instructional Methods of Four Teachers						
Instructional Methods	**A**	**B**	**C**	**D**	**Frequency of Use of Each Method Across Teachers**	**Overall Prevalence of Methods**
Activity Packets/Worksheets	-	1	3	3	C3 > D > B	
Ask For/Use Examples	2	1	2	3	D3 > A > C > B	
Didactic Questions	1	1	1	2	D > B > C > A	
Discussion	4	4	3	3	A2 > B3 > D4 > C	2
Drawings, Pictures/Posters/ Visuals/Diagrams	3	2	2	3	A5 > D5 > C > B	4
Experiments/Labs/Computer Labs	4	4	3	1	A1> B1 > C4 > D	1
Field Trips	-	-	2	4	D2 > C	
Graphs/Charts	-	-	3	-	C5	
Hands-On Activity	2	3	4	3	C1 > B > D > A	5
In-Class Activity	3	3	1	2	A4 > B > D > C	
Individual Work/Project	2	2	1	4	D1	
Lecture	4	1	4	1	C2 > A3 > B, D	3
Notes	2	4	2	3	B2 > D > A > C	
Student Reading Textbook Aloud	2	4	-	1	B4 > A > D	
Use Of Technology	2	3	3	3	B5 > C > D > A	
Number of methods that occurred in 4 out 4 data sources	3	4	2	2		
Teacher who used and/or cited the most diverse instructional methods across data sources	**B > A > D > C**					

A, B, C, and D = Teachers; numbers in columns 2 to 5 correspond to number of times a method occurred across data sources, e.g., 4 means that particular method occurred in all four data sources (class observations, interviews, content representations, and survey). In column 6, the number following A, B, C, or D is the frequency of use of that particular method within a teacher. For example, C3 means that *activity packets/worksheets* was the third most prevalent method in Teacher C. Note that only the five most prevalent methods are included here; the letters (teachers) without a number next to them mean that the corresponding method was not in the top five. The last column identifies the five most prevalent methods across the four teachers (1 = most prevalent).

Table 5.23. Similarities and Differences of Instructional Methods of Four Teachers			
Teacher A	**Teacher B**	**Teacher C**	**Teacher D**
Across teachers, the most prevalent methods were *experiments/labs/computer labs* and *discussion*			
Least consistent with use of methods – not one method occurred in all data sources	Most consistent with use of methods – four methods occurred in all data sources		
Used *In-Class Activity* (non-hands-on) the most		Used *Hands-On* the most	
Lecture-Oriented		*Lecture*-Oriented	
	Used Technology the most		
Experiments/Labs	*Experiments/Labs*	*Experiments/Labs*	
Discussion	*Discussion*		*Discussion*
		Activity Packets/Worksheets	
			Individual Work/Project
	Notes		
			Field Trips
Although weak of use of *hands-on activity* was incongruent with his goal and belief to *engage students in hands-on activities*, his focus on *experiments/labs* was congruent with this goal and belief. Use of *lecture* and *discussion* were congruent with his goals and beliefs *to transmit facts* and to *teach his students how to acquire knowledge*.	*Notes*, *discussion*, and *student reading textbook aloud* were congruent with her goal and belief to *transmit facts. Experiments/labs* and *use of technology* were congruent with her goal and belief of *developing students' positive attitudes toward science.*	Methods were congruent with his three most prevalent goals and beliefs (*Transmit facts, content, knowledge, and/or benchmarks/ standards; Prepare students for society/ higher education/ career/future; and Develop/instill positive attitudes toward science*)	Some methods used were incongruent with her goals and beliefs, e.g., one of her three most prevalent goals and beliefs was *to represent a body of knowledge*, yet *experiments/labs* was not a strong method used in her instruction.

5.4.2.3.3 Discussion: Instructional Methods

5.4.2.3.3.1 Instructional Methods of Individual Teachers

Teacher A's use of *experiments/lab/computer labs* may be explained by his goal and belief to *engage students in hands-on activities* to keep them interested and engaged in his class (see Table 5.23). It must be noted, however, that some of the *in-class activities and experiments/labs/ computer labs* that he actually included in his lessons were not truly hands-on; as he described in an interview below, they were simply class work that he called an activity or lab that allowed students to "get up" and, therefore, give them the impression that they were doing a lab activity instead of sitting and listening to him talk.

> Teacher A interview:
> *G: "So how do you then present the different types of pollution to them? Like smog, global warming, how do you do that?*
> *T: pretty much for this, it's pretty much straight lecture.*
> *G: lecture?*
> *T: Yeah, this is kind of a difficult one. I never really found great labs for it. But I gave them like a chart where they went around and this is just to get them of their seats more than anything, to make it feel like a lab even though there is really nothing experimental. But it's this I give them a chart and they have like all the different types of pollution. And I like put articles in different lab stations. So they can just go and they have to do a little bit of research in each lab station to figure out what is it caused by, what is this type of pollution caused by, what are the effects on a human, you know, stuff like that."*

The other methods that Teacher A used and/or cited (*discussion*, *lecture*, and *drawings/pictures/posters*), which are *didactic* and *didactic-with-application* types of instructional methods, also may have been associated with his goals and beliefs to *transmit facts, content, knowledge, and/or benchmarks/standards* and to *help students acquire knowledge or awareness*. Teacher A liked to engage his students in *discussions*, even though he admitted this approach took a lot of time because his students got excited to share their personal experiences. It is also important to note that for Teacher A, his own educational experience influenced his selection of instructional methods. For example, he liked using *drawings/pictures/posters* because, in addition to his belief that these methods helped some students understand the concepts he's teaching, his mentor used these methods as well (see next quote). All five of Teacher A's most prevalent methods seemed appropriate for teaching about air and water pollution, and allowed him to provide facts about sources and causes of pollution, as well as a concrete way to show his students how pollution affects plant growth.

> Teacher A interview:
> *"If I talk about that cycle* [construction of ozone molecule], *as long as I draw it with pictures, they are usually pretty good on the board, and I tell them to draw it on their notes, and stuff like that. And maybe a lot of it had to do with my mentor teacher when I was at Lansing School she was really big on having them draw pictures for a lot of things to describe themselves and a lot of times they have options, if you wanna describe it in a paragraph, that's fine. If you want to do it in a picture and a sentence that's fine too. And so I try to use sketches because some learn a lot by drawing pictures and showing things."*

As with Teacher A, Teacher B's selection of instructional methods such as her use of *didactic* and *didactic-with-application* types of instructional methods (e.g., notes, *discussion*, and student reading textbook aloud) may be explained by her goal and belief to *transmit facts, content, knowledge, and/or benchmarks/ standards* (see Table 5.23). Similarly, Teacher B's use of *experiments/labs/ computer labs* and use of technology also appeared to have been associated with her goals and beliefs to *develop/instill positive attitudes toward science* and *develop/instill positive attitudes toward learning/education* in general. Teacher B recognized the importance of using fun learning activities to increase her chances of building her students' interest and positive attitudes in science (see next quote). For example, she used *discussion*, *notes*, and *experiments/labs/ computer labs* extensively to teach about classification of organisms. These different methods allowed her to provide students with scientific facts about classification systems as well as allowed them to work in groups to let them experience exactly how they would classify things.

> Teacher B interview:
> G: "*What is your approach to helping them appreciate science?*
> *T: Think, well, one of the things that helps me is I'm a specialized background. So I'm pretty good about teaching things in different ways, which I find I do a lot in my classrooms as well. Just trying to, you know, hit the visual learner, and the verbal learner, and things like that. And I've found that you can't just teach something or say something one time, you really need to review, constant review, and I do that like at my openers in the morning, the bell-ringer type activity in the morning, try to make it fun, try to have labs, try to vary it. I never have them come in and just sit, you know, for two or three days straight - we would never do that. And so, yet I've gotta get the content to them."*

For Teacher C, his use of *hands-on activity* and *experiments/labs/ computer labs* showed a strong connection to his goals and beliefs to *prepare his students for society/higher education/career/future* and to *develop/instill positive attitudes toward science*. Teacher C's use of these two methods spoke of the value he ascribed to letting students try or experience a phenomenon that he was teaching about after they heard about it in his *lecture*. In addition, Teacher C used *packets/worksheets* to serve largely both as drill exercises and a test/quiz.

Use of this method may indicate the importance Teacher C ascribed to knowing and remembering scientific facts. This teacher also believed that his students needed to hear and learn facts from him first, so he used *lecture* and *activity packets/worksheets* for students to take home more than using *discussions*. Moreover, Teacher C believed that by requiring his students to make their *graphs/charts* by hand (not with the computer), he would help them obtain a deep understanding of how to create *graphs/charts* and to develop that skill to prepare them for a future career in science. Finally, the nature of Teacher C's topics (forces and motion) may have been easily applicable to the use of *hands-on* and *experiments/labs/ computer labs* instructional methods.

As with the three other teachers, Teacher D's use of *didactic* and *didactic-with-application* types of instructional methods (e.g., *ask for/use examples*, *discussion*, *drawings/pictures/posters*) appeared to follow from her goal and belief to *transmit facts, content, knowledge, and/or benchmarks/standards*. Similarly, these *didactic* and *didactic-with-application* types of methods as well as *individual work/project* were consistent with Teacher D's desire to reach her students, because these methods allowed her to accommodate her students' different learning styles and needs. For example, instead of giving examples to students, Teacher D wanted to ask them for examples because she believed they would remember concepts better if they provided examples to which they could relate.

I expected a higher occurrence of *experiments/labs/computer labs* or other *activity-driven* and *process-oriented* instructional methods based on Teacher D's goals and beliefs to *represent a body of knowledge* and *develop science process skills*. However, these methods were not represented in Teacher D's five most-prevalent methods due to Teacher D's limitations in funds/resources, space, and time, illustrating some incongruence between this teacher's goals and beliefs and instructional methods.

5.4.2.3.3.2 Most Prevalent Instructional Methods Across Teachers

Most of the instructional methods used by the four teachers seemed to be associated with their goals and beliefs about teaching science, and this may explain the prevalence of *experiments/labs/computer labs* and *discussion* across teachers (1 and 2 in the last column, Table 5.23). For example, use of activity-oriented methods (e.g., *experiments/labs/computer labs*) consistently occurred to match goals and beliefs to *develop/instill positive attitudes toward science*, *engage students in hands-on activities*, or *prepare students for society/higher education/career/future*. Similarly, use of *didactic* and *didactic-with-application* types of instructional methods (e.g., *discussion*) consistently appeared to support *transmit facts, content, knowledge, and/or benchmarks/standards*, which is a *didactic*-oriented goal and belief. However, some incongruence also was observed, which points to the complex nature of the relationship between goals and beliefs and instructional methods; that is, goals and beliefs do not always explain teachers' use of instructional methods, or other factors affect teachers' decisions on choice of methods.

It is also possible that some of the observed incongruence is a methodological issue that may have influenced the results of this study. For example, the dominant occurrence of *didactic questions* in class observations of all four teachers may have been largely a result of the use of class observations as a data collection method, as use of *didactic questions* may have been more easily observed in the classrooms than in the interviews, CoRes, or surveys. These findings point to the strengths and weaknesses of data collection methods, and therefore the need for careful interpretation of results.

As with pedagogical approaches, all four teachers employed multiple instructional methods. Some teachers used the same methods for the same or for different purposes, or they used different methods altogether based on multiple factors, including unique characteristics and needs of their students, barriers or constraints in their teaching context (e.g., lack of time, space, funding), content taught, their views about teaching and learning, and their styles of teaching, among others.

Teacher B had the most representations of instructional methods across data sources (4 methods occurred in all 4 data sources – see shaded areas in column 3, Table 5.22), which may suggest that Teacher B was the most consistent in terms of use of instructional methods. Teacher B's long teaching career (23.5 years) may have strengthened her knowledge and ability to use instructional methods consistently across varied and multiple teaching contexts. But, as with Teacher C, using methods consistently may mean that it may have been difficult for Teacher B to use, adapt, and apply new or different instructional methods in other teaching contexts, especially if she is strongly convinced that her methods are the most effective, if not the only effective methods of teaching.

5.4.2.4 Student Skills

5.4.2.4.1 Individual Teachers

Teacher A, County X: taught air and water pollution in 7th grade

Teacher A used and/or cited multiple student skills, and the most prevalent skills he used and/or cited across data sources were (1) *critical thinking/thinking on their own/analytical/evaluation skills*, (2) *observation skills*, (2) *social/communication skills*, (2) *writing*, (3) *reading*, (4) *information gathering*, and (5) *predicting* (see Table 5.24). None of the student skills occurred in all data sources, but *critical thinking skills/thinking on their own/analytical/evaluation skills* occurred in 3 of 4 data sources. No student skills were found in the survey.

Table 5.24. Five Most Prevalent Student Skills in Teacher A's Class

Teacher A	**Data Sources**				
Student skills	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Critical Thinking/Think On Their Own/Analytical/ Evaluation Skills	31.3	27.8	100.0	-	1
Information Gathering	15.6			-	4
Observing	6.3	11.1		-	2
Predicting	12.5			-	5
Reading	9.4	5.6		-	3
Social Skills/Communicating (Ability To Explain, Describe)	6.3	11.1		-	2
Writing	6.3	11.1		-	2

Teacher B, County Y: taught classification of organisms in 7th grade

Teacher B used and/or cited multiple student skills, and the most prevalent skills she used and/or cited across data sources were (1) *using numbers*, (2) *computer skills*, (3) *classifying*, (4) *critical thinking*/thinking on their own/analytical/evaluation skills, and (5) *observing* (see Table 5.25). None of the student skills occurred in all data sources, but using numbers occurred in 3 of 4 data sources.

Table 5.25. Five Most Prevalent Student Skills in Teacher B's Class

Teacher B	**Data Sources**				
Student skills	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Classifying	20.0		100.0		3
Computer Skills		25.0		33.3	2
Critical Thinking/Think On Their Own/Analytical/ Evaluation Skills	21.3	12.5			4
Observing	20.0	12.5			5
Using Numbers (E.G., Calculating %, Measuring, Estimating, Ranking)	1.3	12.5		33.3	1

Teacher C, County Z: taught forces and motion in 6th grade

Teacher C used and/or cited multiple student skills, and the most prevalent skills he used and/or cited across data sources were (1) *ability to record/document data or findings*, (2) *inferring/interpreting*, (3) *problem solving*, (4) *ability to make conclusions/recommendations*, and (5) *critical thinking/thinking on their own/analytical/evaluation skills* (see Table 5.26). None of the student skills occurred in all data sources, but all the five most prevalent skills occurred in 3 of 4 data sources. No student skills were found in the survey.

Table 5.26. Five Most Prevalent Student Skills in Teacher C's Class					
Teacher C	**Data Sources**				
Student skills	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Ability to Make Conclusions/Recommendations	2.0	7.6	14.3	-	4
Ability To Record/Document Data/Findings	10.2	12.1	14.3	-	1
Critical Thinking/Think on Their Own/Analytical/Evaluation Skills	2.0	1.5	14.3	-	5
Inferring/Interpreting	10.2	6.1	14.3	-	2
Problem Solving	8.2	6.1	14.3	-	3

Teacher D, County Z: taught agents of erosion and rocks and minerals in 5th grade

As with the other teachers, Teacher D also used and/or cited multiple student skills, and the most prevalent skills she used and/or cited across data sources were (1) *reading skills*, which was the only student skill found in the survey (100%) and was dominant in the CoRe (90%), (2) *critical thinking/thinking on their own/analytical/evaluation skills*, (3) *computer skills*, (4) *predicting*, and (5) *information gathering* (see Table 5.27). Of all the student skills in Teacher D, only *reading skills* occurred in all data sources.

Table 5.27. Five Most Prevalent Student Skills in Teacher D's Class					
Teacher D	**Data Sources**				
Student skills	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Computer Skills		4.3	10.0		3
Critical Thinking/Think on Their Own/Analytical/ Evaluation Skills	29.7	26.1			2
Information Gathering	5.4	8.7			5
Predicting	12.2	4.3			4
Reading	8.1	8.7	90.0	100.0	1

5.4.2.4.2 Combined Results of Four Teachers

Across the four teachers, the most prevalent student skill was *critical thinking/thinking on their own/analytical/evaluation skills*. The majority of the most prevalent student skills in all four teachers were process skills (asterisked items in Table 5.28). Even though Teacher D had one student skill (*reading*) appear in 4 of 4 data sources (see shaded areas in column 5, Table 5.28), Teacher C had five skills occur in 3 of 4 data sources (see shaded areas in column 4, Table 5.28), and, therefore, displayed the most skills across data sources.

Table 5.28. Summary of Five Most Prevalent Student Skills Across the Four Teachers

Student skills	**A**	**B**	**C**	**D**	**Frequency of Use of Each Student Skill Across Teachers**	**Overall Prevalence of Student Skills**
*Ability To Make Conclusions/ Recommendations**	-	-	3	-	C4	
*Ability To Record/Document Data/Findings**	-	-	3	-	C1	
*Classifying**	-	2	-	-	B3	
Computer Skills	-	2	1	2	B2 > D3 > C	4
*Critical Thinking/Think on Their Own/Analytical/ Evaluation Skills**	3	2	3	2	A1 > D2 > B4 > C5	1
*Inferring/Interpreting**	-	1	3	1	C2 > B > D	
*Information Gathering**	1	-	2	2	A4 > D5 > C	5
*Observing**	2	2	2	2	A2 > B5 > D > C	3
*Predicting**	1	-	2	2	D4 > A5 > C	5
*Problem Solving**	-	-	3	-	C3	
Reading	2	1	2	4	D1 > A3 > C > B	2
Social Skills/Communicating (Ability To Explain, Describe)*	2	1	1	2	A2 > D > B > C	
Using Numbers (e.g., Calculating %, Measuring, Estimating, Ranking)*	1	3	2	-	B1 > C > A	
Writing	2	-	2	2	A2 > C > D	
Number of skills that occurred in 4 of 4 data sources	0	0	0	1		

Table 5.28 Continued:

Number of skills that occurred in 3 of 4 data sources	1	1	5	0		
Teacher who used and/or cited the most diverse student skills across data sources	**C > A > B > D**					

A, B, C, and D = Teachers; numbers in columns 2 to 5 correspond to number of times a student skill occurred across data sources, e.g., 4 means that particular skill occurred in all four data sources (class observations, interviews, content representations, and survey). In column 6, the number following A, B, C, or D is the frequency of use of that particular skill within a teacher. For example, B3 means that classifying was the third most prevalent student skill in Teacher B. Note that only the five most prevalent skills are included here; the letters (teachers) without a number next to them mean that the corresponding skill was not in the top five. The last column identifies the five most prevalent skills across the four teachers (1 = most prevalent). Skills with asterisks were coded as process skills.

Table 5.29. Similarities and Differences of Student Skills Emphasized by the Four Teachers

Teacher A	Teacher B	Teacher C	Teacher D
Critical thinking/thinking on their own/analytical/evaluation skills was the most prevalent skill across the four teachers' classes Overall, science process skills were the most prevalent across the four teachers			
		Most consistent in terms of building skills – displayed the most skills across data sources (5 skills occurred in three of four data sources)	
		Most process skills-oriented	
		Ability to Make Conclusions/ Recommendations	
		Ability to Record/ Document Data/ Findings	
		Problem Solving	
		Inferring/Interpreting	
Reading			*Reading* – occurred in all data sources; congruent with Teacher D's goal and belief of reaching students

Table 5.29 Continued:

	Using Numbers (Calculating %, Measuring, Estimating, etc)		
Writing			
Social Skills/ Communicating			
	Computer Skills		*Computer Skills*
	Classifying – consistent with topic taught		
Information Gathering – matched his *knowledge acquisition* goal and belief			*Information Gathering*
Observing – consistent with topics taught	*Observing* – consistent with topic taught		
Predicting – consistent with topics taught			*Predicting*
The other skills Teacher A cited and/or used did not match his goals and beliefs, but some (*critical thinking, observing, predicting*) were consistent with the topics taught (air and water pollution).	Skills did not directly match her goals and beliefs, but were fostered through the instructional methods she used to *develop students' positive attitudes toward science* and some were consistent with topic taught (classification of organisms).	Skills were fostered because his goal and belief was to *prepare his students for society/future*; also skills were fostered as a result of instructional methods used to *develop positive attitudes toward science*; skills were consistent with topic taught (forces and motion).	Process skills (*critical thinking, information gathering, predicting*) matched her goal and belief to *develop process skills*, and were consistent with topics taught (agents of erosion and rocks and minerals).

5.4.2.4.3 Discussion: Student Skills

5.4.2.4.3.1 Student Skills in Individual Teachers

Looking closely at individual teachers, similarities and differences in student skills were observed. Five of the seven most prevalent student skills found in Teacher A (*critical thinking/thinking on their own/analytical/evaluation skills, observing, predicting, information gathering, and social/communicating*) were process skills, even though developing process skills was only the fourth most prevalent goal and belief of Teacher A. Some of these skills (e.g., *observing, predicting, social/communicating*) have resulted from *engaging students in hands-on activities*, which was one of Teacher A's three most prevalent goals and beliefs. *Information gathering* matched Teacher A's goal and belief to *transmit facts, content, knowledge, and/or benchmarks/standards* and *help students acquire knowledge or awareness*. The process skills that were observed also occurred related to the topics that Teacher A taught at the time of the study – air pollution and water pollution. For example, *critical thinking* is important for students to be able to examine multiple causes and effects of pollution and to assess how they contribute to or help reduce pollution.

Reading and writing are not science process skills, but occurred high in Teacher A's list, because he believed many of his students needed help with reading and writing. Consequently, Teacher A incorporated *reading* in his instruction by asking for volunteers to read from the textbook during *lecture*s and *note taking*. To foster development of writing skills, Teacher A included essay questions in his exams and required students to write in complete sentences when they answered a question. He also required students to submit science journals and/or lab reports.

In Teacher B, all but one (*computer skills*) of the five most prevalent student skills found across data sources were process skills. *Classifying* directly matched the content taught by Teacher B – classification of organisms. Overall, the emphasis on process skills expressed by Teacher B were not directly related to her goal and belief to *develop/instill positive attitudes toward science*, but, as a result of using different activities to increase or develop students' liking for science, Teacher B may have fostered or developed process skills. Using computers was a significant part of Teacher B's instruction, because she believed it allowed her students to work at their own pace, and it was yet another way for her to *develop/instill positive attitudes in students toward science and toward education* in general. None of the five most prevalent student skills found in Teacher B appeared to be associated with her goal and belief to *transmit facts, content, knowledge, and/or benchmarks/standards*. Finally, although Teacher B aspired to *develop/instill positive attitudes toward education*, the student skills that she fostered did not match her goal and belief.

In Teacher C, all of the five most prevalent student skills found across data sources were process skills, even though *developing process skills* was only his sixth most prevalent goal and belief. This may be attributed to his goal and belief to *prepare students for society/higher education/career/future*, as he expressed in his interview that he wanted his students to develop a career in science. He believed that his students needed to have the skills that scientists have to have a science career, which is why he focused on developing science process skills in his students. In addition, as with Teacher B, Teacher C also used diverse activities to improve students' attitudes toward science, so this also may have contributed to the predominance of process skills in his instruction.

Finally, most of the process skills cited and/or used directly matched content taught by Teacher C – forces and motion. For example, learning about forces and motion requires the ability to collect and record data, solve math problems, infer and interpret data, and make conclusions based on data.

For teacher D, some of the most prevalent student skills she cited and/or used across data sources were process skills (*critical thinking/thinking on their own/analytical/ evaluation skills, predicting,* and *information gathering*), and they matched her goal and belief to *develop process skills.* Process skills also matched the contents that she taught – agents of erosion and rocks and minerals. For example, students needed to think critically when they examined numerous causes and effects of erosion. They also needed to be able to predict possible consequences or impacts of erosion.

As with Teacher A, the occurrence of *information gathering skills* for Teacher D may be explained by her goal and belief to *transmit facts, content, knowledge, and/or benchmarks/standards*. However, no skills occurred to match Teacher D's goal and belief to *represent a body of knowledge*.

Reading skills and computer skills appeared to be associated with Teacher D's goal and belief to *reach students.* For example, as with Teacher A, Teacher D focused on *reading skills* because she believed her students needed help with reading. Consequently, she included reading in her instruction, such as during *lectures* and *note taking*, wherein she and her students took turns reading parts of a textbook. Moreover, Teacher D used computers to meet the different learning styles of her students and to provide them with an additional learning resource. For example, in addition to hearing *lecture*s in the classroom, students watched videos online to learn more about rocks and minerals. Students also used computers to gather information from online resources to complete individual class projects. In doing so, Teacher D may have helped foster computer skills in her students.

5.4.2.4.3.2 Most Prevalent Student Skills Across Teachers

Although multiple student skills were cited and/or used by each teacher, some skills were more prevalent than others, possibly indicating difference in each teacher's focus on a variety of student skills at the time of the study. The variability in prevalence of student skills within each teacher and the incongruence of some skills to goals and beliefs, pedagogical approaches, and instructional methods may have been influenced by a combination of contextual (students' needs, the nature of content taught, school requirements/standards and benchmarks, assessments/MEAP tests) and personal factors (e.g., goals and beliefs of teachers).

Looking at all teachers, however, it is interesting to note that most of the student skills emphasized were science process skills, even though individually, teachers did not all have the same pedagogical approaches, instructional methods, goals and beliefs about teaching, or content taught (see Table 5.30). But many of those skills were congruent with the specific content that individual teachers taught, as well as with the strong prevalence of *activity-driven* and *process-oriented* pedagogical approaches and *experiments/labs/computer labs* instructional methods across the four teachers. The other skills that occurred unrelated to content seemed more needs-based, that is, they resulted from a teacher's perception of students' needs at any given time during the study.

The predominance of *critical thinking/think on their own/analytical/ evaluation skills* when all occurrences of student skills across teachers are combined may reflect a general indication of the current direction that the teachers had in terms of *skill development* of their students. For Teacher C, it seemed as if his goal and belief to *prepare his students for society/higher education/career/future* may have explained why he was the most consistent in terms of student skills observed across data sources. This may mean Teacher C was the most skills-focused of the four teachers, although, because of his goal and belief, he may have been less open to fostering other student skills, particularly if they were not process-related, compared with the other teachers.

Table 5.30. Similarities and Differences of the Four Teachers in Terms of their Goals and Beliefs, Pedagogical Approaches, Instructional Methods, and Emphasis on Student Skills

Teacher A	Teacher B	Teacher C	Teacher D
▪ male, 32 years old ▪ Taught air and water pollution ▪ Teaches 7th grade Science, multiple class groups ▪ Least experienced in teaching (3 years) ▪ Not trained in MEECS ▪ Three most prevalent goals and beliefs about teaching science: (1) transmission of facts, (2) *knowledge acquisition*, and (3) *engage students in hands-on activities* ▪ Least consistent with use of approaches and methods across data sources ▪ Least *didactic* ▪ Most prevalent instructional methods: experiments/labs and *discussion* ▪ Student skills: process skills and basic academic skills (e.g., writing, reading)	▪ female, 57 years old ▪ Taught classification of organisms ▪ Taught 7th grade Science and Reading, multiple class groups ▪ Most experienced in teaching (23.5 years) ▪ Most MEECS-trained – Ecosystems and Biodiversity, Water Quality, Air Quality, and Land Use Units ▪ Three most prevalent goals and beliefs about teaching science: (1) transmission of facts, (2) develop positive attitude toward science and (3) develop positive attitudes toward education ▪ Most consistent with use of instructional methods across data sources ▪ Most prevalent instructional methods: experiments/labs and notes ▪ Student kills: process skills and technology skills (e.g., computer skills)	▪ male, 59 years old ▪ Taught forces and motion ▪ Taught 6th grade Science, multiple class groups ▪ Most experienced in teaching (22 years) ▪ MEECS-trained – Water Quality Unit ▪ Three most prevalent goals and beliefs about teaching science: (1) transmission of facts, (2) prepare students for society/future, and (3) develop positive attitudes toward science ▪ Most consistent with use of pedagogical approaches across data sources ▪ Most *activity-driven* and *process-oriented* ▪ Most prevalent instructional methods: hands-on and *lecture* ▪ Emphasized the most student skills ▪ Student skills: process skills	▪ female, 33 years old ▪ Taught agents of erosion and rocks and minerals ▪ Taught 5th grade Science, Language Arts/English, Mathematics, Social Studies/Social Science, one class group ▪ Moderately experienced in teaching (8 years) ▪ MEECS-trained – Land Use Unit ▪ Three most prevalent goals and beliefs about teaching science: (1) transmission of facts, (2) *represent a body of knowledge*, and (3) reach students ▪ Most *didactic* and *project-based* ▪ Least *activity-driven* and *process-oriented* ▪ Most prevalent instructional methods: individual/work projects and *field trips* ▪ Student skills: basic academic skills (e.g., reading), process skills, and technology skills (e.g., computer skills)

5.4.3 Manifestations of Pedagogical Content Knowledge (PCK)

5.4.3.1 Individual Teachers

Teacher A, County X: taught air and water pollution in 7th grade

As their elements of PCK in the previous section, the four teachers also demonstrated multiple manifestations of PCK across data sources. Teacher A's PCK was manifested the most in his (1) *reasons/purposes of using particular approaches, methods, or instructional strategies*, (2) *knowledge of student learning or understanding*, (3) *activities or examples that connected well with students*, (4) *ways used to overcome barriers or constraints in teaching context*, and (5) *reasons/purposes of selecting and emphasizing particular concepts* (see Table 5.31). None of the PCK manifestations demonstrated by Teacher A occurred in all data sources, but *reasons/purposes of using particular approaches, methods, or instructional strategies* and *knowledge of student learning or understanding* occurred in 3 of 4 data sources. No PCK manifestations were observed in the survey.

Table 5.31. Five Most Prevalent PCK Manifestations of Teacher A

Teacher A	**Data Sources**				
PCK Manifestations	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Reasons/Purposes of Selecting and Emphasizing Particular Concepts	12.5	13.0		-	5
Knowledge of Student Learning or Understanding	33.3	13.0	26.7	-	2
Ways Used to Overcome Barriers or Constraints in Teaching Context	16.7	15.2		-	4
Reasons/Purposes of Using Particular Approaches, Methods, or Instructional Strategies	6.3	32.6	73.3	-	1
Activities or Examples That Connected Well With Students	29.2	13.0		-	3

Teacher B, County Y: taught classification of organisms in 7th grade

Across data sources, Teacher B's PCK was manifested the most in his (1) *reasons/purposes of using particular approaches, methods, or instructional strategies,* (2) *knowledge of student learning or understanding,* (3) *activities or examples that connected well with students,* (4) *reasons/purposes of selecting and emphasizing particular skills, and* (5) *ways used to overcome barriers or constraints in teaching context* (see Table 5.32). As with Teacher A, none of the PCK manifestations demonstrated by Teacher B occurred in all data sources, but *reasons/purposes of using particular approaches, methods, or instructional strategies* and *knowledge of student learning or understanding* occurred in 3 of 4 data sources. No PCK manifestations were found in the survey.

Table 5.32. Five Most Prevalent PCK Manifestations of Teacher B

Teacher B	**Data Sources**				
PCK Manifestations	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Reasons/Purposes of Selecting and Emphasizing Particular Skills	10.2	2.6		-	4
Knowledge of Student Learning or Understanding	24.5	10.3	30.0	-	2
Ways Used to Overcome Barriers or Constraints in Teaching Context	4.1	5.1		-	5
Reasons/Purposes of Using Particular Approaches, Methods, or Instructional Strategies	12.2	66.7	70.0	-	1
Activities or Examples That Connected Well With Students	38.8	2.6		-	3

Teacher C, County Z: taught forces and motion in 6th grade

Across data sources, Teacher C's PCK was manifested the most in his (1) *reasons/purposes of using particular approaches, methods, or instructional strategies*, (2) *knowledge of student learning or understanding*, (3) *reasons/ purposes of using particular activities*, (4) *ways used to overcome barriers or constraints in teaching context, and* (5) *reasons/purposes of selecting and emphasizing particular skills* (see Table 5.33). As with Teachers A and B, none of the PCK manifestations demonstrated by Teacher C occurred in all data sources. However, unlike Teachers A and B, Teacher C's four most prevalent PCK manifestations occurred in 3 of 4 data sources. No PCK manifestations were found in the survey, just as with Teachers A and B.

Table 5.33. Five Most Prevalent PCK Manifestations of Teacher C

Teacher C	**Data Sources**				
PCK Manifestations	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Reasons/Purposes of Selecting and Emphasizing Particular Skills	10.7	12.5		-	5
Knowledge of Student Learning or Understanding	28.6	25.0	20.0	-	2
Ways Used to Overcome Barriers or Constraints in Teaching Context	3.6	2.5	20.0	-	4
Reasons/Purposes of Using Particular Approaches, Methods, or Instructional Strategies	28.6	32.5	20.0	-	1
Reasons/Purposes of Using Particular Activities (e.g., Problems, Demonstrations, Simulations, Investigations, and Experiments)	7.1	10.0	40.0	-	3

Teacher D, County Z: taught agents of erosion and rocks and minerals in 5th grade

Across data sources, Teacher D's PCK was manifested the most in her (1) *reasons/purposes of using particular approaches, methods, or instructional strategies,* (2) *knowledge of student learning or understanding,* (3) *activities or examples that connected well with students,* (4) *ways used to overcome barriers or constraints in teaching context, and* (5) *reasons/purposes of using particular activities* (see Table 5.34). Unlike the other three teachers, two of the five most prevalent manifestations of Teacher D's PCK emerged from all four data sources, namely, (1) *reasons/purposes of using particular approaches, methods, or instructional strategies* and (2) *knowledge of student learning or understanding*. The three other manifestations occurred in 3 of 4 data sources.

Table 5.34. PCK Manifestations of Teacher D

Teacher D	**Data Sources**				
PCK Manifestations	**CO (%)**	**In (%)**	**CoRes (%)**	**Su (%)**	**Overall Prevalence**
Knowledge of Student Learning or Understanding	12.7	27.6	16.2	50.0	2
Ways Used to Overcome Barriers or Constraints in Teaching Context	7.3	8.6	10.5		4
Reasons/Purposes of Using Particular Approaches, Methods, or Instructional Strategies	20.0	31.0	39.0	50.0	1
Reasons/Purposes of Using Particular Activities (e.g., Problems, Demonstrations, Simulations, Investigations, and Experiments)	3.6	6.9	12.4		5
Activities or Examples That Connected Well With Students	50.9	6.9	19.0		3

5.4.3.2 Combined Results of Four Teachers

Reasons/purposes of using particular approaches, methods, or instructional strategies and *knowledge of student learning or understanding* were the only two PCK manifestations that occurred in 3 of 4 data sources across all teachers, and, therefore, were the most prevalent. All four teachers demonstrated multiple manifestations of PCK, and they had much in common. Teachers A, B, and D shared the same four most prevalent PCK manifestations across all four data sources, namely, *1) reasons/purposes of using particular approaches, methods, or instructional strategies; 2) knowledge of student learning or understanding, 3) activities or examples that connected well with students,* and *4) ways used to overcome barriers or constraints in teaching context.* The three teachers differed in their fifth PCK representation. Teacher C shared the same first, second, and fourth PCK manifestations with Teachers A, B, and D, and his fifth PCK representation with Teacher B (*reasons/purposes of selecting and emphasizing particular skills*).

Although the four teachers shared similar PCK manifestations, the extent of these manifestations varied across teachers. Based on frequency of use, Teacher D was strongest in (1) *reasons/purposes of using particular approaches, methods, or instructional strategies,* (2) *knowledge of student learning or understanding,* (3) *ways used to overcome barriers or constraints in teaching context, and* (4) *activities or examples that connected well with students* (see column 6, Table 5.35). Teacher D was also the most consistent across data sources in demonstrating PCK manifestations (2 manifestations occurred in 4 of

4 data sources and 4 manifestations occurred in 3 of 4 data sources – see shaded areas in column 5, Table 5.35), and therefore overall, had the strongest PCK of the four teachers. Teacher B was strongest among the teachers in *reasons/purposes of selecting and emphasizing particular skills*. Teacher C was strongest among the teachers in *reasons/purposes of using particular activities.* Teacher A was strongest among the teachers in *reasons/purposes of selecting and emphasizing particular concepts* (see column 6, Table 5.35).

Table 5.35. Summary of Five Most Prevalent PCK Manifestations of Four Teachers

PCK manifestations	**A**	**B**	**C**	**D**	**Frequency of Use of Each PCK Manifestation Across Teachers**	**Overall Prevalence of PCK manifestations**
Reasons/Purposes of Selecting and Emphasizing Particular Concepts	2	2	2	3	A5 > D > B > C	
Reasons/Purposes of Selecting and Emphasizing Particular Skills	-	2	2	1	B4 > C5 > D	
Knowledge of Student Learning or Understanding	3	3	3	4	D2 > C2 > B2 > A2	2
Ways Used to Overcome Barriers or Constraints in Teaching Context	2	2	3	3	D4 > C4 > A4 > B5	3
Reasons/Purposes of Using Particular Approaches, Methods, or Instructional Strategies	3	3	3	4	D1 > C1 > B1 > A1	1
Reasons/Purposes of Using Particular Activities (e.g., Problems, Demonstrations, Simulations, Investigations, and Experiments)	-	1	3	3	C3 > D5 > B	5
Activities or Examples That Connected Well With Students	2	2	-	3	D3 > A3, B3	4
Number of manifestations that occurred in 3 of 4 data sources	2	2	4	4		
Number of manifestations that occurred in 4 of 4 data sources	0	0	0	2		
Teacher who demonstrated the strongest PCK based on occurrence and frequency of use of PCK manifestations across data sources	**D > C > B > A**					

A, B, C, and D = Teachers; numbers in columns 2 to 5 correspond to number of times a PCK manifestation occurred across data sources, e.g., 4 means that particular manifestation occurred in all four data sources (class observations, interviews, content representations, and survey). In column 6, the number following A, B, C, or D is the frequency of use of that particular PCK manifestation within a teacher. For example, C5 means that reasons/purposes of selecting and emphasizing particular skills was the fifth strongest PCK manifestation in Teacher C. Note that only the five strongest PCK manifestations are included here; the letters (teachers) without a number next to them mean that the corresponding PCK manifestation was not in the top five. The last column indicates the five most prevalent PCK manifestations across the four teachers (1 = most prevalent). Note that the teacher who demonstrated the strongest individual manifestation is the teacher listed first in column 6. For example in *reasons/purposes of selecting and emphasizing particular concepts*, Teacher A was the strongest, followed by Teacher D, then Teacher B, and then finally, Teacher C.

5.4.3.3 Discussion: Manifestations of Pedagogical Content Knowledge (PCK)

5.4.3.3.1 Manifestations of PCK of Individual Teachers

One way that Teacher A demonstrated his PCK was in his *reasons/ purposes of using particular approaches, methods, or instructional strategies*, as illustrated in the quote below. Using activity packets to supplement textbooks that lacked information on types of pollutants and their sources and impacts demonstrated his attempt to enhance his students' knowledge, which was congruent with one of his goals and beliefs.

Teacher A class observation:

> *"Also, some of it [information] is from this packet. I kind of got some stuff, did some research and got some stuff for it. You might want to read over the packet very carefully because some of the information you're not going to find in your book, you're going to find in your packet."*

The occurrence of (1) *reasons/purposes of using particular approaches, methods, or instructional strategies* and (2) *knowledge of student learning or understanding* as the two most prevalent manifestations of Teacher A's PCK may suggest that these two types of knowledge are associated with his decisions on what to teach, how, and why, more than the other types of knowledge (manifestations). The same thing may be said for the three other teachers whose PCK also was demonstrated the most in those same areas.

Lack of teaching experience may have played a big role in Teacher A's weak PCK relative to the other teachers – he was the youngest and had been teaching for only three years compared with Teachers B and C, who had been teaching for 23.5 and 22 years, respectively, at the time of this study. Teacher A's lack of experience also may have been tied to his seeming inconsistent use of pedagogical approaches and instructional methods. Some researchers have suggested that PCK is developed through teaching experience (Gess-Newsome, 1999; Lee *et al.*, 2007; Magnusson *et al.*, 1999; Van Driel & De Jong, 2001). Having taught for only three years at the time of the study, Teacher A may not have developed his PCK as much as Teachers B or C. Perhaps related to teaching experience is teacher education, which may have played a role in Teacher A's relatively less developed overall PCK compared with the other teachers. At the time of the study, he was still pursuing a master's degree whereas the other teachers already possessed a master's degree.

Of the four teachers, I did not expect to see Teacher B have the strongest manifestation of PCK in *reasons/purposes for selecting and emphasizing particular skills*, because she was not the strongest in terms of her emphasis on diverse student skills. I had predicted Teacher C or Teacher A. I did expect, however, to find Teacher B have weaker knowledge of *ways used to overcome barriers or constraints* in a teaching context compared with the other teachers, because she talked the least about barriers or constraints in class. While not discussing her challenges may not necessarily mean Teacher B had the fewest barriers or constraints surrounding her teaching, it is possible that she did have fewer challenges compared with the other teachers, or that these challenges did not influence her teaching as much as her other types of knowledge (manifestations). Finally, in contrast to Teacher A, age and length of teaching experience did not seem to increase the strength of Teacher B's overall PCK. Also, in contrast to the possible association between lack of consistency in use of instructional approaches or methods and the overall weak occurrence of Teacher A's PCK, Teacher B's consistency did not appear to have contributed to a strong PCK either. This seeming congruence (among PCK elements) and incongruence (between PCK elements and overall PCK) is another example of the complex relationships between individual PCK elements and actual occurrence and strength of PCK. As mentioned earlier, these possible associations (or lack thereof) also may be a result of methodological issues such as small sample size, or that variables were not adequately or appropriately addressed by some data collection methods.

I expected to see Teacher C as the strongest in demonstrating his PCK in terms of *reasons/purposes of using particular activities*, because he was the most *activity-driven* of the four teachers. In the quote below, Teacher C demonstrated his PCK in his *reasons/purposes of using particular activities* through his use of various small experiments to help students understand what happens to individual substances when they are combined and go through chemical reactions.

Teacher C interview:

> *"I do another one called…well, I call it liquid plus liquid equals solid and that's when I take steel wool and I soak it for 48 hours in vinegar. The steel wool breaks down and I get iron acetate. Then the iron acetate, I take and I pour that off, no, no, I put ammonia in a container and I put the iron acetate in the ammonia and it coagulates. It takes all that iron from the acetate and it rebonds it so it looks like a sludge it's on the top. And of course, in the process the ammonia ends up losing its smell as well because of the chemical reaction. We do that, I do three or four of those so that they get the understanding that when you have a chemical reaction or chemical change, that substances give up their properties and form something new. And that's the focus and the emphasis and then we're done with matter and move on."*

As with Teacher B, age, length of experience, and consistent use of pedagogical approaches did not seem to contribute to the strength of Teacher C's overall PCK. Teacher C's consistency of use of pedagogical approaches may suggest that his teaching was possibly less open to things that did not align with his goals and plans for his students (e.g., to *prepare them for society/higher education/career/future*), resulting in a more structured overall pedagogy. This was markedly different, for example, from Teacher D's overall pedagogy, in that she was more flexible and always was adjusting her lessons based on her students' needs and on current events at her school.

Teacher D's PCK was represented the most in her *reasons/purposes of using particular approaches, methods, or instructional strategies*. As the next quote illustrates, Teacher D used *reading* as an instructional method because many of her students had poor reading skills. She also *asked students to come up with their own examples* about what they were learning, because she believed that helped her students remember concepts better. She also used *experiments*, although only a few, to add to or reinforce concepts that they read or discussed.

Teacher D's CoRe responses:

> *"I use calendar pictures from the Sierra Club for visual aides. We read aloud the section and discuss as we go along because many students struggle with reading if it's done on their own. I have them think of examples that they've seen themselves so they're more likely to remember them. When possible, I try to do an experiment or discuss one that's been done in the past. At our upcoming field trip there is a model town inside a clear bubble w/a fan blowing sand around. I will talk about this ahead of time and when we are there I will refer back to it. It shows how deposition of sediment (sand) occurs when it's blown around."*

In the next quote, Teacher D's use of the root word "deposit" from the word "deposition" and her "making a deposit in a bank" analogy illustrated her PCK in terms of *activities or examples that connected well with her students.* The students related to her example of dropping off money in a bank when one makes a deposit, and it helped them understand that deposition "drops off" sediments.

Teacher D class observation:

"As a river flows downstream, the water starts to slow down. So it starts going really fast, but as it gets closer to the end, it slows down. This slowing down causes the river to drop some sediments. Sediments are the materials that are dropped by the agents of erosion. Sediments include sand, soil, and rock. The dropping of sediments by the agents of erosion is called deposition. Ok? So what is the root word of deposition?
S: Deposit?
T: Deposit. What is a deposit? [Calls a student.]
[Student answers]
T: No, that's a withdrawal. A deposit is putting something in. Or dropping something off…A deposit is like dropping something off. If you go to the bank and make a deposit, what are you leaving behind?
S: Your money.
T: Your money. Ok. So deposition is the dropping off or the leaving behind of sediments."

Teacher D's strong knowledge of *ways to overcome barriers or constraints* in her teaching context was expected, because, in contrast with Teacher B, Teacher D openly talked about the obstacles or challenges that she encounters in her class and her school in general (see next two quotes). Interestingly, the existence of these barriers or constraints may have provided Teacher D with opportunities to build her PCK.

Teacher D CoRe responses:
"Meeting needs of such a wide variety of students with much limited funds/resources and with all the GLCEs, standardized tests, etc. Also, with all the various methodologies we're supposed to use, strategies that work, 6 traits of writing, 4 square writing, literature circles, writers and reader's workshop and those are just for Language Arts and Literature. It's insane.

We practice reading strategies to help improve their ability to read instructional texts. We use a lot of worksheets, but we don't talk about most of them together in class because of low reading level of some students.

Teacher D interview:

"Yeah, we had a, um, a board meeting last night. They're, uhh, talking about uh closing our building down…actually the state of Michigan has changed the curriculum so that next year the topics, many of the topics that I teach, like the ecosystem and…it's supposed to go up to the sixth grade. And so, I'm contemplating on going, you know, and moving up to the sixth grade…we have the you know Michigan standards and benchmarks and all that basically that we're suppose to follow… You know what I mean and there are times, I mean I'm sure everybody has this, uh, you know in their job and there are times when you wonder if it's worth it and things like that and I think that happens in the teaching profession, you know, much more than other professions."

Another example of congruency occurred in terms of *knowledge of student learning or understanding* and *activities or examples that connected well with students* of Teacher D. I also expected to see Teacher D as the strongest in these two PCK manifestations, because she aspired to reach her students (goal and belief), and certainly one way to do that would be to know her students' learning needs and preferences, strengths and weaknesses, and prior knowledge to be able to find activities or examples to which they can relate.

<u>5.4.3.3.2 Most Prevalent Manifestations of PCK Across Teachers</u>

Findings across teachers showed some congruence and incongruence between PCK manifestations and PCK elements (goals and beliefs, pedagogical approaches, instructional methods, and student skills). For example, Teacher C occurred, as expected, the strongest in demonstrating his PCK in terms of *reasons/purposes of using particular activities*, possibly because he was the most *activity-driven* of the four teachers. In contrast, I predicted Teacher C or B to have a stronger manifestation of PCK in his/her r*easons/purposes of using particular approaches, methods, or instructional strategies* compared with Teacher B and D because they were the strongest and most consistent in pedagogical approaches and instructional methods, respectively. However, Teacher D occurred the strongest.

In addition, although I predicted Teacher C or B to have a stronger overall PCK than Teacher D because they were more consistent in their use of pedagogical approaches and instructional methods and were more skills-focused than Teacher D, the latter occurred the strongest. These mixed findings possibly suggest that prevalence of individual elements of PCK does not predict or indicate prevalence of individual PCK manifestations or strength of teachers' overall PCK. Arguably, this may be attributed to the nature of PCK, which, according to some researchers, is the result of the integration of individual elements of PCK and not the sum of those elements (Loughran *et al.*, 2004; Park & Oliver, 2008). Subsequently, this may help explain why Teacher D had the strongest PCK of the four teachers, even though she was less experienced in terms of teaching, less consistent in her use of pedagogical approaches and methods, and less focused on student skills than Teachers B and C. Teacher D's lack of experience does not support an earlier claim by some researchers that more experienced teachers have stronger PCK than those who are less-experienced (Lee *et al.*, 2007; Park & Oliver, 2008; Van Driel & De Jong, 2001).

Another factor that may help explain why Teacher D had the strongest PCK may be her flexibility in terms of what to teach and how. From my class observations, it was evident that Teacher D was more willing to adjust her plan for the day to take advantage of teachable moments than the other teachers. Such instances may have allowed Teacher D to connect more with her students and learn more ways to improve her teaching and her students' learning, thereby improving her overall PCK (Park & Oliver, 2008).

Finally, the fact that Teacher D had only one class group on which to focus every day may have helped her strengthen her PCK, because it may have been easier for her to integrate her teaching across the subjects, and identify areas where she might be able to change or improve to teach her students more effectively. The other teachers may have had to adjust to different groups of students and may have had less time to reflect on their teaching and develop and strengthen their PCK.

The consistent occurrence of *reasons/purposes of using particular approaches, methods, or instructional strategies* (most prevalent in all teachers) and *knowledge of student learning or understanding* (second most prevalent in all teachers) as the strongest areas where PCK of the four teachers was demonstrated may suggest that these two types of knowledge affect the four teachers' instruction more than their other types of knowledge, despite their differences and similarities in content and grade level taught, approaches and methods, student skills, goals and beliefs, age, and years of teaching experience. This is somewhat consistent with Park & Oliver's (2008) belief that there is an association between understanding of students' misconceptions and overall PCK. According to them, PCK is the "understanding and enactment of how to help students understand specific subject matter using multiple instructional strategies, representations, and assessments whole working within the contextual, cultural, and social limitations in the learning environment (2008, p. 264)."

The lack of occurrence of PCK manifestations in surveys is considered a data collection issue. None of the survey questions asked about teachers' PCK, so I did not expect to find much evidence of PCK from that data source. I included surveys as another source for examining PCK data because one teacher (D) showed evidence of PCK in her responses to the survey questions. In future studies, surveys can be used to collect PCK data, but they should include questions that specifically target PCK.

5.4.4 Action Competence (AC)

5.4.4.1 Individual Teachers

Teacher A, County X: taught air and water pollution in 7th grade

Of the five elements of AC, the most prevalent in Teacher A across four data sources was *knowledge/insight*, followed by *planning and action experiences*, *critical thinking and reflection*, *commitment*, and then *visions* (see columns 2-5, Table 5.36a). No AC elements occurred in all data sources, but *knowledge/insight* occurred in 3 of 4 data sources (68% in class observations, 77.5% in interviews (77.5%), and 100% in CoRes). *Knowledge of effects,* *knowledge of causes,* and *general awareness of environmental issues/problems* were considerably more prevalent than *knowledge of change strategies* and *knowledge of alternatives and visions.* No AC was observed in the survey.

<u>Teacher B, County Y: taught classification of organisms in 7th grade</u>

Of the five elements of AC, the most prevalent in Teacher B across four data sources was *planning and action experiences*, followed by *knowledge/ insight*, *commitment*, *visions*, and then *critical thinking and reflection* (see columns 6-9, Table 5.36a). No AC element occurred in all data sources. *Planning and action experiences* occurred in interviews (47.4%) and in the survey (50%). *Knowledge/Insight* was the only AC element observed in class observations. As with Teacher A, *knowledge of effects*, *knowledge of causes*, and *general awareness of environmental issues/problems* were considerably more prevalent than *knowledge of change strategies* and *knowledge of alternatives and visions*. *Visions* occurred in the survey (25%), but it was not observed anywhere else. No action competence was observed in CoRes.

Teacher C: County Z taught forces and motion in 6th grade: No evidence of action competence was observed in all data sources.

<u>Teacher D, County Z: taught agents of erosion and rocks and minerals in 5th grade</u>

Of the five elements of AC, the most prevalent in Teacher D across four data sources was *knowledge/insight*, followed by *planning and action experiences*, *critical thinking and reflection*, *commitment*, and then *visions* (see

Table 5.36a). No AC elements occurred in all data sources, but *knowledge/ insight* and *planning and action experiences* occurred in 3 of 4 data sources. As with Teacher A, *commitment* and *visions* occurred the least of all the AC elements. As with Teachers A and B, *knowledge of effects* and *knowledge of causes* were Teacher D's two most prevalent *knowledge/insight* components, but the three teachers differed in the third: Teacher D's was *knowledge of change strategies*, but Teachers A and B's was *general awareness of environmental issues/problems*. No action competence occurred in the survey.

5.4.4.2 Combined Results of Four Teachers

Based on the number of times an AC element occurred across data sources and on the frequency of use of an AC element across data sources, the most prevalent AC element across Teachers A, B, and D was *knowledge/insight*, followed by *planning and action experiences*, *critical thinking and reflection*, *commitment*, and *visions* (see column 6, Table 5.36b). AC was not found in any of the data sources from Teacher C. Based on mean percents and mean ranks, the most prevalent AC element across the three teachers was *knowledge/insight*, followed by *planning and action experiences*; prevalence of *critical thinking and reflection*, *commitment*, and *visions* did not appear to be considerably different from one another. Based on prevalence of AC elements in each of the four teachers, Teacher D was the most AC-oriented, followed by Teacher B and Teacher A (see last row, Table 5.36b). Teacher D also had the most representations of AC across data sources (AC elements occurred 11 times across data sources, including 2 elements that occurred in 3 of 4 data sources, see column 4, table 5.36b). Based on mean percents, Teacher B was the most AC-oriented, followed by Teacher D and then Teacher A (see column 2, Table 5.36c).

Table 5.36a. Occurrence and Frequency of Action Competence in Three Teachers*

	TEACHER A (COUNTY X)				TEACHER B (COUNTY Y)				TEACHER D (COUNTY Z)			
Elements of AC	CO	In	CoRes	Su	CO	In	CoRes	Su	CO	In	CoRes	Su
Knowledge/Insight	**68.0**	**77.5**	**100.0**	**-**	**100.0**	**31.6**	**-**		**61.3**	**68.8**	**73.4**	**-**
1) Effects	*27.8*	*27.5*	*16.7*	-	*33.3*	*5.3*	-		*22.5*	*17.2*	*20.0*	-
2) Causes	*28.9*	*22.5*	*25.0*	-	*33.3*	*5.3*	-		*20.5*	*17.2*	*20.0*	-
3) Alternatives and Visions	*1.0*	*5.0*	*8.3*	-		*5.3*	-		*5.6*		*6.7*	-
4) Change Strategies	*2.1*	*5.0*	*16.7*	-		*10.5*	-		*3.5*	*17.2*	*20.0*	-
5) General Awareness of Environmental Issues/Problems	*8.2*	*17.5*	*33.3*	-	*33.3*	*5.3*	-		*9.2*	*17.2*	*6.7*	-
Commitment		**5.0**		**-**		**15.8**	**-**	**25.0**	**1.4**	**10.3**		**-**
Critical Thinking and Reflection	**9.3**	**2.5**		**-**		**5.3**	**-**		**14.1**	**6.9**		**-**
Visions	**2.1**			**-**			**-**	**25.0**	**1.4**			**-**
Planning and Action Experiences	**20.6**	**15.0**		**-**		**47.4**	**-**	**50.0**	**21.8**	**13.7**	**26.6**	**-**
TOTAL	100.0	100.0	100.0	-	100.0	100.0	-	100.0	100.0	100.0	100.0	-

Numbers are in percents, and are the frequencies of use of each AC element within a data source for each teacher (raw number of occurrences of EACH element within a data source divided by the total raw number of occurrences of ALL elements within a data source); CO = Class Observations; In = Interviews; CoRes = Content Representations; Su = Surveys; shaded areas are the main elements of AC

* One teacher (Teacher C) did not display AC

Table 5.36b. Prevalence of AC Elements Across Three Teachers* Based on Occurrence and Frequency of Use

AC Component	A	B	D	Frequency of Use of Each AC Element Across Teachers	Prevalence of AC Elements
Knowledge/Insight	3	2	3	A1 > D1 > B2	1
Commitment	1	2	2	B3 > D4 > A4	4
Critical Thinking and Reflection	2	1	2	D3 > A3 > B5	3
Visions	1	1	1	B4 > A5 > D5	5
Planning and Action Experiences	2	2	3	D2 > B1 > A2	2
Number of times AC element occurred in 3 of 4 data sources	1	0	2		
Most AC-Oriented Teacher	**D > B > A; no AC was observed in C**				

A, B, C, and D = Teachers; numbers in columns 2 to 4 correspond to number of times an AC element occurred across data sources, e.g., 3 means that particular AC element occurred in 3 of 4 data sources (e.g., class observations, interviews, and content representations). In column 5, the number next to the letter (teacher) refers to the frequency of use of that particular element within a teacher. For example, A1 means that *Knowledge/Insight* was the number one most prevalent AC element in Teacher A. The last column indicates the overall prevalence of each AC element across the three teachers (1 = most prevalent). Prevalence (extent of use) of each AC element was determined based on the number of times an element occurred across data sources (e.g., 4 of 4 or 1 of 4 data sources) and frequency of use of an element across data sources (e.g., most-cited and/or used in 4 of 4 data sources or 1 of 4 data sources) in each teacher.

In terms of occurrence and frequency of use, Teacher D was the most AC-oriented teacher because she was strongest in two AC elements (*Critical Thinking and Reflection and Planning and Action Experiences*) and second strongest in two other elements (*Knowledge/Insight and Commitment*). Teacher B also was strongest in two elements (*Commitment* and *Visions*), but was second strongest in only one element (*Planning and Action Experiences*). Teacher A was strongest in only one element (*Knowledge/Insight*).

* One teacher (Teacher C) did not display AC

Table 5.36c. Prevalence of AC Elements Across Three Teachers* Based on Mean Percents and Mean Ranks

	Most AC-Oriented Teacher	Most Prevalent AC Element Across Teachers	
AC elements	Mean Percent	Mean Percent	Mean Rank Across Teachers A, B, & D
Knowledge/Insight (K)	A (61.4) > D (50.9) > B (32.9)	48.4	1, 1, 1 = 1
Commitment (Com)	B (10.2) > D (2.9) > A (1.3)	4.8	4, 3, 4 = 3.7
Critical Thinking and Reflection (CT & R)	D (5.2) > A (3.0) > B (1.3)	3.2	3, 5, 3 = 3.7
Visions (V)	B (6.2) > A (0.5) > D (0.4)	2.4	5, 4, 5 = 4.7
Planning and Action Experiences (PAE)	B (24.4) > D (15.5) > A (8.9)	16.3	2, 2, 2 = 2
Most AC-Oriented Teacher	**B > D > A; no AC was observed in C**	**K > PAE > Com, CT & R, and V**	**K > PAE > Com, CT & R, and V**

Mean percents and mean ranks were calculated from only three teachers who used and/or cited AC (A, B, and D)

Mean percent for each element per teacher (Column 2): sum of frequencies of use of each element in all data sources divided by 4 times 100.
Mean percent for each element across all teachers who demonstrated use of AC (Column 3): sum of all individual frequencies of each element in all data sources in 3 teachers divided by 12 times 100.

Mean "rank" of each element across teachers who demonstrated use of AC (Column 4): sum of "ranks" of each element in all 3 teachers divided by 3. For example, *Knowledge/Insight* was the most prevalent in all 3 teachers, so 1 + 1 + 1 = 3/3 = 1.

In mean percent analysis, higher percent (frequency) in each data source led to higher overall mean percent. For example, even though *Planning and Action Experiences* occurred in 3 of 4 data sources in Teacher D and only in 2 of 4 data sources in Teacher B, the mean percent was higher in Teacher B (24.4%) compared to Teacher D (15.5%) because Teacher B had higher frequencies (values) than Teacher D.

In terms of mean percents, Teacher B was the most AC-oriented teacher because compared with Teacher A or Teacher D, she was strongest in 3 AC elements (*Commitment, Visions,* and *Planning and Action Experiences*).

* One teacher (Teacher C) did not display AC

5.4.4.3 Discussion: Action Competence

5.4.4.3.1 AC in Individual Teachers

Teacher A, County X: taught air and water pollution in 7th grade

Use of AC

Teacher A focused more on *knowledge/insight* and *planning and action experiences* than the three other elements (K > PAE > CT & R > Com > V). Expectedly, Teacher A's use of AC was illustrated within the context of two major topics – water pollution and air pollution – because these were the two topics that he taught at the time of the study. In terms of *knowledge/insight*, Teacher A promoted *awareness of environmental issues/problems* and *knowledge of causes and effects* by asking students questions about or engaging them in *discussions* on polluted cities in the United States (Los Angeles versus New York), specific types of water pollution (sewage, chemical, groundwater) and air pollution (acid rain, smog, carbon monoxide), causes and impacts of air and of water pollution, greenhouse effect, global warming, renewable and nonrenewable resources, alternative forms of energy, and waste disposal and management.

In terms of *knowledge of alternatives and visions*, Teacher A discussed the possibility of adopting Saudi Arabia's use of desalination as a solution to address the increasing global concern about lack of clean and fresh water for human survival. As well, Teacher A asked his students about ways to prevent water pollution. Interestingly, the use of Saudi Arabia as an example connected well with students and generated a rich *discussion* in the class, especially when the teacher mentioned to the possible involvement of Saudi Arabia in the

September 11, 2001 attacks to the United States – an illustration of Teacher A's PCK in *activities or examples that connected well with students.*

Teacher A talked about change strategies in his class in the contexts of ways to prevent water pollution, how to avoid carbon monoxide poisoning, how to *hypothetically* address global warming (because he taught it as a theory, not a fact), and how the government responded to increasing ozone layer destruction. It was evident that Teacher A promoted *knowledge of change strategies* by focusing on prevention and solution.

Planning and action experiences included *discussions* about how *people in general* should dispose of wastes, how to develop alternative sources of fuel or energy, and how to address impacts of water or air pollution. It should be emphasized that these possible solutions identified by students were not targeted specifically for student participation; these actions were suggestions for adults.

Teacher A also fostered development of students' *observation skills* using a *lab experiment* (effect of pollution on seed germination) and engaged students in cooperative *discussions* and sharing of ideas using an *in-class activity* to identify types and different sources of pollution, and their impacts on human health and the environment. Teacher A used a *lab experiment* to demonstrate the effects of pollution on plants because he believed his students would be more engaged and interested in the topic than listening to his *lecture*. This is an illustration of Teacher A's PCK – *reasons for using particular approaches, methods, and strategies* and *knowledge of student learning.*

Under the AC criteria used in this study (see Appendix C.1), *planning and action experiences* include providing students with concrete, real life experiences in planning and acting on environmental issues or problems, and giving students opportunities to develop skills and confidence to identify and solve problems, set goals, gather information, communicate, and manage time and logistics to take action. Although Teacher A did not provide his students with real life experiences in planning and taking action during the course of this study, the *lab experiment* and *in-class activity* described above did provide an opportunity for his students to develop *observation skills*, *gather information*, learn more about an environmental issue, and *communicate* what they learned to others. I consider these skills and activities important aspects of *planning and action experiences*.

One of the ways that Teacher A promoted *critical thinking and reflection* was by asking students to think about why the United States has not seriously pursued the development of alternative sources of energy, despite the increasing flow of ideas and especially when the country is in the middle of an oil crisis. Although he gained little participation from his students in this particular question, Teacher A made an attempt to help students think and ask questions.

Another way that Teacher A facilitated *critical thinking and reflection* was by asking students to think about global warming and why they believed (or not) it is a true phenomenon. In doing this, however, Teacher A had to talk about global warming as a theory because some of his students (and their parents) did not believe in global warming and he was advised by the School Board the year before to change the way he presented the topic to his students to be respectful of some parents' beliefs (see next quote). Teacher A's experience is an example of Chawla & Cushing's (2007, p. 448) observation that in the United States, "environmental educators face strong pressures not to advocate any political position." Despite the slight tension and discomfort in the classroom, Teacher A said his students were well engaged in the *discussion*. Although Teacher A did not go beyond discussing global warming, Chawla & Cushing (2007, p. 448) believe that engaging students in *discussions* can facilitate their personal decisions and "help prepare students for political action."

Teacher A interview:

> *"I still teach, for example, natural selection, I have to teach it as a theory, because I can't teach anything otherwise. I also have to teach global warming as a theory, not a scientific fact. I had a parent and* School Board *member that was very upset coz I showed them inconvenient truth last year - devote too much to one side of the argument."*

The only instance in which *commitment* was observed in Teacher A was in his goal of helping his students make independent decisions about the environment by providing them with information and encouraging them to ask questions, and to talk to him or to others about environmental problems or issues (e.g., global warming). He believed that having correct information and listening to other students' thoughts about environmental problems or issues would help students decide whether they would be involved and, if so, in what ways, in solving environmental problems or issues.

Finally, *visions* was fostered when Teacher A asked his students what the future would look like if the United States would explore alternative sources of fuel such as water. Teacher A talked about the pros and cons of pursuing such projects, especially cost, time, and safety. Additionally, Teacher A referred back to Saudi Arabia's use of the desalination process to address the country's lack of freshwater, and asked his students if this might be needed in the future in the United States and in other parts of the world.

Associations between PCK and AC

The prevalence of the *knowledge/insight* AC element in Teacher A's instruction seemed logical because two of his most cited goals and beliefs – *transmit facts, content, knowledge, and/or benchmarks/standards* and *help students acquire knowledge or awareness* – spoke about knowledge. It is not clear if the prevalence of the *planning and action experiences* element was associated with Teacher A's goal and belief to *engage his students in hands-on activities*, because *planning and action experiences* may or may not involve hands-on activities. Nonetheless, teachers' goals and beliefs may predict to some extent the elements of AC that will be present in their classrooms.

Although the *knowledge/insight* element was the most prevalent element of AC observed in Teacher A, it was largely limited to *knowledge of causes*, *knowledge of effects*, and *general awareness of environmental issues or problems. Knowledge about alternatives and visions* and *knowledge of change strategies* were comparably weak. Jensen (2000a) pointed that a strong focus on *knowledge of effects and causes*, and the absence or lack of focus on *knowledge about change strategies and alternatives and visions* will only generate concerns or worry, will weaken *commitment*, and will contribute to action paralysis. To fully provide action-oriented knowledge, which is a key ingredient in developing AC, teachers need to expose their students to ways of creating social change and finding solutions.

Moreover, although a good part of the *planning and action experiences* element appeared to have been met by Teacher A (e.g., developing skills such as *critical thinking/thinking on their own/analytical/ evaluation skills, observing skills, social/communication skills, writing, information gathering, and predicting*), it was evident that students did not have any real world experiences in the class to plan and to take action on an environmental problem or issue. This could be attributed to barriers or constraints in Teacher A's teaching context, such as lack of time, lack of funds, lack of resources (books and other materials), lack of support from some parents, fear of getting reprimanded by the school administrator or the School Board, and the need to teach curriculum requirements, benchmarks and standards, or the GLCEs (Grade Level Content Expectations), among others.

In his interviews, Teacher A expressed that the ways that he addressed the barriers or constraints he was facing affected the kinds of activities that he did in the class. Consequently, this also may have affected the *planning and action* opportunities that he could have provided to his students. For example, Teacher A could not take his students to a field trip because of lack of funds to pay for transportation (see next quote), and the difficulty of asking permission from the parents and the school administration. According to Chawla & Cushing (2007, p. 440), "experiences with nature in childhood and youth are key entry level variables that predispose them to take an interest in nature themselves and later work for its protection." Thus, absence of such experiences could weaken the potential for fostering the development of students' AC.

Teacher A interview:

"So, um, yeah I think, I think physical science awards me a little bit more opportunity for them to see it in real life, where a lot of times environmental science…could we go out and observe things? Yeah, we could, umm, I guess we could walk around the yard, but um you know I don't think we can go very far without funding for field trips."

Teacher A was also limited in the number of real experiments that he could do in class due to lack of time and lack of resources (materials) (see next quote). Finally, he was also limited in what he could say to students about environmental concerns for fear of additional complaints and/or reprimand from parents, the School Board, and/or school administrator. Consequently, much of the *planning and action experiences* in Teacher A's class was addressed through *discussions* of hypothetical situations (more *didactic*-oriented approaches and methods). Hypothetical situations are arguably less effective in fostering action competence and ultimately, actions for the environment, because according to Chawla & Cushing (2007, p. 441), "students need opportunities to learn and practice action skills."

Teacher A interview:

G: "It sounds like the amount of time plays a huge role in what you would include…"
T: "Yeah, it probably does. I would agree with that. You know I could probably go out, and if I did the environmental science I'd have to find quite a few more labs to do. But I could probably find a lab if I only had 6 chapters to do all year, you could find a lab for

almost anything you did I'm sure by then. I feel pressured right now to get to physical sciences. I feel anytime, when they start to get to 5 and 6 (chapters) of the environmental science book I feel it's time I got to start kicking it up…"
G: What is your general approach in terms of teaching?
T: "I try to mix it up as much as possible. I am not gonna lie to you and say I wish I did more hands-on more often, or inquiry-based more often. For one, it's not…in a 50-minute time, it's not really feasible. I don't have time to do a lot of things. You're limited in activities too, so it's trying to find a good one that's cheap, and interesting, at the same time, coz one of them is how much money you can spend on it. Coz the school is not gonna give me any money to spend on it. It's from my pocket to do a lot of these things. And too if I do how long it's gonna take to set-up for what the kids are gonna get of it. So it's interesting, some of them are so elaborate, some of the set-ups I found that by the time it's done there's so much that could go wrong."

Barriers or challenges need to be addressed to increase teachers' use of AC in the classroom. For example, research suggests that parents and other family members are believed to influence students' participation in political action or wanting to help their community/school/country, or doing something to improve their society (Chawla & Cushing, 2007; Flanagan *et al.,* 1998; Fletcher *et al.*, 2000; Pancer & Pratt, 1999). If the families value social justice, then students tend to value doing something to improve society, or children tend to participate in community activities when their parents are also active/involved or give their approval and encouragement to take part. This implies a need for teachers to reach out to parents, enlisting their support and involvement in class activities/projects Chawla & Cushing (2007).

Teacher B, County Y: taught classification of organisms in 7th grade

Use of AC

In contrast to Teacher A, Teacher B focused more on *planning and action experiences* than *knowledge/insight*, although as with Teacher A, she also emphasized these two elements more than the others (*critical thinking and reflection*, *commitment*, and *visions*) (PAE > K > CT & R, Co > V). Teacher B fostered *planning and action experiences* for her students by engaging them in an activity through a partnership with Kroger, a local grocery retailer, wherein students helped spread the word about pollution prevention (see next quote). After engaging students in a series of *discussion* about different types of pollution, Teacher B asked them to think and plan how they could help reduce pollution and its harmful effects on animals, people and the environment. Then students participated in more cooperative *discussions* and shared ideas about possible solutions that people in general and students such as themselves could get involved with to help reduce pollution. The class ended up with a project to write or draw their messages on Kroger grocery bags that shoppers used. According to the teacher, this activity got everyone involved and excited, because the students had fun drawing and writing on the bags, and they felt as if they were doing something useful and worthwhile. This part illustrates Teacher B's PCK – *activities or examples that connected well with students.*

> Teacher B interview:
> *"One of the things that we do is they design… I go to our local Kroger store, get the paper sacks, bring them back to the classroom and after we talk about air, water and land pollution and we do quite a bit on that in class, the students design, and write on a bag, they write a message and they illustrate it and color it,*

they're really quite nice. Then we return them to Kroger and Kroger uses them for groceries and so people who shop at Kroger get a message from our students about pollution."

Teacher B's use of *discussion* was consistent with Chawla & Cushing's (2007) suggestion that part of providing students with direct (real world) experience entails giving them a chance to discuss and analyze public issues together, and identify shared goals, resolving conflicts, and finding strategies for addressing problems or issues. These experiences develop students' confidence, public speaking skills, ability to work with people and accept them as they are, and exercise leadership (Pancer & Pratt, 1999; Roker *et al.*, 1999). Csobod (2000, p. 214) considered discussions as examples of "indirect action or invisible participation." Ultimately, such experiences will help prepare students for political action (Chawla & Cushing, 2007). Onyango-Ouma *et al.* (2009) used *discussions* to engage Kenyan students in investigating the causes and sources of infections and preventing further transmission of worms as part of a health education program implemented in Kenya. Onyango-Ouma *et al.* (2009) reported this experience possibly contributed to developing students' *commitment* to finding a solution to their community's problem.

Although I did not personally observe the *planning and action experience* that was described by Teacher B in her interview, the experience was real world in the sense that it was a real issue or problem in their community that Teacher B and her students identified and attempted to address. In addition, the suggested solutions also were targeted toward youths and adults alike, unlike in Teacher A's class in which students identified possible solutions that were targeted specifically for adults. Chawla & Cushing (2007) cautioned, however, that close partnership between school and community should be established and strengthened, to ensure that authentic action experiences are integrated to students' learning, and in turn will help build students' *commitment*.

Teacher B also facilitated *knowledge/insight* in the context of different types of pollution and ways to prevent them. She engaged her students in multiple *discussions* about air, water, and land pollution to give them ample opportunity to ask questions, and share their personal knowledge and experiences about the causes and the impacts of different types of pollution on animals, humans, and the environment as a whole. She also encouraged her students to participate in finding solutions to problems, and to remember that their actions can shape or change not only their lives but also the world. Teacher B's careful selection of using multiple *discussions* as a way to engage her students in the lesson illustrated her PCK (*reasons for using particular approaches, methods, and strategies*).

Another way that Teacher B promoted *knowledge/insight* (awareness, *knowledge of effects*, and *knowledge of causes*) was observed in her class when she used *discussion* and an *in-class activity* to teach about classification of animals. The animals that they talked about have become extinct. Students learned that because of unregulated over-hunting by market hunters and habitat destruction by humans (cause), some animal species (e.g., domed tortoise, dodo) were completely wiped out (effect).

Aside from promoting *commitment* in the context of pollution and ways to prevent or reduce it, Teacher B described in one of her interviews that, in a *discussion* with her class on how to help prevent polar bear extinction, she promoted *commitment* by encouraging her students to do their own part to make a difference. Teacher B explained to her students that if every individual did his/her part to minimize air pollution, for example, using energy saving bulbs such as compact fluorescent light bulbs instead of incandescent bulbs, then the amount of pollutants that reach the air would reduced, and this ultimately would help reduce global warming that is now threatening the polar bear's habitat. The examples of activities or actions that Teacher B provided were limited to private sphere environmentalism according to Stern (2000), that is, only individual activities or actions, which according to Jensen & Schnack (1997) are only one type of environmental action. Nonetheless, the polar bear *discussion* raised many questions and prompted further *discussion* among students, because a few students did not see the connection between their personal actions and saving polar bears from extinction. This was an illustration of Teacher B's PCK – *activities or examples that connected well with students.*

The *visions* element was observed in Teacher B's survey response regarding her goal as a teacher: "Hopefully they will see the connections between their actions and future consequences." This illustrates that Teacher B wanted her students to think about their actions now and how those will affect their future lives – which is part of the process of developing *visions*.

In one of her interviews, Teacher B described an example in which she promoted *critical thinking and reflection* in her class by encouraging and helping her students recognize and appreciate other students' points of view or feelings about environmental concerns such as global warming that might be different than theirs.

Associations between PCK and AC

In contrast to Teacher A for whom goals and beliefs appeared to explain the occurrence of certain elements of AC, the predominance of the *planning and action experiences* element in Teacher B did not directly match her three most prevalent goals and beliefs about teaching, which possibly suggests that for some teachers, factors other than their goals and beliefs predict their use of AC in the classroom.

Although some of Teacher B's and Teacher A's approaches and methods were similar, Teacher B's barriers or constraints in her teaching context did not appear to have significantly affected the *planning and action experiences* of her students. Based on this finding, it is difficult to conclude whether Teacher B had fewer barriers or constraints compared with Teacher A. But it appears that regardless of barriers and constraints, Teacher B still engaged her students in real world *planning and action experiences*.

Although her three most prevalent goals and beliefs did not align with her use of *planning and action experiences*, it appears that Teacher B's use of *activity-driven*, *process-oriented*, and *project-based* approaches and related methods allowed her to provide students with real world *planning and action experiences*. The possibility of providing real world *planning and action experiences* to students as opposed to experiences based on hypothetical situations, as did Teacher A, could be attributed to the presence or absence of barriers or constraints in the teaching context, or the teacher's ability to address or negotiate these challenges. For example, both Teachers A and B included a *discussion* of global warming in their lessons. However, Teacher A had to temper the discussion because of prior demand by the School Board and parents not to advocate a specific political stand. In contrast, Teacher B's school project to address pollution in her local community received support and appreciation from parents and school administrators. In this case, the amount of support for the teachers influenced the kinds of activities that teachers were able to do.

In contrast with Teacher A, the *knowledge/insight* element of AC was second only to *planning and action experiences* in Teacher B (Tables 5.36a and 5.36b), even though both teachers reported that their number one goal and belief about teaching was to *transmit facts, content, knowledge, and benchmarks/ standards* (see Tables 5.5 and 5.6). As with Teacher A, *knowledge/insight* for Teacher B also focused more on *general awareness of environmental issues or problems*, *knowledge of causes*, and *knowledge of effects*. As with Teacher A, *knowledge/insight* for Teacher B appeared to have been supported by two of her five most prevalent pedagogical approaches – *didactic* and *didactic-with-application*.

Although *knowledge/insight* results for Teacher B seemed less congruent with her goals and beliefs than for Teacher A, both teachers shared similar approaches and methods that were congruent with *knowledge/insight*. This may suggest that *didactic* and *didactic-with-application* approaches and related instructional methods are needed to foster *knowledge/insight* (especially *general awareness of environmental issues or problems*, *knowledge of causes*, and *knowledge of effects*).

Teacher D, County Z: taught agents of erosion and rocks and minerals in 5th grade

Use of AC

As with Teacher A, Teacher D focused more on *knowledge/insight* and *planning and action experiences* than the three other elements of AC (K > PAE > CT & R > Com > V) (Tables 5.36a and 5.36b). Awareness, *knowledge of causes* and *knowledge of effects* were facilitated in class *discussions* about the following: the impacts of land uses (e.g., farming, lumbering, mining, manufacturing industries); United States consumption of goods and services; causes, impacts, and ways to prevent runoff and erosion; causes, impacts, and ways to prevent or reduce water, air, or land pollution; and alternative forms of energy, among other environmental issues and problems.

Teacher D facilitated *knowledge of change strategies* by asking students to devise their own personal change strategies to help the environment after reading The Lorax to her class. She used reading as a method because, although her students loved to hear stories, they needed help with reading (PCK – *reasons for using particular approaches, methods, or strategies* and *knowledge of student learning or understanding*). She chose The Lorax because her students were familiar with the story and connected with it (PCK – *activities or examples that connected with students*). According to Chawla & Cushing (2007, p. 440), "reading about nature and the environment is a key entry level variable that predispose youth to take an interest in nature and work to protect it later in life." Teacher D wanted to ask students to give their own ideas or examples, because she believed that students were more likely to remember the change strategies if the ideas or examples came from them. She also believed that it would be more meaningful for them and they would more likely connect with the topic if their personal ideas or examples were solicited (PCK – *activities or examples that connected well with students*).

Asking students for their own ideas may be seen as a collaborative *decision making* process, that allows young people to take control of their environment and other elements of their lives, which is a fundamental part of democracy (Csobod, 2000; Chawla & Cushing, 2007). Flekkoy & Kaufman (1997 p. 442) believe a collaborative *decision making* process "helps young people gain autonomy, a sense of self-worth, respect for other people's perspectives, and negotiation skills." Some of the personal change strategies they talked about were individual consumer actions (again, referred by Stern (2000) as private sphere environmentalism), including turning off the water when brushing teeth to save water, recycling soda cans and other materials that can be recycled, reusing plastic bags, planting trees, and using products with high post consumer content. Through these every day examples, Teacher D encouraged students' *commitment* in getting involved in solving environmental problems or issues.

In terms of *knowledge of alternatives and visions*, Teacher D and her class talked about alternative forms of energy (e.g., nuclear power plants, windmills and wind turbines, ethanol) and ways to prevent or reduce erosion (e.g., terracing, planting ground cover, preventing or limiting driving in certain areas).

As with *critical thinking and reflection* and the different types of knowledge (*knowledge of effect; causes; change strategies; alternatives* and *visions;* and *general awareness*), Teacher D facilitated *planning and action experiences* by *discussing* issues or problems related to erosion, use of nonrenewable resources, numerous land uses (e.g., agriculture, mining, generation of electricity, deforestation), and different types of pollution. Teacher D explained in her interviews that, due to lack of time, space, and funds to buy materials for experiments and hands-on activities (see next two quotes), she substituted *discussions* and *individual projects for experiments, hands-on activities*, or *field trips* (PCK – *ways to address barriers or constraints in teaching context*). Consequently, planning and action did not happen in a real world context, but students thought, identified, and shared with each other ways of addressing the issues and problems listed above.

> Teacher D interview:
> *T: "Well, a lot of factors influence my teaching. Uhh, you know materials, number one. Like I said before, we don't have a lot of money in the district, so when it comes to doing a lot of labs, I can't*

do a whole lot of lab experiment…and so a lot of times, if I do one, I just do one. Instead of doing, instead of having all the kids do it, umm, you know so that's one thing. Umm, the amount of space and the lack of uhh, you know, uh sinks and, and counters and things like that. Or for the scratch test activity, we don't have a lot of samples, so they make a book for a test instead of performing scratch tests and doing other experiments. The kids' need uh play a big role in it. I you know depending on the year, and you know the reading levels of the kids and umm the maturity levels and, and things like that, that can umm make a big difference as to how I actually teach them because I had kids that we could really go in depth."

Teacher D class observation:
"So, if you look at page 226, they have an experiment. We are not going to be doing…we are not going to be doing that experiment as a group ok?...I'm saying we're not going to do that in groups like you did your owl pellets ok? We don't have the materials, we don't have uhh the money to get all of that stuff and do it as groups. If we did do it, we would do it with me showing you guys and having some volunteers to come up and we would discuss it as a class. Ok?"

In Teacher D's classroom, *critical thinking and reflection* was promoted in multiple *discussions* and by thinking about causes and effects of environmental issues or problems, such as depletion of nonrenewable resources (e.g., oil) leads to higher prices because of lack of supply; building dams produces electricity, but it also may result in habitat change; use of pesticides in agriculture helps increase production of farmers, but it can also be harmful to water and plants and animals; and vehicles help transport people and food, but they also cause air pollution.

In one of her interviews, Teacher D represented *commitment* by stating that one of her goals in teaching science is to help her students understand the value of the environment and its interconnectedness with humans and the rest of the world, and to help her students to become better citizens as a result of that understanding. This goal addressed a part of the *commitment* element of AC, which is helping students understand their own attitudes and values toward environmental problems or issues, in addition to promoting their motivation, *commitment*, and drive to get involved in solving environmental problems or issues.

Finally, Teacher D fostered development of *visions* in her students when she asked them how they would like it if a developer decided to build a Taco Bell (fast food chain) in their community. "How will this development affect you (students) personally and your community? What would you do if someone wants to build a house, a mall, or start mining in your community?" The students also debated on what they could or should do about that particular issue, what role they could play, and who should decide whether the building of Taco Bell should be allowed. As with the other examples that Teacher D used in her class, the use of Taco Bell and contextualizing the example in the students' own community helped draw and maintain their participation throughout the *discussion* (PCK – activities or examples that connected with students).

Associations between PCK and AC

As with Teacher A, the prevalence of *knowledge/insight* in Teacher D was congruent with her number one goal and belief about teaching - *transmit facts, content, knowledge, and/or benchmarks/standards*, and it appeared to have been associated with her use of *didactic* and *didactic-with-application* pedagogical approaches. As with Teachers A and B, findings from Teacher D seem to suggest that *transmit facts, content, knowledge, and/or benchmarks/standards* goal and belief, *didactic* and *didactic-with-application* approaches, and related *didactic*-oriented instructional methods are needed to foster *knowledge/insight* (especially *knowledge of effects*, *knowledge of causes*, *general awareness of environmental issues or problems*, and *knowledge of change strategies*).

Planning and action experiences was congruent with certain PCK elements in Teacher D, namely, her goal and belief (*develop science process skills*), pedagogical approaches (*activity-driven* and *project-based*, instructional method (*individual work/project*), and the student skills she emphasized (*critical thinking/thinking on their own/analytical/evaluation, computer skills, predicting, and information gathering*).

Compared with Teacher A and Teacher B's pedagogical approaches that supported *planning and action experiences*, only *activity-driven* and *project-based* approaches were found in the five most prevalent approaches of Teacher D; *process-oriented* approach was not in Teacher D's top five approaches. This partial incongruence, coupled with presumably the presence of relatively more barriers or constraints (compared with Teacher B), may have played a role in the lack of real world *planning and action experiences* for students in Teacher D's class. Another possible explanation may be the young age of her students (5th grade). Given her strong *knowledge of her students' learning or understanding* (PCK), she may have felt they were too young to be involved in actual *problem solving* in the community. Overall, however, Teacher D still had the strongest *planning and action experiences* in terms of number of occurrence and frequency of use (see column 5, Table 5.36b), but in terms of providing real world experiences, it was still Teacher B who was the strongest in this regard.

It is interesting to note that even though the kinds of goals and beliefs, approaches, methods, and student skills and the order in which they occurred in Teachers A and D were not exactly the same, the occurrence of AC elements in Teacher D was exactly the same as in Teacher A in terms of the order in which the elements occurred (see column 5, Table 5.36b and column 2, Table 5.36c). That is, both teachers followed this pattern: K > PAE > CT & R > Com > V, although the actual percent values were different. Examples of differences: *Process-oriented* approach was in Teacher A's five most prevalent pedagogical approaches (see Table 5.12), but not in Teacher D's (see Table 5.15). *Conceptual change* was in Teacher D's top five, but not in Teacher A's. *Didactic* was the most prevalent approach for Teacher D, followed by *activity-driven*. It's the exact opposite for Teacher A – the most prevalent was *activity-driven*, followed by *didactic*. *Experiments/labs/computer labs* is the most prevalent method of Teacher A (see Table 5.18), but it's not in the five most prevalent instructional methods of Teacher D (see Table 5.21). Both teachers have the same four most prevalent PCK manifestations, but they differed in the fifth – reasons/*purposes of selecting and emphasizing particular concepts* in Teacher A (see Table 5.31) and *reasons/purposes of using particular activities* in Teacher D (see Table 5.34). These findings suggest that AC can be adopted, used, or applied using multiple approaches and methods, or despite having different goals and beliefs about teaching or PCK. Results from Teachers A, B, and D also s

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suggest that certain PCK elements and manifestations of PCK possibly influence the occurrence of individual elements of AC. Moreover, results seem to suggest that some PCK elements and/or manifestations are more associated with certain elements of AC than others, and this is possibly associated with the extent that an AC element is adopted, used, or applied.

5.4.4.3.2 Interaction of PCK and AC Results of Four Teachers

Combined results of AC are discussed below around (1) associations between manifestations of PCK and elements of AC, (2) pedagogical approaches and AC, and (3) content and AC.

5.4.4.3.2.1 Manifestations of PCK and Elements of AC

Hypothesis: Manifestations of PCK are Associated with AC

Manifestations of PCK seem to be associated with the occurrence of individual elements of AC, suggesting that strong PCK results in or contributes to strong AC. One explanation for the strong use of AC may be the knowledge and comfort levels of teachers in using approaches, methods, or strategies for teaching, and teachers' knowledge of their students. It may be argued that teachers who are knowledgeable or comfortable about which approach, method, or instructional strategy to use and why, or have good knowledge of their students' learning or understanding, know how to incorporate AC in the class better than those who do not have knowledge or have a low level of comfort.

This was illustrated by Teacher D, who demonstrated the strongest (1) *knowledge about approaches, methods, or strategies for teaching* and (2) *knowledge about students' learning or understanding* of the four teachers, and was also the most AC-oriented teacher. However, this association was not consistent with Teacher C, who despite being the second strongest in these two PCK manifestations, he did not display any use of AC in his classroom. Instead, Teachers B and A, who were third and fourth strongest in the two PCK manifestations, respectively, appeared as the second and third most AC-oriented teachers, respectively.

Similarly, teachers who know which activities or representations to use to teach a particular content to a particular group of students may find it easier to incorporate AC into their classrooms, compared with teachers who have to spend a great deal of time figuring out the most effective way to simply teach a particular content. Teacher D, who was the most AC-oriented of the four teachers, was again the strongest in terms of finding activities or representations to teach a particular content to a particular group of students (see column 6, Table 5.35), despite challenges in her teaching context such as lack of time, space, and money to purchase classroom materials. Teacher B also used various activities in her teaching despite a few barriers and constraints in her teaching context. In contrast, Teacher A sometimes struggled to find an activity, or in general, ways to teach a particular concept due to lack of content materials, time, or financial support to purchase instructional materials. Similarly, Teacher C had to deal with lack of funding to purchase classroom materials, so the kinds of activities that he could do were also limited.

Furthermore, knowledge of subject matter (content) may have played a role in the occurrence of AC. For example, although Teacher A appeared to have the strongest science background compared with the other teachers, he expressed a lack of content knowledge in Environmental Science. This may have affected his overall PCK and, in turn, his use of AC. It is likely that, if teachers' content knowledge is weak, their PCK is also weak, because they will be more preoccupied with making sure their content is complete as opposed to planning and preparing to teach content more effectively or meaningfully.

If we look at Teacher C, however, he also had a strong knowledge of subject matter (forces and motion), but he did not display any use of AC in his classroom. This finding suggests that for AC to be used, knowledge of subject matter has to be knowledge about the environment, not just any kind of knowledge. This further suggests that subject matter taught (content) may have promoted Teacher D and Teacher A's use of AC in the classroom who both taught environmental topics – Teacher D taught (1) agents of erosion and (2) rocks and minerals and Teacher A taught (1) water pollution and (2) air pollution.

In summary, findings suggest that certain manifestations of PCK are associated with use of AC by some teachers, but not with others. Factors other than PCK, such as content (subject matter taught) may be associated with use of AC. These other possible associations are discussed in the succeeding sections.

Hypothesis: Teaching Experience is Associated with PCK and AC

Even though the PCK of Teachers' A and B was demonstrated through very similar manifestations (e.g., *reasons/purposes of using particular approaches, methods, or instructional strategies* and *knowledge of student learning or understanding*), the stronger overall PCK of Teacher B compared with Teacher A might be explained by the years of teaching experience of both teachers. Teacher A had been teaching for only three years when this study was conducted. Teacher B had been teaching for twenty-three and a half years at the time of the study (see Table 5.4). Researchers believe that PCK is developed through teaching experience, which implies that teachers who had been teaching longer had more developed or stronger PCK compared with beginning teachers (Gess-Newsome, 1999; Lee *et al.*, 2007; Magnusson *et al.*, 1999; Van Driel & De Jong, 2001). Thus, arguably, Teacher B had more knowledge of approaches, methods, or instructional strategies and *knowledge of student learning or understanding* than Teacher A, which, overall, possibly contributed to stronger PCK in Teacher B than in Teacher A.

In comparing Teacher C and Teacher D's PCK in terms of length of teaching experience, findings did not entirely support my prediction that teaching experience develops and ultimately strengthens PCK (Gess-Newsome, 1999; Lee *et al.,* 2007; Magnusson *et al.,* 1999; Van Driel & De Jong, 2001); that is, the longer one teaches, the stronger his/her PCK becomes. Teacher C had been teaching for twenty-two years at the time of this study and findings showed that, although his PCK was stronger than Teacher B's (who had been teaching for twenty-three and a half years at the time of the study) and Teacher A's (who had been teaching for 3 years at the time of the study), it was not as strong as Teacher D, who had been teaching for only eight years, but had the strongest evidence for PCK among all teachers (see column 6 and last row of Table 5.35). This incongruence of results with previous literature suggests that factors other than length of teaching experience influence teachers' PCK.

In terms of associations among length of teaching experience, PCK, and AC, Teacher A fits my prediction the most in that he is the least experienced, has the weakest PCK, and the weakest AC. Teacher D did not fit my prediction because she had the strongest PCK and AC despite not having the longest teaching experience. Teacher C also did not fit my prediction because despite having the second longest teaching experience and the second strongest PCK, he did not display any use of AC. Finally, Teacher B also did not fit my prediction – she had the longest teaching experience but only had the third strongest PCK and the second most AC-oriented teacher.

5.4.4.3.2.2 Pedagogical Approaches and AC

Pedagogical Approaches that Contribute to *Knowledge/Insight* of AC

As alluded to earlier, the difference in the extent of use of AC might be explained by pedagogical approaches in addition to differences in PCK. Of the ten pedagogical approaches I examined, I predicted *didactic* approach to be associated with the *knowledge/insight* AC element because this approach is commonly used to *transmit facts, content, knowledge, and/or benchmarks/ standards*. In other words, I expected the see the most *didactic* teacher to have the strongest occurrence of *knowledge/insight*. Interestingly, Teacher A, who was the strongest in the *knowledge/insight* element of AC, was the least *didactic* of all teachers (see Table 5.16). Teacher D, who was the most *didactic* of all teachers, represented *knowledge/insight* only second to Teacher A.

The occurrence of Teacher A as the least *didactic* of the four teachers may have been a function of my analysis, wherein I ranked an approach that occurred in 4 data sources higher than an approach that appeared in 3 or less data sources. *Didactic approach* appeared in all 4 data sources in Teachers B, C, and D, and only in 3 data sources in Teacher A. If we examine the percent values, however, Teacher A was considerably higher in CoRes (83.3%) and survey (50%) compared with corresponding values in the other teachers, suggesting that even though he was the least *didactic* of the four teachers, he addressed the five types of knowledge more than the other teachers in the context of his topic (water and air pollution). These findings possibly suggest that being *didactic* can only promote *knowledge/insight,* if the facts or knowledge is about *causes, effects, change strategies, and alternatives and visions* of an environmental problem or issue. It is not just any type of facts or knowledge.

Pedagogical Approaches that Contribute to *Planning and Action Experiences* and *Critical Thinking and Reflection* of AC

I predicted several pedagogical approaches to be strongly associated with the occurrence of *planning and action experiences* (*activity-driven, project-based,*

inquiry, guided inquiry, and process-oriented) and *critical thinking and reflection* (*conceptual change and didactic*), because of the potential opportunities that these approaches present for students' participation in planning and taking action on a real world environmental problem or issue, and for examining conflicts of interest, pros and cons of a problem or an issue, and/or examining the causes and effects of problems or issues from structural and social perspectives. There was not one teacher that was strongest in all of these approaches, but Teacher C was strongest in two approaches – *activity-driven* and *process-oriented* (see Table 5.14). His use of *didactic* was weak compared to the other teachers, and he did not demonstrate any use of *conceptual change*. Despite being the strongest in two approaches that I predicted to be strongly associated with *planning and action experiences*, Teacher C did not display any use of it, so he did not fit my prediction. This may have been because his topic (forces and motion) and the *activity-driven* and *process-oriented* activities and lessons he used were not in the context of an environmental problem or issue.

Teacher D, who was the strongest in *planning and action experiences* and *critical thinking and reflection* (see column 5, Table 5.36b), was also the strongest in the use of *project-based* and *conceptual change* pedagogical approaches of the four teachers (see column 6, Table 5.16). According to Csobod (2000), *project-based* approaches provide opportunities for active participation, which is the most crucial factor for developing AC because it provides students with real world and direct experiences in planning and action. Hence, use of *project-based* and *conceptual change* approaches to teach environmental topics (agents of erosion and rocks and minerals) may have made it easier for her to incorporate *planning and action experiences*

Teacher D also was the most *didactic* and the second strongest in the use of *didactic-with-application* of all the teachers (see column 6, Table 5.16). As Teacher D explained, her use of both approaches was attributed to the presence of barriers and constraints in her teaching context, which limited her capacity to use *activity-driven* or more *inquiry-based* approaches. Arguably, her use of *didactic* and *didactic-with-application* approaches may have been more appropriate for her students, who were younger (5th graders) compared with the other students, and therefore, may have needed a more teacher-driven approach to teaching. *Didactic* and *conceptual change* approaches include a lot of asking questions (e.g., why, how), *discussions*, or debates among students, which could have facilitated the integration of *critical thinking and reflection* in her instruction.

Teacher A was the only teacher that displayed use of *inquiry*, but this was one of his weakest approaches, therefore, it was not likely to have promoted the use of *planning and action experiences* in his classroom, even though he taught environmental topics (water and air pollution). Teacher A was second to Teacher D in use of *conceptual change*, so that may explain why he is also second in terms of use of *critical thinking and reflection*.

Finally, Teacher B, who was the second strongest in *planning and action experiences*, was also the second strongest in *process-oriented, activity-driven,* and *project-based* approaches of all the teachers. Although Teacher B's use of *didactic* was second to Teacher D, her use of *conceptual change* was not as strong as Teachers D or A, so that may explain why she was weak in her use of *critical thinking and reflection* compared to the two teachers. This finding may have also been affected by the subject matter that she taught (classification of organisms), which was not related to an environmental problem or issue. It appears that certain pedagogical approaches can help foster use of AC, but this association appears strong only when the subject matter is taught in the context of an environmental problem or issue.

Pedagogical Approaches that Contribute to *Commitment* and *Visions* of AC

I predicted *discovery/exploration* and *activity-driven* approaches to be associated with the occurrence of *commitment* and *visions* of AC. Chawla & Cushing (2007) believe that giving students opportunities to experience nature enables them to bond with nature, and may help foster their *commitment* to protect it. Similarly, it may be possible that by giving students an opportunity to get to know a place, a community, a group of people – anything of interest to them – on their own through *discovery/exploration* approaches, such experiences may help foster their *commitment* to be involved in solving an issue or problem related to what they discovered or explored. Furthermore, such personal experiences may encourage students to envision their future lives, that is, may give them ideas or help develop their dreams and/or perceptions about their future lives and how they can improve them and the society in which they will be growing up.

Teacher C was the strongest in use of *discovery/exploration* and *activity-driven* pedagogical approaches, but he did not display any use of AC, therefore he did not fit my prediction. As with other findings in Teacher C, the absence of AC in his instruction may be because the subject matter he taught was not related to an environmental problem or issue, and hence, the activities and lessons that he used in class had nothing to do with an environmental problem or issue.

Teacher B, who was the strongest in *commitment* and *visions*, was only the third strongest in *discovery/exploration* and the second strongest in *activity-driven* approaches, so she did not fit my prediction either. Interestingly, Teacher B included AC in her instruction despite teaching a subject matter that was not related to an environmental problem or issue. This suggests that while subject matter taught appears to play an important role in the use of AC in the classroom for some teachers, it is not always necessary.

The approaches used and the occurrence of *commitment* and *visions* in the other two teachers did not show a clear pattern either of the possible association between *discovery/exploration* and *activity-driven* approaches and occurrence of *commitment* and *visions*. Thus, for these fur teachers, *commitment* and *visions* may have been influenced by factors other than their pedagogical approaches, such as subject matter taught, personal conviction, or goals and beliefs.

5.4.4.3.2.3 Content and AC

A third possibility that may help explain the differences in occurrence and extent of use of AC across teachers is content or subject matter taught. Expectedly, the nature of some topics may have lent themselves to more AC applications and linkages independent of the individual teachers. At the time of the study, Teacher A taught water pollution and air pollution within environmental science, Teacher B taught classification systems within life science, Teacher C taught forces and motion within physical science, and Teacher D taught agents of erosion and rocks and minerals within earth science.

Based on the nature of the topics taught, I expected to see Teacher A to be the most AC-oriented, followed by Teacher D, Teacher B, and then Teacher C (A>D>B>C). Results did show that Teacher C had the least use of AC; in fact, there was no AC observed in Teacher C. But my prediction that Teacher A would have the most use of AC was not supported by the results. Rather, Teacher D had the most use of AC, followed by Teacher B, and then Teacher A (D>B>A; no AC in C).

Although Teacher D's topics were within the earth science curriculum of her school, she taught them in the context of environmental problems or issues, thereby perhaps enabling her to apply AC into her classroom. This may be attributed to her personal conviction as an environmentalist, to encourage her students to appreciate and value the environment, and understand their co-dependence with it. Teacher D also had the strongest PCK of all the teachers, so her strong PCK may have further promoted her use of AC in the classroom.

Teacher B talked about environmental issues in her lessons even though she did not have an environmental topic to teach. She did have a life science topic (classification of organisms), which I would argue was closer to an environmental topic than Teacher C's forces and motion (physical science). As with Teacher D, Teacher B's result may be partially attributed to her personal conviction as an environmentalist. Furthermore, her result also may indicate an association between PCK and AC. In Teacher B's case, findings suggest that teachers with stronger overall PCK still can promote AC even though the topics they have to teach do not necessarily address environmental issues or problems. Results showed that Teacher B had a stronger PCK compared with Teacher A. As discussed earlier, however, this suggestion does not hold true for Teacher C, for whom no AC was found despite having a stronger PCK compared with Teachers A and B.

For Teacher A, despite having an environmental topic to teach, he did not display the strongest use of AC. This may be attributed to, among other factors, Teacher A's lack of environmental subject matter knowledge as he had admitted in his interview. Teacher A did not have a strong environmental knowledge about his subject, which may have translated into a weaker PCK, and hence a weaker use of AC in his classroom.

To summarize associations between content and AC, findings suggest that content can make it easier for some teachers to apply AC in the classroom, but it is not the only factor that is needed to make that happen. Other factors include personal conviction, goals and beliefs about teaching science, and PCK of teachers. Overall, findings suggest that AC is associated with the kinds of goals and beliefs, pedagogical approaches, instructional methods, student skills, and PCK that each teacher possesses, within their specific teaching contexts. While it is expected that the more congruent these factors are, the stronger the use of AC, intricacies within the teaching contexts of teachers (e.g., topics taught, barriers, age of students) as well as personal backgrounds and experiences of teachers appeared to play a role in the extent or lack thereof that AC was used in the classroom.

5.5 CONCLUSIONS, IMPLICATIONS FOR ENVIRONMENTAL EDUCATION, AND RECOMMENDATIONS FOR RESEARCH

In this chapter I attempted to answer my second research question ("To what extent does teachers' pedagogical content knowledge in using science education and environmental education curricula and content materials represent elements of action competence?") by examining and comparing occurrences of elements of PCK (goals and beliefs, pedagogical approaches, instructional methods, and student skills), actual manifestations of PCK, and elements of AC of four science teachers and identifying possible associations between PCK and AC.

5.5.1 Goals and Beliefs about Teaching Science

The goals and beliefs about teaching science of the four teachers encompassed a broader range compared with those suggested in the PCK literature. This implies a need to identify other goals and beliefs of teachers about teaching science to obtain a clearer understanding of teachers' PCK. In addition, possible associations exist between goals and beliefs of teachers about teaching science and their use of AC.

The four teachers shared the same number one goal and belief about teaching – *transmit facts, content, knowledge, and/or benchmarks/standards* – despite differences in content and grade level taught, age, and length of teaching experience, among others. This finding seems to support the "teaching for the test" phenomenon that appears to be increasing particularly in the schools of these four teachers. Despite sharing the same number one goal and belief, however, many of the teachers' goals and beliefs occurred to be bound within the content that they (have to) teach as dictated by the GLCEs or the MI benchmarks and standards for science; only a few were more general or not limited to a particular content or topic. This suggests that, teachers' goals and beliefs and their daily decisions about what and how to teach were influenced by content, in addition to other factors, and therefore, may not have as strong a predictive power as content (subject matter taught).

5.5.2 Pedagogical Approaches

Each teacher used and/or cited multiple pedagogical approaches in his/her teaching, but the extent of use of each approach varied across teachers. The most prevalent approaches across teachers were *activity-driven* and *didactic*, and Teacher C was the most consistent in terms of use pedagogical approaches. Based on patterns or trends in results from pedagogical approaches and AC, it appears that some approaches promote AC in some teachers, but not in others.

Activity-driven, *process-oriented*, and *project-based* approaches appeared to be needed to foster real world *planning and action experiences.* The possibility of providing *real world planning and action experiences* to students, as opposed to experiences based on hypothetical situations, could be attributed to the lack of or fewer barriers or constraints in the teaching context, which consequently may affect how a teacher addresses them (PCK). Results suggest that, when barriers or constraints are great, teachers resort to more use of *didactic* and *didactic application* approaches and related methods rather than *activity-driven*, *process-oriented*, or *project-based* approaches, resulting in less authentic *planning and action experiences* for students. In some instances, use of *didactic* and *didactic-with-application* approaches may have been more appropriate for younger (5th graders) students. Some researchers suggest that age plays a role in the types, level, or extent of AC with which students can get involved (Chawla & Cushing, 2007; Eames *et al.,* 2006).

Didactic and *didactic-with-application* approaches and related instructional methods occurred to be needed to foster *knowledge/insight*, especially *general awareness of environmental issues or problems*, *knowledge of causes*, and *knowledge of effects*. *Didactic* and *conceptual change* approaches, which include a lot of asking questions (e.g., why, how), *discussions*, or debates among students, appear to be related to facilitate *critical thinking and reflection*.

The absence of AC in Teacher C, despite his being the strongest in *activity-driven*, *didactic-with-application*, *process-oriented*, and *discovery/exploration* pedagogical approaches, was incongruent with findings from the three other teachers. Based on the pedagogical approaches that Teacher C used and/or cited and the trends of results obtained from the other three teachers, *planning and action experiences*, *knowledge/insight*, *commitment*, and *visions* were expected to appear strong in Teacher C. This incongruence possibly suggests that factors other than pedagogical approaches influence AC (e.g., curriculum materials, content taught).

Extent of congruence between goals and beliefs and approaches was found to be variable across teachers. Some pedagogical approaches occurred to represent, manifest, or embody a goal and belief and vice versa, others did not. As suggested by Lim & Chai (2008) and Friedrichsen & Dana (2005), the variability in congruence between pedagogical approaches and goals and beliefs about teaching science of the four teachers indicate that other factors beside goals and beliefs influence their pedagogical approaches, or that pedagogical approaches do not always match a teacher's goals and beliefs about teaching. For these four teachers, these factors include lack of money to buy class materials, tools, or equipment, lack of time, lack of space, and content taught, curriculum requirements and materials, and MEAP test preparations.

In summary, pedagogical approaches appear to be an important element of PCK that needs to be examined further to help us understand the factors influencing teachers' use of AC and in finding ways to increase that use. Results also suggest that *didactic*, *didactic-with-application*, *activity-driven*, *process-oriented*, *project-based*, *conceptual change,* and *discovery/exploration* pedagogical approaches may have stronger associations with individual elements of AC than other approaches.

5.5.3 Instructional Methods

Findings in instructional methods mirrored those in goals and beliefs and pedagogical approaches in that the four teachers shared similar instructional methods, but also differed in some. As well, the extent that the teachers used and/or cited instructional methods also differed. The most prevalent instructional methods were *experiments/labs/computer labs* and *discussion*, and Teacher B was the most consistent in terms of use of instructional methods. Instructional methods were used in multiple pedagogical approaches. Conversely, an individual approach was characterized by multiple methods that were also used in other approaches. Moreover, some instructional methods represented one or more goals and beliefs, and conversely, some goals and beliefs were embodied in multiple methods.

Two instructional methods appeared to lend themselves toward more use of AC for the teachers – *discussions* and *field trips*. According to Chawla & Cushing (2007), Hahn, 1998, and Niemi & Junn, 1998, *discussion* of public issues is an important part of students' political socialization, which fosters their political interest and activity. Teachers A, B, and D all used *discussions* in their classes, but Teacher C did not. This may help explain the absence of AC in his instruction. In terms of *field trips*, Chawla & Cushing (2007) pointed that these activities can provide students with critical experiences with nature/environment. Of the four teachers, only Teacher D and Teacher C used and/or cited *field trips*, which may help explain the strongest occurrence of AC in Teacher D's instruction, but not with Teacher C.

5.5.4 Student Skills

A similar pattern to that seen in goals and beliefs, pedagogical approaches, and instructional methods was seen in the student skills. Some skills were associated with more than one goal and belief, pedagogical approach, or instructional method. In addition, congruence among skills and goals and beliefs, pedagogical approaches, and instructional methods was variable across teachers.

Critical thinking/thinking on their own/analytical/evaluation skills, observing, information gathering, and *predicting* are all considered process skills, and these skills represented one of the three most prevalent goals and beliefs across the four teachers - *develop science process skills*. Science process skills were predominant even though the four teachers did not all have the same pedagogical approaches, instructional methods, goals and beliefs about teaching, and content taught. This predominance may be an indication of increased attention on learning about science processes in schools.

This study found that in general, process skills appeared to have contributed to the occurrence of *planning and action experiences*, *critical thinking and reflection*, and *knowledge/insight* elements of AC, but only when the skills were used and in consistent within the context of an environmental problem or issue. Otherwise, skills did not appear to have an association with AC.

The occurrence of *reading skills* and *computer skills* in the five most prevalent student skills across the four teachers possibly suggests that some student skills are incidental or unintended, that is, they are a result of a teacher's use of an approach or method that was meant to address a different need in the class (e.g., use of computers to encourage students' interest in class, not to primarily develop their computer skills).

5.5.5 Manifestations of Pedagogical Content Knowledge

Some representations were stronger in one teacher compared with another, possibly suggesting that some teachers have stronger or more developed PCK than others. Strong PCK occurred to be associated with strong AC for some teachers (e.g. D), but not for others (e.g. C). This implies a need to (1) strengthen teachers' PCK to nurture or improve teachers' capacity to develop AC in students and (2) determine other factors that may affect teachers' use of AC in the classroom.

Individual manifestations of PCK occurred to be associated with individual elements of AC. Stronger occurrence of knowledge of approaches, methods, and instructional strategies, knowledge of student learning or understanding, and activities and examples used that connected well with students appeared to be related to stronger display of *planning and action experiences*, *commitment*, and *visions*. The presence of fewer barriers or constraints in the teaching context also occurred to strengthen occurrence of real world *planning and action experiences*, and perhaps even *commitment* and *visions*. Teachers having more barriers or constraints may have been more preoccupied with trying to address those challenges and, hence, focused more on the *knowledge/insight* and *critical thinking and reflection* elements of AC. Some researchers have characterized elements of AC as found on a ladder, and the stages at the bottom steps point more toward *knowledge/insight* and *critical thinking and reflection*, which are arguably easier to address compared with *planning and action experiences*, which is on a higher level (Uzzell, 1994).

Findings on manifestations of PCK and AC described above suggest that (1) reasons for using particular approaches, methods, or instructional strategies, (2) knowledge of student learning or understanding, (3) ways used to overcome barriers or constraints in teaching context and (4) activities or examples that connected well with students may influence the occurrence and extent of use of AC elements and, therefore, need to be examined closely and strengthened to help improve a teacher's capacity to develop AC. Results also suggest, however, that factors other than PCK may influence the occurrence and extent of use of AC. The true nature of PCK-AC relations cannot be determined in this study, but this knowledge will contribute in determining whether one PCK manifestation has a stronger influence on an AC element over another manifestation, or exactly how PCK can be utilized to increase use of AC in science classrooms.

Length of teaching experience seemed to be related to strength of PCK in some teachers, but not in others. This incongruence of results with previous literature suggests that there are other factors besides length of teaching experience that influence a teacher's PCK.

5.5.6 Action Competence

The most represented AC element across the four teachers was *knowledge/insight*, followed by *planning and action experiences*, *critical thinking and reflection*, *commitment*, and *visions*. Teacher D displayed the most use of AC. This may suggest that, compared with the other teachers, Teacher D had the highest capacity to foster AC in her students.

Although *knowledge/insight* was the most prevalent element of AC observed across teachers, it was largely limited to *knowledge of causes* and effects and *general awareness of environmental issues or problems*. Knowledge about alternatives and *visions* and *knowledge of change strategies* were comparably weak. Proponents of AC argue that action-oriented knowledge is key to developing AC, and to provide an action-oriented knowledge, ways of creating change (*knowledge of change strategies*) and finding solutions (*knowledge of alternatives and visions*) must be present (Jensen, 2000b).

Although the *planning and action experiences* element of AC was considerably more prevalent than *critical thinking and reflection*, *commitment*, and *visions* across the four teachers, its occurrences were mostly suggestions for people in general, not specific ideas or opportunities for students to get involved in real world planning and taking action toward an environmental issue or problem. Real world *planning and action experiences* were seen only in Teacher B's class. Much of the *planning and action experiences* in the other classes were addressed through *discussions* of hypothetical situations (more *didactic*-oriented approaches and methods). This lack of authentic *planning and action experiences* could be attributed to barriers or constraints in teaching context of the other teachers, such as lack of time, lack of funds, lack of resources (books and other materials), lack of support from some parents, fear of getting reprimanded by the school administrator or the School Board, and the need to teach curriculum requirements, benchmarks and standards, or the GLCEs (Grade Level Content Expectations), among others.

The extent of occurrence or use of individual elements of AC varied across the four teachers; that is, some elements occurred stronger in one teacher than in another. In addition, *critical thinking and reflection*, *commitment*, and *visions* were considerably less prevalent than *knowledge/insight* and *planning and action experiences* across teachers.

5.5.7 Other Factors That Possibly Influenced the Occurrence or Use of AC

Besides pedagogical approaches and manifestations of PCK, content or subject taught occurred to have influenced the occurrence and extent of use of AC for some teachers, but not for others. In particular, the nature of some topics may have lent themselves to more AC applications and linkages independent of the individual teachers – teachers who taught an environmental topic may have found it easier to use and apply AC in their classrooms compared with someone who taught topics that were not directly related to environmental issues or problems. But findings also appeared to suggest that content specifically influenced *knowledge/insight* more so than the other AC elements and that lack of content knowledge may reduce a teacher's ability to use AC in the classroom.

Personal conviction of teachers also seemed to have played a role in teachers' use of AC. Two teachers incorporated AC in their instruction whenever they could, in one teacher even when she was teaching a different subject (not science) (Teacher D), and in another, even when her topic was not about the environment (Teacher B). Thus, these teachers' use of AC in their instruction occurred more as a reflection of their personal beliefs that they needed to help inform or bring awareness to their students about environmental issues or problems that happen around them.

5.5.8 Recommendations for Future Research and EE Practice

This chapter characterized the PCK and use of AC of four science teachers and identified the elements and manifestations of teachers' PCK and the elements of AC that were more prevalent than others. Possible associations between PCK and AC also were identified. However, the nature and extent of these possible relationships were not identified. If development of student AC is an important goal in Environmental Education, then future research on examining PCK-AC relationships will contribute to finding ways to increase teachers' use of AC in the classroom and to increase teacher's capacity to develop student AC. In particular, studies that examine the following will be a significant contribution:

1) Nature of relationships between/among teachers' goals and beliefs related to teaching science, pedagogical approaches, instructional methods, student skills, and manifestations of PCK and their use of AC, including factors that promote their congruence, as well as the predictive power of such variables to teachers' use of AC
2) Barriers or constraints in the teaching context of teachers that prohibit their use of AC in the classroom and how to address them
3) Other factors that may strengthen PCK and promote use of AC, e.g., content or subject matter taught; personal conviction; age and other socio-demographic characteristics of students; additional roles or tasks

that teachers do besides teaching; environmental knowledge; attitudes, behaviors, or actions of teachers related to the environment; length of teaching experience, teacher education and professional development experiences

4) Whether higher use of AC equals higher capacity to foster AC, and whether this results in stronger AC in students.

Finally, I also recommend the use of multiple methods to examine teachers' PCK and its possible relationship with AC. As mentioned earlier, it appears that some methods are limited in the types of data that they can provide and are, thus, less effective at examining elements or manifestations of PCK. Consequently, it is important to use mixed methods to capture a more holistic manifestation of PCK and AC, and to triangulate data.

In terms of EE practices that promote teachers' use of AC and foster the development of students' AC, the following are my recommendations based on findings from this study and the literature (Csobod, 2000; Chawla & Cushing, 2007; Jensen & Schnack, 1997; Onyango-Ouma *et al.*, 2009):

Teachers need to

1) Engage students in real world *planning and action experiences*. Start with the local community.
2) Make time for children to experience and discover nature/environment.

3) Practice and engage students in democratic and collaborative *decision making* in the classroom.
4) Make time for discussions of environmental issues.
5) Practice action-oriented, participatory, and student-centered pedagogical approaches and methods.
6) Revisit the goals and beliefs to assess whether they are aligned with or supportive of use of AC in the classroom.
7) Use multiple approaches and methods to create the conditions necessary to incorporate more authentic or real world learning opportunities into the classroom.
8) Account for barriers or constraints in teaching context.
9) Engage students in *critical thinking and reflection*.
10) Provide students the opportunity to envision about their future and set goals.
11) Reach out to and involve the parents!
12) Involve other teachers and school administrators.
13) Participate in teacher training to learn about different approaches and methods to apply AC in the classroom.
14) Reflect and think pedagogically – be intentional when teaching.

In addition to practice recommendations, I also recommend a reform in curriculum and assessment to include AC as a significant part of what needs to be taught and what eventually gets measured. Making AC a required component of the curriculum may be an effective way, if not the only way, for teachers to include AC in their teaching. These recommendations are by no means a complete list of suggested practices to increase teachers' use of AC, and may or may not all work for every teacher. Nonetheless, an attempt was made to consider both the personal and structural factors that were unique to each teacher.

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CHAPTER 6

INTERACTIONS IN EE CURRICULUM, PCK, AND AC: SUMMARY, CONCLUSIONS, AND IMPLICATIONS FOR RESEARCH AND PRACTICE

6.1 INTRODUCTION

The purposes of my dissertation research were to characterize the interactions found in an Environmental Education (EE) curriculum, science teachers' pedagogical content knowledge (PCK) and their use of action competence (AC), and to identify factors that appear to be associated with use of AC in curriculum and instruction. To achieve these purposes, my dissertation research was divided into three parts: (1) analysis of the Water Quality Unit of the Michigan Environmental Education Curriculum Support (MEECS); (2) a survey of MEECS training participants; and (3) an in-depth examination of pedagogical content strategies and use of AC of four science teachers in Michigan. Knowledge from this research will help inform EE research and practice as well as teacher education and professional development in finding ways to incorporate and strengthen use of AC in the curriculum and to increase teachers' use of AC. My ultimate goal is to increase capacity of teachers to develop AC in their students.

The elements of PCK that I examined in my study – goals and beliefs about teaching science, pedagogical approaches, instructional methods, and student skills – appeared to be related to the elements of AC. As well, my study found that some manifestations of PCK possibly are related to the occurrence of AC. A summary of findings, conclusions, and implications for future research and EE practice are presented below.

6.2 ACTION COMPETENCE (AC)

Planning and action experiences and *critical thinking and reflection* were consistently in the top three most prevalent elements of AC in the curriculum, the MEECS survey results, and the four teachers' perspectives. *Knowledge/Insight* was the first most frequently mentioned AC element in the curriculum and used by the four teachers. *Commitment* was the first most frequently mentioned in the MEECS survey, but only the fourth most frequently mentioned in the curriculum and by the four teachers. *Visions* were consistently the least prevalent element of AC in the curriculum, the MEECS survey, and the four teachers. The low prevalence of *commitment* and *visions* is problematic because, according to Jensen (2000b, p. 234), "if there is no *commitment* to fight for *visions*, one cannot speak of action competence."

Although *knowledge/insight* was the most prevalent element of AC in the curriculum and in the four teachers, it was largely limited to *knowledge of causes* and effects and general awareness of environmental issues or problems. Knowledge about alternatives and *visions* and knowledge of change strategies were comparably weak. Proponents of AC argue that action-oriented knowledge is key to developing AC, and to provide action-oriented knowledge, ways of creating change (knowledge of change strategies) and finding solutions (knowledge of alternatives and *visions*) must be present (Jensen, 2000a, 2000b; Jensen & Schnack, 1997).

Moreover, although *knowledge of causes* was generally the most prevalent within the *knowledge/insight* element (*knowledge of effects* followed a close second), it was largely limited to ecological or economic causes of environmental problems or issues. There was minimal inclusion of how social and cultural factors influence people's behaviors or actions toward the environment. Proponents of AC argued, that to find solutions to environmental problems or issues, *knowledge of causes* needs to include how social structures and cultural practices contribute to environmental problems or issues because these are also a result of social and cultural structures (Jensen, 2000a, 2000b; Jensen & Schnack, 1997).

Similarly, although the *planning and action experiences* AC element was in the top three in the curriculum, the MEECS survey, and the four teachers, there was actually a lack of authentic planning and action in those occurrences. In other words, much of the planning and taking action was not done in the context of a real problem or issue in the community, the school, or a place to which students can relate. In addition, most occurrences of planning and action were actually suggestions for people in general, not specific ideas or opportunities for students to get involved in real world planning and action taking toward an environmental problem or issue. Some researchers have found that real world experiences are important to prepare and enable students to take action in the future (Eames *et al.*, 2006). These findings, therefore, suggest a need to ensure that students get real opportunities to be involved in an environmental issue or problem to achieve competence in taking action.

Another finding of my study relates to the nature of *critical thinking and reflection* that was observed. First, the reflection piece was generally weak and the "*critical thinking*" part did not delve too much into the social and political contexts of a problem or issue, or in questioning students' values, perceptions, conditions, and opinions. Critical thinking focused more on understanding or recognizing that multiple views about a problem exist and on weighing the pros and cons of possible solutions. This issue is tied to the issue of *knowledge of causes*' lack of focus in social and cultural structures. This is problematic because, without reflection, students are not given a chance to think about their prior knowledge and previous experiences and assess what they are learning, which will affect future decisions that they make (Eames *et al.,* 2006). Also building on Jensen & Schnack's (1997) argument that environmental problems are a result of both personal choices and societal-political structures, the lack or absence of analyzing how social and political structures contribute to occurrence of environmental problems or issues allows only for partial resolution of a problem or issue.

The findings on the occurrence and extent of individual elements of AC as well as the nature of these occurrences have important implications for curriculum development, teacher education, and professional development. First, to be used to develop AC, EE and Science curricula need to embody *knowledge/insight*, *planning and action experiences*, *commitment*, *critical thinking and reflection*, and *visions*. Specifically, the curricula need to ensure that *knowledge/insight* is holistic, which means the curricula need to focus equally on *knowledge of effects*, *knowledge of causes*, knowledge of alternatives and *visions*, and knowledge of change strategies. Researchers believe that the absence of knowledge of alternatives and *visions* and knowledge of change strategies will not enable students to move from concern or worry about environmental problems or issues into action taking (Jensen, 2000a).

Second, EE and science curricula need to provide opportunities for students to participate in solving real community problems or issues to develop their capacity to take action. Third, the curricula need to provide opportunities for students to think about their future, their dreams, and their *visions* and how these will affect their decisions. These need to be accommodated within the curricula instead of telling students what their future would look like or what their dreams should be, and consequently, what they need to learn. Action competence is grounded on democratic education – on letting students decide how they want to participate in solving environmental problems or issues. The curricula need to support this to develop AC. Fourth, the curricula need to strengthen the reflection aspect of AC, and *critical thinking* needs to include the social, political, and cultural contexts of environmental problems or issues.

Aside from strengthening the curricula, teacher education and professional development can help increase teachers' use of AC. Teacher education and professional development can teach pre-service and in-service teachers to be intentional in their teaching and to think pedagogically. For example, teachers need to be intentional in including social, political, and cultural structures into their instruction even though, at times, it may be difficult to do so. Teachers need to think pedagogically how they can give students real world experiences – in spite of the many barriers or constraints that they encounter in their teaching contexts. Teachers should be provided with specific ideas or strategies on how to incorporate "difficult" topics into teaching. In short, teacher education and professional development should help teachers develop or improve their pedagogical content knowledge (PCK) in incorporating AC into their teaching.

My study also found that Teacher D displayed the most use of AC. This may suggest that Teacher D had the highest capacity to foster AC in her students. Future research should test whether higher use of AC equals higher capacity to foster AC, and whether this results in stronger AC in students.

6.3 PCK AND ITS ASSOCIATION WITH AC

6.3.1 Goals and Beliefs and AC

Goals and beliefs about teaching science were only examined in the MEECS survey and the four teachers. Of the four most prevalent goals and beliefs in the four teachers, only *transmit facts, content, knowledge, and/or benchmarks/standards* was found in the most prevalent goals and beliefs of MEECS respondents. None of the other goals and beliefs in the top four or five in both groups matched. This supports an earlier suggestion (Chapter 5) that transmission of facts, content, knowledge, and/or benchmarks/standards is still the most prevalent goal and belief about teaching. The prevalence of this goal and belief also may indicate that "teaching for the test" remains a strong driver of teachers' overall instruction.

At the category level, the top four categories of goals and beliefs of MEECS survey respondents were found in the top five categories of the four teachers (skill development, attitude/behavior change, *student development*, and *global/real world connections*), although the rankings (order) of the categories were not exactly the same. Although similarities were observed, differences in categories of goals and beliefs between the four teachers and the MEECS survey participants also were found. Some categories (e.g., *inquiry*, career benefits/teacher development, content/subject matter) found in one group were not found in the other group or, if they were, their prevalence (based on percent distribution) was markedly different. It is not known why there are similarities and differences, but they possibly could be attributed to similarities and differences in school contexts, needs of students, availability or lack of resources, curriculum requirements, standards and benchmarks or Grade Level Content Expectations (GLCEs), and teacher backgrounds, among other factors.

My study also found that the goals and beliefs about teaching science of survey respondents and the four teachers encompassed a broader range compared to the ones suggested in the literature (Magnusson *et al.,* 1999), both in terms of number of categories and category types. In addition, some goals and beliefs (e.g., facilitating understanding of interdependence/connections between people and the world/environment; seek social reform/foster good citizenship) also appeared to be related to the teachers' use of AC. This finding implies a need to examine more closely how goals and beliefs and use of AC might be related.

As reported in Chapter 5, many of the goals and beliefs about teaching of the four teachers appeared to be limited within the content that they (had to) teach, and as a whole, their goals and beliefs were largely dictated by the GLCEs or the Michigan Standards and Benchmarks for Science. This may suggest that, to maximize use of AC in the classroom, elements of AC need to be included in the GLCEs and the Standards and Benchmarks. A study looking at how AC is integrated within the GLCEs and Standards and Benchmarks would help inform how we could increase teachers' use of AC.

6.3.2 Pedagogical Approaches and AC

The curriculum, survey respondents, and the four teachers had similarities and differences in pedagogical approaches used and/or cited. Consistently the most prevalent in the curriculum, the MEECS survey, and the four teachers were *activity-driven*, *didactic*, and *process-oriented* approaches. Consistently the least prevalent across the curriculum, the MEECS survey, and the four teachers were *guided inquiry*, *inquiry*, and academic rigor approaches. Discovery/exploration was in the five most frequently mentioned pedagogical approaches in the MEECS survey, but not in the four teachers; it was absent in the Water Quality Unit. Project-based was less frequently mentioned in the Water Quality Unit. Didactic with application was in the five most used and/or cited in the four teachers and in the Water Quality Unit. Conceptual change was in the five most frequently mentioned pedagogical approaches in the Water Quality Unit, but not in the four teachers and in the MEECS survey. These findings suggest that

(1) teachers use multiple approaches and that, in general, there is variability in the extent to which teachers use an approach; (2) teachers do not use all the approaches that are suggested in the curriculum; and (3) there is a mismatch between what approaches they say they use and what they actually do in the classroom.

Patterns or trends in findings about pedagogical approaches and AC appear to suggest that the extent of use of pedagogical approaches may be one factor influencing the varying extent of use of AC. For example, in Chapter 5, the use of *activity-driven*, *process-oriented*, and *project-based* approaches seemed important to foster real world *planning and action experiences* instead of hypothetical "as-if" scenarios. Findings also appeared to suggest that authentic *planning and action experiences* were made possible because of the lack of or presence of fewer barriers or constraints in a teachers' teaching context. In contrast, teachers who had more barriers or constraints in their teaching context used *didactic* and *didactic* with application approaches more, which resulted in less authentic *planning and action experiences* for students. These findings imply a need to address and reduce barriers or constraints in the teaching context for teachers to provide more authentic experiences for their students.

Activity-driven, *didactic*, and *process-oriented* approaches were found in the top five most used and/or cited pedagogical approaches in the curriculum, the MEECS survey, and the four teachers. In terms of AC, *critical thinking and reflection* and *planning and action experiences* were found in the top three most used and/or cited in the three data sources. These findings possibly suggest that the three approaches are needed for *critical thinking and reflection* and *planning and action experiences* to be present.

The relatively strong presence of *discovery/exploration* in the MEECS survey may help explain the strongest occurrence of the *commitment* element of AC in the survey because as allowing students to discover or explore subjects or interests on their own may provide opportunities to students to develop their emotional engagement and desire or motivation (*commitment*) to take part in something, including finding solutions to environmental problems or issues. This was found by Eames *et al.* (2006) in a study they conducted that investigated the kinds of pedagogical approaches that promoted student AC.

The presence of *didactic* and *didactic* with application approaches in the top five approaches of both the curriculum and the four teachers may help explain the strongest occurrence of *knowledge/insight* in both. Didactic and *didactic* with application pedagogical approaches seemed associated with high occurrences of the *knowledge/insight* AC element, as observed in Chapter 3 (curriculum analysis) and in Chapter 5 (four teachers).

Finally, *visions* consistently appeared the least frequently used and/or cited in the curriculum, the MEECS survey, and the four teachers. *Commitment* also was relatively weak in the curriculum and as expressed by the four teachers. These findings suggest a need to strengthen the use of *visions* in the curriculum as well as in the classroom, perhaps by encouraging and supporting teachers' use of multiple approaches (including *project-based*, *discovery/exploration*, and *conceptual change*) and by integrating ideas about how to incorporate *visions* into instruction during teacher education and professional development. Use of multiple approaches ultimately may help increase teachers' capacity to develop AC in their students.

6.3.3 Instructional Methods and AC

My study found that the most prevalent instructional methods across the four teachers do not match all of those in the Water Quality Unit in Chapter 3 and the MEECS survey in Chapter 5. The most used and/or cited instructional methods across the four teachers were experiments/labs/computer labs, discussion, lecture, in-class activity, and drawings/pictures/posters, but only discussion was found in the top five methods in the curriculum and experiments/labs/computer labs in the top five methods in the MEECS survey. The other methods found in the top five in the curriculum and in the MEECS survey were found in some of the teachers, but not all. These cases of incongruence indicate that, as in the pedagogical approaches, the methods suggested in the curriculum or in the survey were not always used in the classroom, perhaps due to factors influencing the teaching context of individual teachers. Further study of these factors will enhance our understanding of PCK and AC and their possible relationship.

My study also found that an instructional method can be used in more than one pedagogical approach or that an approach can include instructional methods that other approaches also include. Similarly, a pedagogical approach can represent more than one goal and belief or category of goals and beliefs, or that one goal and belief or one category of goals and beliefs is embodied in more than one pedagogical approach. Magnusson *et al.* (1999) noted similar patterns and explained that it is not the use of a particular strategy but the purpose of employing it that distinguishes a teacher's orientation to teaching science, suggesting that teachers may use the same methods or approaches, but their purposes for using them may be different.

6.3.4 Student Skills and AC

Of the top five skills-foci, *critical thinking/thinking on their own/analytical/ evaluation skills* was the first most prevalent student skills in the curriculum, in the MEECS survey, and in the four teachers. *Problem solving* was the third most prevalent student skills in the curriculum and in the survey, and *predicting* was the fifth most prevalent student skills in the curriculum and in the four teachers. As the three skills above, many of the other student skills found in the curriculum, the MEECS survey, and the four teachers were process skills (e.g., information gathering, observing, *inferring/interpreting*, research/ investigation/field data collection). The predominance of process skills may indicate increased attention on learning about science processes in schools.

My study also found that process skills appeared to be associated with occurrences of *planning and action experiences*, *critical thinking and reflection*, and possibly other elements of AC. As such, an investigation of the relationship between process skills and AC is recommended to enlighten EE practitioners and researchers about ways to increase teachers' use of AC.

My study also found that some skills observed in the curriculum, survey, and the four teachers were incidental or unintended. In other words, these skills (e.g., computer skills) resulted from teachers' use of an approach or method that was intended to address a different need in the class. For example, the use of computers by some teachers was intended primarily to keep students interested in the class, not to develop their computer skills. As Eames *et al.* (2006) identified, this implies a need for teachers to be more aware of their pedagogical decisions and strategies to maximize use of AC in the classroom.

My study found that congruence between and among goals and beliefs about teaching science, pedagogical approaches, instructional methods, and student skills was varied across the curriculum, the MEECS survey, and the four teachers. That is, some goals and beliefs were represented, manifested, or embodied in some pedagogical approaches, instructional methods, and/or student skills and vice versa, others were not. According to Lam & Kember (2006), teachers' approaches to teaching normally follow their conceptions (beliefs) about teaching, but if contextual influences increase, they affect the ways teachers teach. These contextual influences possibly include lack of funds to buy class supplies, materials, tools, or equipment; lack of time; lack of space; content or curriculum requirements; and MEAP (Michigan Educational Assessment Program) test preparations. It is important to examine these and other factors more in-depth to enlighten EE practitioners and researchers about factors that influence and increase teachers' use of AC.

Furthermore, the variability described above possibly indicates that there are other factors besides goals and beliefs that influence teachers' use of pedagogical approaches, instructional methods, or student skills, or why approaches, methods, or student skills do not always match goals and beliefs, and so on. Further investigation of possible factors resulting in this variability may be helpful in understanding PCK, and consequently in identifying how PCK can increase teachers' use of AC in the classroom.

6.3.5 PCK Manifestations and AC

My study found that (1) reasons for using particular approaches, methods, or instructional strategies, (2) knowledge of student learning or understanding, (3) ways used to overcome barriers/constraints in teaching context, and (4) activities or examples that connected well with students appeared to influence the occurrence and extent of individual elements of AC in a teacher's instruction more than the other manifestations. Therefore, it is recommended that these individual manifestations be examined more closely and are strengthened to help increase teachers' use of AC and, ultimately, to improve teachers' capacity to develop AC.

It appeared that prevalence of individual elements of PCK did not predict or indicate prevalence of individual PCK manifestations or strength of teachers' overall PCK. Based on consistency in and strength of use of pedagogical approaches, instructional methods, and student skills, I expected Teacher C or B to demonstrate the strongest PCK, but it was Teacher D who did. Teacher D's flexibility in terms of what to teach, when, and how, and the fact that she had only one class group to teach every day may have given her more opportunities to strengthen her PCK compared with the other teachers.

I predict that having a strong PCK may be advantageous to a teacher because it can provide him/her time to plan his/her lessons in a way that will provide experiences that can help develop AC in students. In contrast, a teacher who has a weaker PCK may need more time to plan and prepare a lesson, and, therefore, may not be able to integrate AC into his/her instruction as much as other teachers. Findings from three teachers generally supported this suggestion, but one teacher (Teacher C, male, 6th grade science teacher) did not show any evidence of AC despite having a relatively strong PCK. These findings imply that there is a need to strengthen teachers' PCK, but that PCK may not be the only factor affecting teachers' use of AC in the classroom. Consequently, further investigation of factors influencing teachers' use of AC is recommended.

Some researchers (Gess-Newsome, 1999; Lee *et al.,* 2007; Magnusson *et al.,* 1999; Van Driel *et al.,* 2001) have suggested that PCK is developed through classroom experience, which implies that teachers who have been teaching for a long time have a stronger PCK compared with those who have fewer years of teaching experience. My study found that length of teaching experience seemed to be related to strength of PCK in some teachers, but not in others. This variability suggests that there are other factors besides length of teaching experience that influence PCK.

Findings also showed that, although, in many cases, the order of occurrence of elements of AC or elements or manifestations of PCK appeared the same in the curriculum, the MEECS survey, and the four teachers, there was, in fact, an unequal use (extent) of AC or PCK as shown by the difference in percent values. This finding implies that, along with a reexamination of the goals and objectives and the focus of the curriculum as suggested in Chapter 3, goals and beliefs about teaching science, pedagogical approaches, and instructional methods of curriculum users as well as the student skills, need to be revisited to identify which of these aspects of PCK target which elements of AC. This will help identify the weak points that need to be addressed to increase teachers' use of AC and eventually increase their capacity to foster AC in their students. Subsequently, this will help inform future development of EE curricula that are AC-oriented and guide teachers in how to develop AC in their students.

6.4 OTHER FACTORS ASSOCIATED WITH USE OF AC

Besides elements or manifestations of PCK, content or subject taught also appeared to play a role in the extent of use and distribution of AC in some teachers. In particular, findings suggest that the nature of some topics (e.g., agents of erosion, air and water pollution) may have influenced the integration of the *knowledge/insight* element of AC into some teachers' instruction instead of the overall occurrence of AC, as I earlier hypothesized.

Another factor that may have played a role in the teachers' use of AC was personal conviction. The teacher who displayed the strongest use of AC –

Teacher D – considered herself an environmentalist and, besides the fact that she taught an environmental topic at the time of my study, she consciously talked about the environment and shared with her students some ways to help protect and conserve the environment throughout her class, even when she was not teaching science. So it is possible that she may still talk about environmental problems or issues with her students even when she is not teaching an environmentally-related topic. Another teacher – Teacher B – did not teach an environmentally-related topic at the time of my study, but nonetheless talked about environmental problems or issues in her class. These findings suggest that factors other than elements and manifestations of PCK play a role in the use of AC. It is recommended that the influence of content on use of AC be examined more closely by looking at teachers who teach the same content or at least a topic that is related to the environment.

Another variable that could be studied more in-depth is age of students, which may have affected the types and/or extent of AC-related concepts, topics, or activities that the teachers included in their classes. In my study, age groups of students varied – two classes were 7th grade, one class was 6th grade, and one class was 5th grade. Working with more classes for each grade level (increase sample size) would have enlightened my study as far as the influence of students' age on the teachers' use of AC was concerned. Other variables that could be studied are additional roles or tasks that teachers play or do besides teaching, environmental knowledge, attitudes, behaviors, or actions of teachers, and length of teaching experience.

Finally, in terms of limitations of the study, it may be that some data collection methods were not the most effective ways to collect certain types of data. For example, the survey probably was not the most effective way to identify manifestations of PCK of the four teachers because it didn't specifically ask teachers to describe their PCK. Some PCK manifestations (e.g., reasons/ purposes of using particular approaches, methods, or instructional strategies, knowledge of curriculum, or reasons for choosing particular content) are probably better identified by directly asking the teacher because these types of data were not readily observed in class observations. The use of mixed methods helped address some of these concerns; therefore, it is recommended that future studies use mixed methods when studying PCK to capture more accurately different aspects of PCK.

In conclusion, adopting a critical pluralist perspective in conducting my dissertation research added richness to my work. I also believe my theoretical perspective was also, at best, a more useful, appropriate, and adequate approach to study the meanings of the teachers' social constructions and values (Patterson & Williams, 1998). In my study, these social constructions and values were in the context of how teachers teach EE and their use of AC in the classroom. This was important in my research because it helped me elicit the true manifestations of the teachers' realities in the classroom – the teaching context within which each teacher had to teach. Subsequently, this allowed for comparison and contrast of the teachers' PCK and use of AC. Moreover, findings from the four teachers were compared to findings from the MEECS survey respondents and from the analysis of an EE curriculum. As Eames *et al.* (2006, p.21) noted, although results were highly contextual and may not be generalized to a wider population, some of the themes that emerged support or dispute other researchers' findings and therefore merit further attention. My study has identified some ways to assess PCK and teachers' use of AC and possible associations between PCK and AC, and has provided possible ways to strengthen teachers' PCK, increase use of AC in the classroom, and integrate AC in EE and Science curricula.

6.5 DELIMITATIONS

My study examined only the Water Quality Unit of the Michigan Environmental Education Curriculum Support (MEECS). The Water Quality Unit was selected because, according to the survey of MEECS participants, it was one of the two most used in the past and at the time of the study. Within the Water Quality Unit, I included only five of nine sections in each of the nine lessons, namely, the Objectives, Standards and Benchmarks, Background Information, Procedures, and Assessment Options. Results may be different if all sections were included or if all MEECS Units were evaluated. Although my study hopes to inform future development of EE and/or science curricula that aim to develop AC, results here may apply only to EE and/or science curricula for Michigan and to curricula that have similar content as the Water Quality Unit.

The scope of my study also was limited in terms of the number of participants who were included in the pool of people to be surveyed, in general, and the actual size of the sampling frame, in particular. Only participants of MEECS training sessions conducted between 2006 and 2007 were included in the list, and from that list, only names with verified email and/or mailing addresses were included in the sampling frame. Therefore, results may not be generalized to all participants of the MEECS training participants and users to date.

Finally, my study investigated only four science teachers from three counties in Michigan. I was limited to a small number of teachers because of the sheer amount of data to be collected and analyzed. Science teachers were selected because much of EE in K-12 schools is taught in science classes and most of the users of the Water Quality Unit were science teachers (32.4%). Results may apply only to those who teach science primarily and to teachers who teach in schools within the same districts or in districts having similar characteristics as the four teachers.

6.6 LIMITATIONS

Adopting a critical pluralist perspective allowed me to use mixed methods, such as class observations, semi-structured interviews, CoRes, and surveys (Scott & Oulton, 1999), and to use the strengths of each approach to obtain a holistic understanding of what I was studying (Babbie, 2005). But, as with any type of research, my study had several limitations.

First, the selection of participants to be included in the survey and the small number of teachers in the in-depth investigation affect the generalizability of results (external validity). As described above, only names with verified mail and email addresses were included in the survey sampling frame. Only four teachers were chosen based on their willingness to participate, their location, and the subjects and grade levels they taught. My study could have been strengthened if the sample size was larger for both the survey and the in-depth investigation of teachers.

Second, the absence of using reminder postcards to follow up with mail survey respondents may have affected the response rate. Due to lack of funds, reminders were sent to mail survey respondents via email. This may have presented a problem because not all respondents may have gotten the reminders for various reasons, including absence of or invalid email addresses, SPAM filters, or absence of internet connection at home or school.

Another limitation may be found in the use of interviews and class observations to examine teaching practices of the four teachers. The use of interviews to gather personal opinions, thoughts, ideas, experiences, or practices of the teachers may be a source of internal validity threat. Teachers may not have communicated what they truly felt or thought when they talked with me or when I asked them to describe how they teach a particular content. Similarly, threats to internal validity also can occur from observations. Teachers may not have shown how they usually teach and interact with students when I was present due to lack of comfort or perhaps wanting to show desirable attitudes or behaviors. As suggested by Ary *et al.* (2002), it was, therefore, critical that I used different methods and various sources of data to corroborate findings and to enhance the validity of my study.

Table 6.1 Comparing Results of PCK and AC in the Water Quality Unit (MEECS), MEECS Survey, and Four Teachers

	WATER QUALITY UNIT	SURVEY	TEACHERS
ELEMENTS OF PCK			
Goals & Beliefs about Teaching Science		*Individual goals & beliefs* *1 Develop/instill positive attitudes towards learning/education* *2 Seek social reform/foster good citizenship* *3 Develop critical thinking skills* *4 Teach application of knowledge and skills in real life (tied)* *4 Provide/create fun/safe learning environment (tied)* *5 Transmit facts, content, knowledge, and/or benchmarks/ standards*	*Individual goals & beliefs* *1 Transmit facts, content, knowledge, and/or benchmarks/standards* *2 Develop science process skills* *3 Develop/instill positive attitudes towards science* *4 Engage students with hands-on activities* *5 Prepare students for society/higher education/career/future*
		Categories of goals & beliefs *1 Attitude/behavior change* *2 Skill development* *3 Global/real world connections* *4 Student development*	*Categories of goals & beliefs* *1 Skill development* *2 Didactic* *3 Attitude/behavior change* *4 Student development*

Table 6.1 Continued:

			5 Global/real world connections (tied) *5 Academic rigor (tied)*
Pedagogical Approaches	*1 Activity-driven* *2 Didactic-with-application* *3 Didactic* *4 Conceptual change* *5 Process-oriented*	*1 Activity-driven* *2 Discovery/exploration* *3 Didactic* *4 Project-based* *5 Process-oriented*	*1 Activity-driven* *2 Didactic* *3 Process-oriented* *4 Didactic-with-application* *5 Project-based*
Instructional Methods	*1 Didactic questions* *2 Definitions* *3 Use of technology* *4 Discussion* *5 Compare and contrast*	*1 Hands-on activity* *2 Cooperative learning/group work* *3 Experiments/labs/computer labs* *4 Use of technology* *5 Field trips*	*1 Experiments/labs/ computer labs* *2 Discussion* *3 Lecture* *4 Drawings/pictures/posters*
Student Skills	*1 Critical thinking/think on their own/ analytical/evaluation* *2 Inferring/interpreting*	*1 Critical thinking/think on their own/analytical evaluation* *2 Research/investigation/field data collection*	*1 Critical thinking/think on their own/analytical/ evaluation* *2 Reading skills*

Table 6.1 Continued:

	3 Problem solving *4 Ability to apply knowledge learned to real world situations* *5 Predicting*	*3 Problem solving* *4 Decision making* *5 Social skills*	*3 Observing* *4 Computer skills* *5 Information gathering (tied)* *5 Predicting (tied)*
MANIFESTATIONS OF PCK			*1 Reasons/purposes of using particular approaches, methods, or instructional strategies* *2 Knowledge of student learning or understanding* *3 Activities or examples that connect with students* *4 Ways used to overcome barriers/constraints in teaching context* *5 Reasons/purposes of using particular activities*

Table 6.1 Continued:

ACTION COMPETENCE	*1 Knowledge/Insight* *2 Critical Thinking and Reflection* *3 Planning and action experiences* *4 Commitment* *5 Visions*	*1 Commitment* *2 Planning and action experiences* *3 Critical Thinking and Reflection* *4 Knowledge/Insight* *5 Visions*	*1 Knowledge/Insight* *2 Planning and action experiences* *3 Critical Thinking and Reflection* *4 Commitment* *5 Visions*

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APPENDICES

APPENDIX A:

NON-RESPONSE ANALYSES

Table A.1. Non-Response Analysis: Comparing Age Group, Gender, and Education Level Between Respondents (R) and Non-Respondents (NR)

Age Group	**R # of instances**	**NR # of instances**	**Total # of instances**	**% of # of instances within R**	**% of # of instances within NR**	**Difference in % within R and % within NR**
≤ to 29	2	2	4	5.6	12.5	-6.9
30 to 39	9	6	15	25.0	37.5	-12.5
40 to 49	12	1	13	33.3	6.3	27.1
50 to 59	13	5	18	36.1	31.3	4.9
60 to 69	0	2	2	0.0	12.5	-12.5
TOTAL	36	16*	52	100.0	100.0	
Gender						
Male	11	6	17	30.6	37.5	-6.9
Female	25	10	35	69.4	62.5	6.9
TOTAL	36	16*	52	100	100	
Education level						
16 years (Bachelors Degree)	1	2	3	3.1	12.5	-9.4
17 to 19 years (Graduate degree)	21	9	30	65.6	56.3	9.4
20 or more years (Graduate Degree)	10	5	15	31.3	31.3	0
TOTAL	32	16*	48	100.0	100.0	-

* = 4 missing data

	Frequency	Percent
Respondent	36	64.3
Non-respondent	20	35.7
Total	56	100

	Education level	**Gender**	**Age Group**
Chi-Square	22.875	6.231	18.962
df	2	1	4
Asymp. Sig.	0.000	0.013	0.001

Table A.2. Non-Response Analysis: Comparing Primary Goals and Beliefs Between Respondents (R) and Non-Respondents (NR)

Primary Goals or Beliefs About Teaching	R # of instances	% of # of instances within R	NR # of instances	% of # of instances within NR	Difference in % within R and % within NR
Create/keep curiosity			4	5.6	-5.6
Develop critical thinking skills	5	3.4	3	4.2	-0.8
Develop science process skills	5	3.4	3	4.2	-0.8
Develop stewardship	6	4.0	3	4.2	-0.2
Develop/instill positive attitude towards learning/education	7	4.7	4	5.6	-0.9
Prepare students for society/higher education/career/future	1	0.7	6	8.5	-7.8
Provide/create fun/safe learning environment	6	4.0	4	5.6	-1.6
Represent science as guided inquiry	5	3.4			3.4
Represent science as inquiry	11	7.4	1	1.4	6.0
Seek social reform/foster good citizenship	7	4.7	5	7.0	-2.3
Teach application of knowledge and skills in real life	10	6.7	5	7.0	-0.3
Transmit facts, content, knowledge, benchmarks/standards	11	7.4	6	8.5	-1.1
Use authentic situations to provide real world experiences	15	10.1	1	1.4	8.7

R = respondents
NR = non-respondents

Table A.3. Non-Response Analysis: Comparing Instructional Methods Between Respondents (R) and Non-Respondents (NR)

Instructional Methods	R # of instances	% of # of instances within R	NR # of instances	% of # of instances within NR	Difference in % within R and % within NR
Conducting experiments	14	7.7	5	6.8	0.9
Cooperative learning	17	9.4	10	13.7	-4.3
Field trips	10	5.5	2	2.7	2.8
Hands-on activities	16	8.8	6	8.2	0.6
Individual projects	5	2.8	7	9.6	-6.8
Investigation/research	10	5.5	3	4.1	1.4
Journals/learning logs/sketches	7	3.9	4	5.5	-1.6
Lecture	3	1.7	2	2.7	-1.0
Notes	7	3.9			3.9
Reading for meaning	2	1.1	3	4.1	-3.0
Use of technology	11	6.1	5	6.8	-0.7
Use outside as classroom	4	2.2	3	4.1	-1.9
Vocabulary	5	2.8			2.8
Writing			4	5.5	-5.5

R = respondents
NR = non-respondents

APPENDIX B:

COMPARISONS BETWEEN MAIL AND WEB SURVEY RESPONDENTS

Table B.1. Summary Chi Square Table Comparing Mail and Web Survey Respondents

This table compares mail and web survey respondents according to response variables on the first column. *P*-values less than 0.05 are considered significant.

Variable	N (number of valid cases)	Pearson Chi Square	*df* (degrees of freedom)	*P*-value	Significant?	Number of cells with expected count less than 5; minimum expected count
Survey Group	131	25.527	4	0.000	*	3 (30%); 1.10
Age Group	115	6.753	5	0.240		5 (41.7%); 0.31
Gender	115	0.063	1	0.851		0; 11.58
Education Level	111	3.344	2	0.188		1 (16.7%); 2.59
School type	131	2.654	6	0.851		11(78.6%); 0.82
Ethnicity						
White	125	39.618	31	0.138		59 (92.2%); 0.26
Multiracial	88	19.384	12	0.080		22 (84.6%); 0.20
American Indian	74	13.890	12	0.308		22 (84.6%); 0.20
Alaska Native	39	1.124	1	0.289		2 (50%); 0.41
Asia Pacific Islander	52	14.027	10	0.172		20 (90.9%); 0.17
Black/African American	101	33.454	27	0.182		52 (92.9%); 0.29
Hispanic/Latino	85	15.228	14	0.363		23 (76.7%); 0.22
Teaching grade level						
Kindergarten	131	0.053	1	0.818		2 (50%); 0.82
1st grade	131	0.053	1	0.818		2 (50%); 0.82
2nd grade	131	0.013	1	0.910		2 (50%); 1.10
3rd grade	131	0.369	1	0.544		2 (50%); 1.65
4th grade	131	1.147	1	0.284		0; 6.05
5th grade	131	0.001	1	0.981		0; 6.05
6th grade	131	1.407	1	0.236		0; 9.34
7th grade	131	0.176	1	0.675		0; 9.07
8th grade	131	0.005	1	0.942		0; 10:17

Table B.1 Continued:

9th grade	131	4.513	1	0.032	*	0; 7.42
10th grade	131	2.987	1	0.084		0; 8.79
11th grade	131	0.862	1	0.353		0; 7.97
12th grade	131	1.108	1	0.293		0; 7.15
Subjects Taught						
Arts/Music	131	1.564	1	0.211		2 (50%); 1.10
Language Arts/English	131	0.387	1	0.534		0; 10.44
Math	131	0.317	1	0.573		0; 12.37
Social Studies/Soc Sci.	131	1.353	1	0.245		0; 10.72
Science	131	3.501	1	0.061		0; 7.97
Literacy	131	0.037	1	0.848		1 (25%); 4.67
Agriscience	131	0.517	1	0.472		2 (50%); 0.55
Technology	131	6.907	1	0.009	*	1 (25%); 4.40
Environmental Science	131	4.966	1	0.026	*	0; 6.60
International Studies	131	0.382	1	0.537		2 (50%); 0.27
Special Education	131	0.013	1	0.910		2 (50%); 0.27
Life Skills	131	2.383	1	0.123		2 (50%); 1.65
Other Subject	131	4.410	1	0.036	*	0; 5.22
Number of years teaching at current school	128	24.340	26	0.557		46 (85.2%); 0.28
Total number of years teaching	128	38.829	38	0.432		72 (92.3%); 0.28
Number of MEECS-trained individuals						
Ecosystems and Biodiversity	131	3.371	1	0.066		0; 17
Energy Resources	131	2.286	1	0.131		0; 17.86
Water Quality	131	2.875	1	0.090		0; 12.09
Air Quality	131	0.758	1	0.384		0; 16.21
Land Use	131	0.123	1	0.725		0; 15

Table B.2. Combined Occurrences of Primary Goals and Beliefs in the Mail and the Web Surveys

Note: Numbers in bold are the totals for that particular category of goals and beliefs

		Mail Survey (N=36)		Web Survey (N=95)		Mail and Web Combined (N=131)	
Categories	**Primary Goals and Beliefs**	Freq	%	Freq	%	Freq	%
Academic Rigor		**2**	**1.8**	**7**	**1.9**	**9**	**1.9**
	represent a body of knowledge	2	1.8	7	1.9	9	1.9
Activity-Driven		**2**	**1.8**	**2**	**0.6**	**4**	**0.8**
	engage students in hands-on activities	2	1.8	2	0.6	4	0.8
Attitude/Behavior Change		**18**	**16.4**	**67**	**18.5**	**85**	**18.0**
	change or shape behaviors			2	0.6	2	0.4
	create/keep curiosity			8	2.2	8	1.7
	develop creativity/creative thinking/ inventiveness	1	0.9			1	0.2
	develop/instill positive attitudes towards learning/education	7	6.4	23	6.4	30	6.4
	develop/instill positive attitudes towards science	4	3.6	12	3.3	16	3.4
	help make responsible/good/informed choices	1	0.9	8	2.2	9	1.9
	inspire career choices/interests	1	0.9	5	1.4	6	1.3
	inspire students	2	1.8	7	1.9	9	1.9
	instill appreciation for God's creation/relationship with God	2	1.8	2	0.6	4	0.8
Career Benefits/Teacher Development				**2**	**0.6**	**2**	**0.4**
	obtain professional development/professional growth			1	0.3	1	0.2
	retirement			1	0.3	1	0.2

Table B.2 Continued:

Conceptual Change		**1**	**0.9**	**1**	**0.3**	**2**	**0.4**
	acquire conceptual change/scientific knowledge	1	0.9	1	0.3	2	0.4
Content/Subject Matter				**2**	**0.6**	**2**	**0.4**
	integrate student interest with curriculum content			1	0.3	1	0.2
	show big picture/broader scope of content			1	0.3	1	0.2
Discovery/Exploration		**1**	**0.9**	**4**	**1.1**	**5**	**1.1**
	allow discovery or exploration	1	0.9	3	0.8	4	0.8
	expose students to different areas of science			1	0.3	1	0.2
Education of Students		**1**	**0.9**	**5**	**1.4**	**6**	**1.3**
	educate students	1	0.9	5	1.4	6	1.3
Global/Real World Connections		**16**	**14.5**	**43**	**11.9**	**59**	**12.5**
	creating apprentice learners	1	0.9	0	0.0	1	0.2
	facilitate understanding	2	1.8	17	4.7	19	4.0
	provide wide experiences			5	1.4	5	1.1
	teach application of knowledge and skills in real life	8	7.3	15	4.1	23	4.9
	use authentic situations to provide real world experiences	5	4.5	6	1.7	11	2.3
Guided Inquiry/Learning Communities				**4**	**1.1**	**4**	**0.8**
	represent science as guided inquiry			3	0.8	3	0.6
	scaffolding			1	0.3	1	0.2
Humanistic		**4**	**3.6**	**9**	**2.5**	**13**	**2.8**
	provide public service/meet various needs of students	3	2.7	4	1.1	7	1.5
	reach students	1	0.9	5	1.4	6	1.3

Table B.2 continued:

Improvement of Pedagogy		**8**	**7.3**	**12**	**3.3**	**20**	**4.2**
	enhance teacher attitude/philosophy	1	0.9			1	0.2
	improve teaching/instruction	5	4.5	8	2.2	13	2.8
	increase subject knowledge	2	1.8	3	0.8	5	1.1
	model best practices for teaching			1	0.3	1	0.2
Inquiry		**4**	**3.6**	**5**	**1.4**	**9**	**1.9**
	represent science as inquiry	4	3.6	5	1.4	9	1.9
Knowledge Acquisition		**7**	**6.4**	**11**	**3.0**	**18**	**3.8**
	help students to acquire knowledge or awareness	7	6.4	11	3.0	18	3.8
Learning		**7**	**6.4**	**27**	**7.5**	**34**	**7.2**
	facilitate or assist in learning/teaching how to learn	3	2.7	7	1.9	10	2.1
	focus on the process of learning	1	0.9			1	0.2
	provide/create fun/safe learning environment	3	2.7	20	5.5	23	4.9
Modeling Ways of Being (Teacher)				**3**	**0.8**	**3**	**0.6**
	be a role model			3	0.8	3	0.6
Project-Based	**NONE**						
Skill Development		**12**	**10.9**	**47**	**13.0**	**59**	**12.5**
	develop academic skills	1	0.9	4	1.1	5	1.1
	develop basic skills			1	0.3	1	0.2
	develop decision making skills			6	1.7	6	1.3
	develop science process skills	3	2.7	6	1.7	9	1.9
	develop social skills	1	0.9	2	0.6	3	0.6
	develop study skills	1	0.9			1	0.2
	develop critical thinking skills	4	3.6	20	5.5	24	5.1

Table B.2 continued:

	develop problem solving skills	2	1.8	8	2.2	10	2.1
Social Reform/Good Citizenship		**13**	**11.8**	**33**	**9.1**	**46**	**9.7**
	develop stewardship	6	5.5	13	3.6	19	4.0
	seek social reform/foster good citizenship	7	6.4	20	5.5	27	5.7
Student Development		**2**	**1.8**	**56**	**15.5**	**58**	**12.3**
	develop personal autonomy of students			7	1.9	7	1.5
	develop student character and values			2	0.6	2	0.4
	develop student potential/competencies/personal agency			15	4.1	15	3.2
	empower students			7	1.9	7	1.5
	encourage students to get involved			1	0.3	1	0.2
	enrich individual students			1	0.3	1	0.2
	helping students achieve their goals and ambitions/be successful	1	0.9	5	1.4	6	1.3
	prepare students for society/higher education/career/future	1	0.9	18	5.0	19	4.0
Teacher-Student/Student-Student Relationships		**2**	**1.8**	**6**	**1.7**	**8**	**1.7**
	create sense of belongingness/feeling of being valued	1	0.9	3	0.8	4	0.8
	cultivate relationships	1	0.9	3	0.8	4	0.8
Didactic		**8**	**7.3**	**13**	**3.6**	**21**	**4.4**

Table B.2 continued:

	transmit facts, content, knowledge, benchmarks/ standards	8	7.3	13	3.6	21	4.4
Visioning		**2**	**1.8**	**3**	**0.8**	**5**	**1.1**
	encourage visioning or setting life goals	2	1.8	3	0.8	5	1.1
	TOTAL	110	100.0	362	100.0	472	100.0

Table B.3. Categories of Goals and Beliefs that Represented Action Competence (AC)

	Mail Survey (N=36)		Web Survey (N=95)		Mail and Web Combined (N=131)	
Categories	Freq	% AC	Freq	% AC	Freq	% AC
Activity-Driven	2	2.6	2	0.7	4	1.1
Attitude/Behavior Change	11	14.3	38	13.9	49	14.0
Conceptual Change	1	1.3	1	0.4	2	0.6
Content/Subject Matter	-	-	2	0.7	2	0.6
Discovery/Explanation	1	1.3	4	1.5	5	1.4
Global/Real World Connections	16	20.8	43	15.8	59	16.9
Guided Inquiry/Learning Communities	-	-	4	1.5	4	1.1
Inquiry	4	5.2	5	1.8	9	2.6
Knowledge Acquisition	7	9.1	11	4	18	5.1
Learning	7	9.1	27	9.9	34	9.7
Skill Development	10	13	42	15.4	52	14.9
Social Reform/Citizenship	13	16.9	33	12.1	46	13.1
Student Development	2	2.6	55	20.1	57	16.3
Teacher-Student/Student-Student Relationships	1	1.3	3	1.1	4	1.1
Visioning	2	2.6	3	1.1	5	1.4
TOTAL	77	100	273	100	350	100
TOTAL %	(77/110)*100 = 70.0		(273/362)*100 =75.4		(350/472)*100= 74.2	

Table B.4. Occurrence of Individual Elements of Action Competence (AC)

Elements of Action Competence	**Knowledge/ Insight**		**Commitment**		**Visions**		**Critical Thinking and Reflection**		**Planning and Action**			
	M	W	M	W	M	W	M	W	M	W	TOTAL No. of Occurrences of AC	TOTAL % of AC
Goals and Beliefs Categories												
Activity-Driven			2	2					2	2	8	1.5
Attitude/Behavior Change			10	38					1		49	9.3
Conceptual Change	1	1	1	1			1	1	1	1	8	1.5
Content/Subject Matter		1		1				1			3	0.6
Discovery/ Exploration			1	4							5	0.9
Global/Real World Connections			7	28			2	17	16	43	113	21.4
Guided Inquiry										4	4	0.8
Inquiry									4	5	9	1.7
Knowledge Acquisition	7	11									18	3.4
Learning	3	7	7	27					3	20	67	12.7
Skill Development			1	2			4	20	5	20	52	9.8
Social Reform/ Good Citizenship			13	33					13	33	92	17.4
Student Development			2	55					1	34	92	17.4
Teacher-Student Relationship			1	3							4	0.8
Visioning					2	3					5	0.9
TOTAL no. of Occurrences	11	20	45	194	2	3	7	39	46	162	529	
PERCENT	9.9	4.8	40.5	46.4	1.8	0.7	6.3	9.3	41.4	38.8		
Percent Mail + Web	5.9		45.2		0.9		8.7		39.3			

APPENDIX C:

ACTION COMPETENCE

Appendix C.1. Criteria for Action Competence (AC)

These criteria, which were developed from the works of Eames *et al.* (2006), Jensen &Schnack (1997), Mogensen (1997), Breiting &Mogensen (1999), and (Jensen, 2000a, 2000b), were used for all AC analyses. AC in the context of environmental education is the students' ability to act on environmental concerns/issues/problems (Jensen & Schnack, 1997). To examine which goals and beliefs represented AC, this investigator identified the goals and beliefs that related to helping students acquire knowledge, develop commitment, practice visions, plan and take action, and think critically and reflect in the context of environmental issues or problems.

Knowledge/Insight

Students...

- Gather/learn to gather information or develop knowledge from various sources *(this is also in planning and action)*
- develop knowledge about effects, causes, change strategies, and alternatives
- increase awareness of the environment

Commitment, motivation, attitudes, and values

Students...

- take ownership or personal responsibility of their learning, decisions, or actions
- make informed decisions on what actions to take
- make a commitment to be active citizens in a democratic society
- identify and understand their own and others' attitudes and values or views and perspectives towards environmental issues (*this is also critical thinking and reflection)*
- develop positive values and attitudes toward the environment
- satisfy their learning interests
- develop connections between themselves and their local environment, culture, and people
- do self-directed research/learning
- become aware that they have a role in environmental action
- increase their interest in the environment

- feel empowered to take action
- have a positive outlook about the world
- develop trust in their power to act or feeling that they can make a difference
- develop social skills (self esteem, ability to cooperate, self concept, self confidence)
- identify their own position regarding an environmental issue or problem
- think about their feelings regarding an issue or problem

Visions

Students...

- set goals or develop visions of their future or how they want their lives or the environment/earth to look like
- ask themselves what they think will happen in the future and the effects of environmental problem at hand to their future
- ask themselves what alternative ways of development are available

Planning and action experiences

Students...

- identify problems, plan (for how to solve), investigate, and present findings
- communicate
- participate in consultative, democratic, collaborative, and cooperative decision making
- work collaboratively towards an action (solution to a problem)
- share ideas and skills
- do higher order thinking skills (e.g., understanding, applying, analyzing, and evaluating) *(this is also in critical thinking and reflection)*
- share their emotional response to an issue they are investigating
- engage in cooperative discussions
- build and practice research skills
- identify possible actions for the environment
- develop skills in order to take action
- think innovatively and creatively about new ideas or different ways to resolve a concern, issue, or problem
- apply knowledge and skills in their other subjects or in real life

Critical thinking and reflection

Students...

- think about root causes of problems, pros and cons of an issue, multiple and/or competing explanations, and possible actions that could be taken
- reflect on experiences at both personal and societal levels

- reflect on their (prior or current) knowledge, actions, participation, attitudes, values, and motivations – e.g., students reflecting on how they impact their environment
- explore, examine, or analyze a problem or issue in depth or at multiple levels (e.g., structural, scientific, and personal)
- question (*this is also in planning and action*)
- be open-minded – change ideas, decisions, and choices when new information is available (*this is also in commitment, motivation, attitudes, and values*)
- challenge current practices

APPENDIX D:

DATA COLLECTION TOOLS AND PROTOCOLS

Appendix D.1. Mail Survey Instrument

TEACHER SURVEY ON TEACHING GOALS AND INSTRUCTIONAL STRATEGIES
Fall 2007

Dear Teacher:

We are conducting this survey to examine different types of teaching goals and instructional strategies in order to improve teacher training and science and environmental education curricula and programs in the future. You have been identified as a participant because you teach science or social studies **and/or** you were/are involved with the Michigan Environmental Education Curriculum Support (MEECS). We encourage your participation because only a small number of teachers are asked to participate in this survey. Your responses are of great importance to the success of this study.

There are 22 short questions in this survey. Please read each question carefully and answer to the best of your ability. Please note that there is no right or wrong answer for questions 15 and 16. We recognize that there are many different ways of teaching and that no one teaching style or strategy is better than others. We simply want to get an idea about the types of teaching strategies and methods that teachers adopt.

Participation in this survey is **voluntary**. You will not be penalized should you choose not to participate. Return of this survey, however, represents your consent to participate in this part of the study. We do not ask for your name to ensure your confidentiality and privacy. At the end of this 4-page survey, you will be asked if you would like to participate in the next phase of this study. If so, we will ask for your name and contact information, which will be treated **confidentially**. Be assured that your names will not be associated with your responses. This survey has an identification or code number on the topmost page on the right only to keep track of distribution.

If you would like additional information about this survey, please contact the study investigator and coordinator, Angelita "Gel" Alvarado at 517-432-5037 (office) or at alvara32@msu.edu. You may also contact the other study investigators, Dr. Geoffrey Habron at 517-432-8086 or at habrong@msu.edu, or Dr. Shari Dann at 517-432-0267 or at sldann@msu.edu. If you would like to hear more about your rights as a participant, you may contact – anonymously, if you wish – Peter Vasilenko, Ph.D., Director of the Human Research Protection Programs at Michigan State University by phone: 517-355-2180, fax: 517-432-4503, email: irb@msu.edu, or mail at: 202 Olds Hall, MSU, East Lansing, Michigan 48824.

Thank you. The survey begins on the next page. Place the completed survey in the enclosed stamped envelope and drop it in the mail. Keep this page for your reference in the future.

Sincerely,
Angelita Alvarado

1. Name of School:

Survey ID: [ ]

2. District:

3. Which of the following BEST describes your type of school? Please circle one.

   a. Public non-magnet
   b. Public magnet
   c. Public, alternative
   d. Public, charter
   e. Public, vocational
   f. Private church-related
   g. Private, not-church related
   h. I don't know
   i. Other (please specify):

4. Which of the following BEST describes the community where your school is located? Please circle one.

   a. Large City (population is at least 250,000)
   b. Mid-size City (population is less than 250,000)
   c. Large Town (population is at least 25,000)
   d. Small Town (population is less than 25,000 but more than 2,500)
   e. Urban fringe within a large city
   f. Urban fringe within a mid-size city
   g. Non-Metropolitan Rural
   h. Metropolitan Rural

5. Approximately how many (in percent) of your **total school population** are... (Please check one box for each item).

	0 to 24%	25 to 49%	50 to 74%	75 to 100%
a. eligible for free lunch?	☐	☐	☐	☐
b. eligible for reduced-priced lunch?	☐	☐	☐	☐
c. English language learners?	☐	☐	☐	☐
d. students with disabilities?	☐	☐	☐	☐

6. Approximately what percent of your school's **total student population** is... (If you don't know the exact percentage, please provide your best estimate).
   a) White: ___%
   b) Multi-racial:___%
   c) American Indian: ___%
   d) Alaska Native: ___%
   e) Asian/Pacific Islander: ___%
   f) Black/African American: ___%
   g) Hispanic/Latino: ___%
   h) Other (please specify): ________________%

7. What grade level/s are you currently teaching? Please circle all that apply.
   a) Pre-K
   b) Kindergarten
   c) 1
   d) 2
   e) 3
   f) 4
   g) 5
   h) 6
   i) 7
   j) 8
   k) 9
   l) 10
   m) 11
   n) 12
   o) College Level
   p) Other, please describe: ______________________

8. What subject/s do you currently teach? Please circle all that apply.

   a) Art/Music
   b) Language Arts/ English
   c) Mathematics
   d) Social Studies/Social Sciences
   e) Science (e.g., Biology, Physics, Chemistry)
   f) Literacy
   g) AgriScience
   h) Technology
   i) Environmental Science
   j) International Studies
   k) Special Education
   l) Life Skills
   m) Language other than English
   n) Other, please specify: ____________________

9. How long have you been a teacher? Please write the number of years clearly below.
   At your current school _____
   Total ______

10. Which of the following Michigan Environmental Education Curriculum Support (MEECS) Units' training have you participated? Please circle all that apply.
   a) Ecosystems and Biodiversity
   b) Energy Resources
   c) Water Quality
   d) Air Quality
   e) Land Use
   f) None – I haven't been trained in any of them
   g) Do not recall specifics, but I did get trained in MEECS

11. Which of the MEECS units have you used in the past? Please circle all that apply.
    a) Ecosystems and Biodiversity
    b) Energy Resources
    c) Water Quality
    d) Air Quality
    e) Land Use
    f) None – I haven't used any of them

12. Which of the MEECS units do you CURRENTLY use? Please circle all that apply.
    a) Ecosystems and Biodiversity
    b) Energy Resources
    c) Water Quality
    d) Air Quality
    e) Land Use
    f) None – I am not using any of them this year

13. If you have already been using the unit in this school year, when did you start? (If you have not started, when do you plan to begin?) Please circle only one answer.
    a) September
    b) October
    c) November
    d) December
    e) January
    f) February or later
    g) I will not use it this year

14. What additional environmental education units, curricula, or programs have you used or currently use? Please list as many as you can remember.
    a) ____________________
    b) ____________________
    c) ____________________
    d) ____________________
    e) ____________________
    f) ____________________

15. What is/are your primary goal/s as a teacher? What do you think should be the concerns of teaching (what should it be about)? Please use the back if you need more space.

Personal goals as a teacher:

Concerns of teaching:

16. How would you describe or characterize the nature of your instruction? Think about how you teach – for example, do you focus on giving your students facts, showing them how to do something then let them do it, let them learn on their own, give them hands-on activities or experiences, take them outdoors? Please list (bullet points) examples of specific methods (e.g., journaling, field trips, and group projects) you use to help your students understand specific concepts. Please use the back if you need more space.

The following questions are intended for statistical purposes

17. Gender   Female ____   Male ____

18. In what year were you born? _____

19. Please circle the number of years that represents the highest grade you have completed.

Elementary	High School	College	Graduate Level
1 2 3 4 5 6 7 8	9 10 11 12	13 14 15 16	17 18 19 20 21 22+

20. Total Continuing Education Units earned: _____   Not Applicable: _____

21. What was/were your college majors/s?

____

____

22. What was/were your college minors?

____

____

Would you be willing to participate further in this study? If so, please provide your name, phone number, and email address, so I may contact you in the next two weeks to talk more about how you might be able to help in this study.

Name: ____________________________
Work Phone Number:_____________ Home Phone Number:_______________
Best place and times to call (e.g., prep hour, before or after school):
____
Email Address:________________________________
School: ______________________________________

THANK YOU very much for your participation in this survey. Your input will give us insights into teachers' teaching goals and strategies. Please put this survey in the addressed, stamped envelope and drop it in the mail.

Appendix D.2. Web Survey Instrument

Michigan State University Teacher Survey on Teaching Goals and Instructional Strategies Spring 2008

Dear Teacher:

We are conducting this survey to examine different types of teaching goals and instructional strategies in order to improve teacher training and science and environmental education curricula and programs in the future. You have been identified as a participant because you teach science or social studies and/or you were/are involved with the Michigan Environmental Education Curriculum Support (MEECS). We encourage your participation because only a small number of teachers are asked to participate in this survey. Your responses are of great importance to the success of this study.

There are 22 short questions in this survey. Please read each question carefully and answer to the best of your ability. Please note that there is no right or wrong answer for questions 15 and 16. We recognize that there are many different ways of teaching and that no one teaching style or strategy is better than others. We simply want to get an idea about the types of teaching strategies and methods that teachers adopt.

Participation in this survey is voluntary. You will not be penalized should you choose not to participate. Completion and submission of this survey, however, indicates your voluntary agreement to participate in this part of the study. We do not ask for your name to ensure your confidentiality and privacy. At the end of this survey, you will be asked if you would like to participate in the next phase of this study. If so, we will ask for your name and contact information, which will be treated confidentially. Be assured that your names will not be associated with your responses.

If you would like additional information about this survey, please contact the study investigator and coordinator, Angelita "Gel" Alvarado at 517-432-5037 (office) or at alvara32@msu.edu. You may also contact the other study investigators, Dr. Geoffrey Habron at 517-432-8086 or at habrong@msu.edu, or Dr. Shari Dann at 517-432-0267 or at sldann@msu.edu. If you would like to hear more about your rights as a participant, you may contact – anonymously, if you wish – Peter Vasilenko, Ph.D., Director of the Human Research Protection Programs at Michigan State University by phone: 517-355-2180, fax: 517-432-4503, email: irb@msu.edu, or mail at: 202 Olds Hall, MSU, East Lansing, Michigan 48824.

Thank you.

Sincerely,
Angelita Alvarado

This consent form was approved by the Social Science/Behavioral/Education Institutional Review Board (SIRB) at Michigan State University. Approved 01/11/08 - valid through 9/26/08. This version supersedes all previous versions. IRB# 07-741. Please click next to begin the survey.

Next >>

1. Name of School

2. District

3. Which of the following BEST describes your type of school? Please check one.

- a. Public non-magnet
- b. Public magnet
- c. Public, alternative
- d. Public, charter
- e. Public, vocational
- f. Private church-related
- g. Private, not-church related
- h. I don't know
- i. Other (please specify)

4. Which of the following BEST describes the community where your SCHOOL IS LOCATED? Please check one.

- a. Large City (population is at least 250,000)
- b. Mid-size City (population is less than 250,000)
- c. Large Town (population is at least 25,000)
- d. Small Town (population is less than 25,000 but more than 2,500)
- e. Urban fringe within a large city
- f. Urban fringe within a mid-size city
- g. Non-Metropolitan Rural
- h. Metropolitan Rural
- i. I don't know

5. Approximately how many (in percent) of your TOTAL SCHOOL POPULATION are... (Please check one for each item).

	25 to 49%	50 to 74%	75 to 100%	Don't Know/Not Sure
a. eligible for free lunch?	☐	☐	☐	☐
b. eligible for reduced-priced lunch?	☐	☐	☐	☐
c. English language learners?	☐	☐	☐	☐
d. students with disabilities?	☐	☐	☐	☐

6. Approximately what percent of your school's total student population is... (If you don't know the exact percentage, please provide your best estimate).

a. White ______

b. Multi-racial ______

c. American Indian ______

d. Alaska Native ______

e. Asian/Pacific Islander ______

f. Black/African American ______

g. Hispanic/Latino ______

h. Other ______

7. What grade level/s are you currently teaching? Please check all that apply.

- ☐ a. Pre-K
- ☐ b. Kindergarten
- ☐ c. 1
- ☐ d. 2
- ☐ e. 3
- ☐ f. 4
- ☐ g. 5
- ☐ h. 6
- ☐ i. 7
- ☐ j. 8
- ☐ k. 9
- ☐ l. 10
- ☐ m. 11
- ☐ n. 12
- ☐ o. College Level
- ☐ p. Other, please describe

______

8. What subject/s do you currently teach? Please check all that apply.

- a. Art/Music
- b. Language Arts/ English
- c. Mathematics
- d. Social Studies/Social Sciences
- e. Science (e.g., Biology, Physics, Chemistry)
- f. Literacy
- g. AgriScience
- h. Technology
- i. Environmental Science
- j. International Studies
- k. Special Education
- l. Life Skills
- m. Language other than English
- n. Other (please specify):

9. How long have you been a teacher? Please write the number of years clearly below.

At your current school

Total

10. Which of the following Michigan Environmental Education Curriculum Support (MEECS) Units' training have you participated? Please check all that apply.

- a. Ecosystems and Biodiversity
- b. Energy Resources
- c. Water Quality
- d. Air Quality
- e. Land Use
- f. None – I haven't been trained in any of them
- g. Do not recall specifics, but I did get trained in MEECS

11. Which of the MEECS units have you used in the past? Please check all that apply.

- [ ] a. Ecosystems and Biodiversity
- [ ] b. Energy Resources
- [ ] c. Water Quality
- [ ] d. Air Quality
- [ ] e. Land Use
- [ ] f. None – I haven't used any of them

12. Which of the MEECS units do you CURRENTLY use? Please check all that apply.

- [ ] a. Ecosystems and Biodiversity
- [ ] b. Energy Resources
- [ ] c. Water Quality
- [ ] d. Air Quality
- [ ] e. Land Use
- [ ] f. None – I am not using any of them this year

13a. If you have already been using the unit in this school year, when did you start? (If you have not started, when do you plan to begin?) Please check only one answer.

- [ ] a. September 2007
- [ ] b. October 2007
- [ ] c. November 2007
- [ ] d. December 2007
- [ ] e. January 2008
- [ ] f. February 2008 or later
- [ ] g. I will not use it this year

13b. Please describe your reasons for using or not using the MEECS curriculum this year.

14. What additional environmental education units, curricula, or programs have you used or currently use? Please list as many as you can remember.

a.

b.

c.

d.

e.

f.

15a. What is/are your primary goal/s as a teacher (personal goals)?

15b. What do you think teaching should be about?

16. How would you describe or characterize the nature of your instruction? Think about how you teach – for example, do you focus on giving your students facts, showing them how to do something then let them do it, let them learn on their own, give them hands-on activities or experiences, take them outdoors? Please list (bullet points) examples of specific methods (e.g., journaling, field trips, and group projects) you use to help your students understand specific concepts.

The following questions are intended for statistical purposes

17. Gender

- [ ] Female
- [ ] Male

18. In what year were you born?

19. Please check the number of years that represents the highest grade you have completed (check only one).
1-8 Elementary
9-12 High School
13-16 College
17-22 Graduate School

- [ ] 1
- [ ] 2
- [ ] 3
- [ ] 4
- [ ] 5
- [ ] 6
- [ ] 7
- [ ] 8
- [ ] 9
- [ ] 10
- [ ] 11
- [ ] 12
- [ ] 13
- [ ] 14
- [ ] 15
- [ ] 16
- [ ] 17
- [ ] 18
- [ ] 19
- [ ] 20
- [ ] 21
- [ ] 22

20. Total Continuing Education Units earned: Please write N/A if this question does not apply to you.

21. What was/were your college majors/s?

a.

b.

c.

22. What was/were your college minors?

a.

b.

c.

Please provide a valid email address.

Would you be willing to participate further in this study? If so, please provide your name and phone number so I may contact you in the next two weeks to talk more about how you might be able to help in this study.

Name	
Work Phone Number	
Home Phone Number	
Best place and times to call (e.g., prep hour, before or after school)	
School	

THANK YOU very much for your participation in this survey. Your input will give us insights into teachers' teaching goals and strategies. Please contact us if you have any questions.

Appendix D.3. Pre-Notice Email for Mail Survey Respondents

Dear teachers and education professionals,

Greetings! We need your help! You have been selected as a participant in a study on teaching strategies and methods and student learning. You have been selected because you are a science or social science teacher **and/or** you participated in the Michigan Environmental Education Curriculum Support (MEECS) training implemented by the Michigan Department of Environmental Quality in 2006. The goal of this study is to identify different teaching strategies and methods that help middle school students learn science, in order to improve teacher training and develop more effective science and environmental education curricula and programs like MEECS.

You will receive a short survey (22 items) in the next three days at your school or home address. We strongly encourage you to complete this survey since this is only sent to selected teachers and education professionals. Your input will be extremely helpful in our understanding of the relationships between teaching strategies and student learning. The survey includes a self-addressed, stamped envelope. You may drop it in any USPS drop box.

THANK YOU VERY MUCH for your participation and support. If you have any questions, please contact me at alvara32@msu.edu or at 517-432-5037.

Sincerely,
Angelita (Gel) Alvarado
PhD Student
Michigan State University

Appendix D.4. Pre-Notice Email for Web Survey Respondents

Dear teachers and education professionals,

Greetings! We need your help! You have been selected as a participant in a study on teaching strategies and methods and student learning. You have been selected because you are a science or social science teacher **and/or** you participated in the Michigan Environmental Education Curriculum Support (MEECS) training implemented by the Michigan Department of Environmental Quality in 2006. The goal of this study is to identify different teaching strategies and methods that help middle school students learn science, in order to improve teacher training and develop more effective science and environmental education curricula and programs like MEECS.

You will receive an email invitation in the next three days where you will be given a unique web link to complete a short survey (22 items). We strongly encourage you to complete this survey since this is only sent to selected teachers and education professionals. Your input will be extremely helpful in our understanding of the relationships between teaching strategies and student learning.

THANK YOU VERY MUCH for your participation and support. If you have any questions, please contact me at alvara32@msu.edu or at 517-432-5037.

Sincerely,
Angelita (Gel) Alvarado
PhD Student
Michigan State University

Appendix D.5. Email for Web Survey Respondents

Dear Teacher,

We are conducting this survey to examine different types of teaching goals and instructional strategies in order to improve teacher training and science and environmental education curricula and programs in the future. You have been identified as a participant because you teach science or social studies and/or you were/are involved with the Michigan Environmental Education Curriculum Support (MEECS).

There are only 22 short questions in this survey. We encourage your participation because only a small number of teachers are asked to participate in this survey. Your responses are of great importance to the success of this study. Please click on the link below to complete the survey.

http://www.surveymonkey.com/s.aspx?sm=9qgt6aGpKKN0HK2uw2_2frHTb31xj_2bqRvzk3BjnfGa2Uw_3d

This link is uniquely tied to this survey and your email address, please do not forward this message.

Thank you very much for your participation!

Sincerely,
Angelita (Gel) Alvarado
PhD Student
Michigan State University

Please note: If you do not wish to receive further emails from us, please click the link below, and you will be automatically removed from our mailing list.
http://www.surveymonkey.com/optout.aspx

Appendix D.6. Reminder Email for Mail Survey Respondents

(One Week after Initial Invitation)

Dear Teachers and Education Professionals,

About a week ago you received a survey from Michigan State University about Teachers' Goals and Instructional Strategies. You are selected because you are a science or social science teacher **and/or** because of your participation in the Michigan Environmental Education Curriculum Support (MEECS) training last year. The purpose of the survey is to seek your help in enhancing our understanding about ways that teachers help their students learn in order to improve teacher training and to develop more effective science or environmental education curriculum for K-12 schools in Michigan.

If you haven't already done so, please fill the survey and drop it in any USPS drop box. It has 22 short questions only and should not take more than half an hour. We highly encourage you to complete it so that we may have a clearer understanding of the types of activities and experiences that help students learn the most. If you didn't receive a survey or have misplaced it, please reply to this email with your name and mailing address so that I may send you another survey right away.

Thank you so much for your time. I am looking forward to receiving your input. Have a wonderful week.

Sincerely,
Angelita (Gel) Alvarado
PhD Student
Michigan State University

Appendix D.7. Reminder Email for Web Survey Respondents

(One Week after Initial Invitation)

Dear Teacher,

Last week we sent you an electronic survey that asks about your teaching goals and instructional strategies. We are conducting this survey in order to improve teacher training and science and environmental education curricula and programs in the future. You have been identified as a participant because you teach science or social studies and/or you were/are involved with the Michigan Environmental Education Curriculum Support (MEECS).

There are only 22 short questions in this survey. We encourage your participation because only a small number of teachers are asked to participate in this survey. Your responses are of great importance to the success of this study. Please click on the link below to complete the survey.

http://www.surveymonkey.com/s.aspx?sm=Y6zOs99EqdJwUvUXAXYZDA_3d_3d

This link is uniquely tied to this survey and your email address. Please do not forward this message.

THANK YOU very much for your participation!

Sincerely,
Angelita Alvarado
PhD Student
Michigan State University

Please note: If you do not wish to receive further emails from us, please click the link below, and you will be automatically removed from our mailing list.
http://www.surveymonkey.com/optout.aspx?sm=Y6zOs99EqdJwUvUXAXYZDA_3d_3d

Appendix D.8. Reminder Email for Mail Survey Respondents

(One Month After Initial Invitation)

Dear Teachers and Education Professionals,

About four weeks ago you received a survey from Michigan State University about Teachers' Goals and and Instructional Strategies. You are selected because you are a science or social science teacher **and/or** because of your participation in the Michigan Environmental Education Curriculum Support (MEECS) training last year. The purpose of the survey is to seek your help in enhancing our understanding about ways that teachers help their students learn in order to improve teacher training and to develop more effective science or environmental education curriculum for K-12 schools in Michigan.

If you haven't already done so, please fill the survey and drop it in any USPS drop box. It has 22 short questions only and should not take more than half an hour. We highly encourage you to complete it so that we may have a clearer understanding of the types of activities and experiences that help students learn the most. If you didn't receive a survey or have misplaced it, please reply to this email with your name and mailing address so that I may send you another survey right away.

Thank you so much for your time. I am looking forward to receiving your input. Have a wonderful week.

Sincerely,
Angelita Alvarado
PhD Student
Michigan State University

Appendix D.9. Reminder Email for Web Survey Respondents

(One Month After Initial Invitation)

Dear Teacher,

About a month ago we sent you an electronic survey that asked about your teaching goals and instructional strategies. We are conducting this survey in order to improve teacher training and science and environmental education curricula and programs in the future. You have been identified as a participant because you teach science or social studies and/or you were/are involved with the Michigan Environmental Education Curriculum Support (MEECS).

There are only 22 short questions in this survey. We STRONGLY encourage your participation because only a small number of teachers are asked to participate in this survey. Your responses are of great importance to the success of this study. Please click on the link below to complete the survey.

http://www.surveymonkey.com/s.aspx?sm=NJYa1Nzg1AzinI0udODvYw_3d_3d

This link is uniquely tied to this survey and your email address, please do not forward this message.

THANK YOU very much for your participation!

Sincerely,
Angelita Alvarado
PhD Student
Michigan State University

Please note: If you do not wish to receive further emails from us, please
click the link below, and you will be automatically removed from our mailing list.
http://www.surveymonkey.com/optout.aspx?sm=NJYa1Nzg1AzinI0udODvYw_3d_3d

Appendix D.10. Thank You Email for Mail Survey Respondents

Dear Teachers,

Greetings! THANK YOU VERY MUCH for completing and returning the survey!!!! We appreciate your help in our research endeavor to enhance understanding of teaching strategies and methods that help students learn science. If you have indicated in your survey that you are willing to participate further in our study, you will be hearing from me this week. I very much look forward to talking with you!!!

Again thank you all for your time, and best wishes for the rest of your school year.

Sincerely,
Angelita (Gel) Alvarado
PhD Student
Michigan State University

Appendix D.11. Thank You Email for Web Survey Respondents

Dear Teacher,

I would like to THANK YOU for participating in our survey. Your input is important in helping us identify teachers' goals and teaching strategies, which will have a significant contribution towards improving teacher training for science and environmental education teachers and developing effective science and environmental education curricula and programs.

I appreciate your time and willingness to help me out. If you have any questions about my study, please do not hesitate to contact me at alvara32@msu.edu or at 517-432-5037.

If you have already completed a survey, please don't do it twice. If you only partially completed it the first time and would like to complete it this time, please click the link to the survey:

http://www.surveymonkey.com/s.aspx

This link is uniquely tied to this survey and your email address, please do not forward this message.

Thank you once again for sharing a little bit of your teaching with me!

Sincerely,
Angelita (Gel) Alvarado
PhD Student
Michigan State University

Please note: If you do not wish to receive further emails from us, please click the link below, and you will be automatically removed from our mailing list.
http://www.surveymonkey.com/optout.aspx

Appendix D.12. The Interview Guide

1) Please describe your class as a whole.

2) Please describe your school, the administration and staff, and resources and facilities available.

3) Please describe the parents' involvement in school/class activities.

4) How much of the Michigan benchmarks and standards or the grade level expectations do you use?

5) How much of the MEECS (Michigan Environmental Education Curriculum Support) do you use?

6) What are your goals and objectives for teaching?

7) Does your teaching approach/strategy/method vary with the topic that you teach?

8) Which part of the curriculum is addressed by the lessons you will teach this week?

9) How do your students prefer to learn? What do you do to address learning styles? Please provide examples.

10) Besides your textbook, what other resources do you use for teaching?

11) What kinds of things do you do that are related to developing students' critical thinking, ability to plan, to think about what they might be able to do related to an environmental issue or problem?

Appendix D13. Informed Consent for Teachers

Teachers' Knowledge, Goals, Instructional Strategies, and Views
about Teaching and Student Learning
INFORMED CONSENT

Dear Teacher:

We invite your help! We are conducting research on the relationships between middle school science teachers' knowledge, goals, instructional strategies, and views about teaching and student learning. This study's focus is teachers, and you have been identified as a suitable participant in our project because you are a middle school science teacher as well as your participation in the MEECS (Michigan Environmental Education Curriculum Support) training conducted by the MI Department of Environment Quality and your use of at least one of the MEECS units. Our end goal is to improve teacher training for future science teachers and improve or develop science and environmental education curricula and programs like MEECS. Your input into this study is invaluable as it will illuminate our understanding of the relationships between teaching and student learning.

We are requesting your consent for you and your class to participate in this project. It will involve 3 to 5 classroom observation periods by the study investigator and coordinator Angelita (Gel) Alvarado, 2 one-hour long interviews, up to 5 short interviews (10 to 15 minutes) to debrief some classroom observations, and an hour long survey that you can fill out at your leisure for two weeks. Gel's observation will be no more than 2 hours each time, and may be completed in a week's time or interspersed throughout several weeks of a particular science unit you are teaching. Gel will work with you to ensure her observations and other interactions with you and your class will minimize any disturbance to your instruction and the students' learning. Gel also intends to do one or two 30-minute group interviews with randomly selected students regarding their experiences in your class and will work with you to avoid taking them out of class for the interview. Gel may also want to browse through your lesson plan and take photographs of your classroom and of your students' work in and around the classroom. For this study, it is essential to audio-tape all interviews and video-tape some of the classroom observations. As part of your participation in this study, you will be asked to help gather parental consent and student assent (consent forms provided by this investigator).

The investigators ensure your privacy and confidentiality to the maximum extent allowable by law. This means that all information received and collected will be treated confidentially. Be assured that your names will not be associated with your responses; no names will be recorded on the notes, interview transcripts, surveys, video recordings, or student work. Only identification numbers or codes will be used. Finally, no real names of people or the school will be used when results are summarized and/or shared at professional conferences or as journal articles.

Your participation in this study is **voluntary** and there is no penalty if you decide not to participate. You may also stop participation at any time. Similarly, your students' participation is **voluntary**. If a student or a parent decides not to have his/her child participate in the group interview or not be audio-taped, the student's name will not be included in the random selection of interviewees. Moreover, parents who choose not to let their children be video-taped or photographed need to inform you (teacher) to ensure that this investigator does not include them in the video-tape or photographs. Participation in this study poses minimal risks to you and your students. Such risks may include feeling uncomfortable to share instructional strategies or feeling uncomfortable with being "evaluated" (on the teachers' part) or fear of getting a bad grade if they talk about their teachers (on the students' part). If you and your class participate, your class will receive some educational materials at the end of your participation.

Should you have any questions about this study, you may contact the study investigator and coordinator: Angelita (Gel) Alvarado, doctoral student, MSU Department of Fisheries and Wildlife, 13 Natural Resources Building, East Lansing, MI 48824, alvara32@msu.edu, 517-432-5037. You may also contact the other study investigators, Dr. Geoffrey Habron, MSU Department of Fisheries and Wildlife, 13 Natural Resources Building, East Lansing, MI 48824, habrong@msu.edu , 517-432-8086, or Dr. Shari Dann, MSU Department of Community, Agriculture, Recreation, and Resource Studies, Natural Resources Building, East Lansing, MI 48824, sldann@msu.edu, 517-432-0267. If you have any questions about your rights or your students' rights as study participants, or are dissatisfied at any time, you may contact – anonymously, if you wish – Peter Vasilenko, Ph.D., Director of the Human Research Protection Programs at Michigan State University by phone: 517-355-2180, fax: 517-432-4503, email: irb@msu.edu, or mail at: 202 Olds Hall, MSU, East Lansing, Michigan 48824.

Please sign and return the consent below and retain the previous information for your reference.

Consent to Participate in the Study on Teaching and Student Learning

I agree to participate in this project. Please initial the appropriate options, sign, and return to Gel Alvarado. Your participation will be limited to the options you initial below.

______ I DO consent to being video-taped as part of this project.
______ I DO NOT consent to being video-taped as part of this project.
______ I DO consent to being audio-taped as part of this project.
______ I DO NOT consent to being audio-taped as part of this project.
______ I DO consent to being photographed as part of this project.
______ I DO NOT consent to being photographed as part of this project.
______ I DO consent to have my classroom photographed as part of this project.
______ I DO NOT consent to have my classroom photographed as part of this project.

______________________	______________________	______________________
Name (print)	Signature	Date

Appendix D.14. Informed Consent for Principals

Teachers' Knowledge, Goals, Instructional Strategies, and Views
about Teaching and Student Learning
INFORMED CONSENT

Dear School Principal:

We invite your help! We are conducting research on the relationships between middle school science teachers' knowledge, goals, instructional strategies, and views about teaching and student learning. This study's focus is teachers, and your teacher/s Mr. /Ms. _______________ and Mr. /Ms. _________________ has been identified as suitable participants in our project because of their participation in the MEECS (Michigan Environmental Education Curriculum Support) training conducted by the MI Department of Environment Quality and their use of at least one of the MEECS units. Our end goal is to improve teacher training for future science teachers and improve or develop science and environmental education curricula and programs like MEECS. Your teachers and their students' inputs into this study are invaluable as it will illuminate our understanding of the relationships between teaching and student learning.
In order to explore the teacher's ways of teaching and their influence on student learning, we need to:

- Watch the teacher's teaching and interaction with his/her class,
- Videotape and/or photograph some of the teacher's teaching and interaction with his/her class,
- Audiotape an interview with a randomly selected group of students,
- Photograph selected work of students in class, or those posted on the walls of the classroom or anywhere in the school building.
- Photograph the teacher's classroom and/or the school building,
- Conduct a teacher survey, and
- Audiotape teacher interviews.

We are requesting your permission to allow the study investigator and coordinator, Angelita (Gel) Alvarado, to conduct the activities listed above. Gel will do up to 5 classroom observations and each visit will be no more than 2 hours, and may be completed in a week's time or interspersed throughout several weeks of a particular science unit the teacher will be covering. The students participating in 30-minute group interviews will be randomly selected; all interviews will be conducted within the school premises. Gel will work with the teacher to ensure her observations and other interactions with the teacher and the students will minimize any disturbance on any part of his/her instruction and the students' learning.

The investigators ensure your teachers' and students' privacy and confidentiality to the maximum extent allowable by law. This means that all information received and collected will be treated confidentially. Be assured that no names of teachers or students will be associated with their responses; no names will be recorded on the notes, interview transcripts, surveys, video-recordings, or student work. Only identification numbers or codes will be used. Finally, no real names of people or the school will be used when results are summarized and/or shared at professional conferences or as journal articles. Your permission to let us conduct this study in your school is **voluntary** and there is no penalty if you decide not to participate. You may also stop participation at any time. Also, participation in this study poses minimal risks to your teachers, students, or school, such as concern for negative publicity for the school, feeling uncomfortable to share instructional strategies or feeling of being "evaluated" (on the teachers' part) or fear of getting a bad grade if they talk about their teachers (on the students' part). The study investigator and coordinator will ensure results obtained from this study will not in any way jeopardize the names of the school, the teachers, and the students.

Should you have any questions about this study, you may contact the Study investigator and coordinator: Angelita (Gel) Alvarado, doctoral student, MSU Department of Fisheries and Wildlife, 13 Natural Resources Building, East Lansing, MI 48824, alvara32@msu.edu, 517-432-5037. You may also contact the other study investigators, Dr. Geoffrey Habron, MSU Department of Fisheries and Wildlife, 13 Natural Resources Building, East Lansing, MI 48824, habrong@msu.edu , 517-432-8086, or Dr. Shari Dann, MSU Department of Community, Agriculture, Recreation, and Resource Studies, Natural Resources Building, East Lansing, MI 48824, sldann@msu.edu, 517-432-0267. If you have any questions about your teacher or your students' rights as study participants, or are dissatisfied at any time, you may contact – anonymously, if you wish – Peter Vasilenko, Ph.D., Director of the Human Research Protection Programs at Michigan State University by phone: 517-355-2180, fax: 517-432-4503, email: irb@msu.edu, or mail at: 202 Olds Hall, MSU, East Lansing, Michigan 48824.

Please read and sign the consent below and retain the letter for your reference.

Consent to Allow Study on Teaching and Student Learning

As Principal of ___________________________(school name), I hereby give permission for my teachers and their students to take part in this study primarily conducted by Angelita (Gel) Alvarado, study investigator and coordinator, and I authorize the use of any information collected for the purposes of the study described above.

______________________	______________________	______________________
Name (print)	Signature	Date

Appendix D.15. Informed Consent for Parents/Guardians

Middle School Students' Views of Their Learning Experiences in Science Class
INFORMED CONSENT

Dear Parent/Guardian:

We invite your help! Your child's teacher, Mr./Ms. ______________ at ____________School is collaborating with Michigan State University in conducting research on relationships between middle school science teachers' ways of teaching and student learning. Your child's teacher was selected because of his/her participation in the training provided by the MI Department of Environmental Quality to use at least one of the five units from the Michigan Environmental Education Curriculum Support (MEECS). The purpose of our study is to examine how your child's teacher's ways of using and teaching one of the five MEECS units may influence your child's learning. Hence the focus of our study is the teachers. Our end goal is to improve teacher training for future science teachers and improve or develop more effective science and environmental education curricula and programs like MEECS.
In order to explore the teacher's ways of teaching and their influence on student learning, we need to:

- Watch the teacher teach and interact with his/her class,
- Videotape and/or photograph some of the teacher's teaching and interaction with his/her class,
- Audiotape an interview with a randomly selected group of students, and
- Photograph selected work of students in class, or those posted on the walls of the classroom or anywhere in the school building.

The study investigator, Angelita (Gel) Alvarado, will conduct up to 5 classroom observations and will work with your child's teacher to ensure her observations and other interactions with your child will minimize the disturbance to your child's learning. Your child will be audio-taped, video-taped, or photographed **ONLY with your consent and your child's assent.** With your consent and your child's assent, your child may be randomly selected to participate in a 30-minute group interview during one of Gel's classroom visits. With approval of the teacher as to when to conduct the interview, Gel will ask your child about their learning experiences in science class, e.g., lessons, activities, projects, what they learned, tests/exams, interactions with teachers.

The investigators ensure your child's privacy and confidentiality to the maximum extent allowable by law. This means that all information received and collected will be treated confidentially. Be assured that your child's name will not be associated with his/her responses; no names will be recorded on the interview transcripts or video recordings. Names on student work will be erased and given a code for analysis purposes. Only identification numbers or codes will be used. Finally, no real names of people or the school will be used when results are summarized and/or shared at professional conferences or as journal articles.

Your child's participation in this study is **voluntary** and there is no penalty if you or your child decides not to participate. If you and/or your child decide not to be audio-taped, participate in the interview, or be video-taped, please inform your child's teacher. Consequently, your child will not be recorded, interviewed, and/or filmed about their experiences in the classroom. You or your child may also stop participation at any time by informing your child's teacher. Moreover, participation in this study poses minimal risks to your child, for example, fear or concern of getting a bad grade if they talk about their teachers or their experiences in class. The study investigator and coordinator will ensure student responses will not affect or jeopardize your child's grade in any way.

Should you have any questions about this study, you may contact the study investigator and coordinator: Angelita (Gel) Alvarado, doctoral student, MSU Department of Fisheries and Wildlife, 13 Natural Resources Building, East Lansing, MI 48824, alvara32@msu.edu, 517-432-5037. You may also contact the other study investigators, Dr. Geoffrey Habron, MSU Department of Fisheries and Wildlife, 13 Natural Resources Building, East Lansing, MI 48824, habrong@msu.edu , 517-432-8086, or Dr. Shari Dann, MSU Department of Community, Agriculture, Recreation, and Resource Studies, Natural Resources Building, East Lansing, MI 48824, sldann@msu.edu, 517-432-0267. If you have any questions about your child's rights as a study participant, or are dissatisfied at any time, you may contact – anonymously, if you wish – Peter Vasilenko, Ph.D., Director of the Human Research Protection Programs at Michigan State University by phone: 517-355-2180, fax: 517-432-4503, email: irb@msu.edu, or mail at: 202 Olds Hall, MSU, East Lansing, Michigan 48824.

Please sign and have your child return the consent below and retain the letter for your reference.

Parent/Guardian Consent for Child to Participate in the Study of Teaching and Student Learning

As parent/guardian of the child named below, please initial appropriate options below, sign your name, and enter the date. By signing this consent form, you authorize the use of any information collected for the purposes of the study described above.

_____ I give my permission for my child to take part in the **video-taping** for research purposes to explore teachers' ways of teaching and their influence on student learning.

_____ I give permission for my child to take part in the **audio-taping of group interview** for research purposes to explore teachers' ways of teaching and their influence on student learning.

_____ I give my permission **for my child to be photographed** for research purposes to explore teachers' ways of teaching and their influence on student learning.

_____ I give permission **for my child's work in class or anywhere in the school building to be photographed or photocopied** for research purposes to explore teachers' ways of teaching and their influence on student learning.

Your child will not be asked to participate in any of the activities without your permission and his/her assent.

____________________________	____________________________
Name of Parent/Guardian	Name of Child (print)
____________________________	____________________
Signature of Parent/Guardian	Date

Appendix D.16. Student Assent Form

(This will be read and verbally stated to the students; their signature is required at the end).

My name is Gel Alvarado. I'm a graduate student from Michigan State University and I am conducting a study on teaching and student learning. I am asking your help in understanding your learning experiences in your science class and your teacher's ways of teaching, for example, the activities that you do, your projects, home works/assignments, tests/exams, your interactions with your teachers and your classmates, what activities did you like and why, etc. My end goal for doing this study is to improve teacher training and science and environmental education programs and curricula in order to help make your learning experiences more effective and more fun!

Participation in this study will involve video and audio taping and/or taking photos of class activities in the school premises, group interviews with randomly selected students, and taking photos or making copies of some of your class work. YOU WILL ONLY BE ASKED TO PARTICIPATE IF YOU HAVE PARENTAL CONSENT AND IF YOU GIVE YOUR ASSENT (IF YOU AGREE) TO PARTICIPATE.

I will be visiting your class up to 5 times, and some of your class activities will be video-taped or photographed.

For the group interviews, I need 6 to 8 students per group; these students will be randomly selected, meaning your names will be drawn out of a hat. We will sit in a circle either here in the classroom or outside (but in the school premises). I have about 15 questions to ask, and the interview will be about half an hour. I will be recording our chat using a digital audio-recorder. Since there are 6 of us (change number based on the number of students in a group), please raise your hand if you want to comment on a question or want to share something. That will make it easier for all of us to hear what each person has to say. Also, please speak clearly and loud enough for everyone to hear. Please remember that the group interview is NOT a test and it is NOT a contest. You will NOT be graded and your responses will NOT affect your grades in any way by participating in this group interview.

Here's what else you should know. You DO NOT have to take part in this study. Participation in this study is **voluntary**, so you can choose not to participate, if you want. Or you can join in the video-taping, photographing, or audio-taping, and if at any time you wish to stop participation, you may do so. It's no big deal if you choose not to participate, or if you decide not to answer a question. In addition, you do not have to worry about your names or your teacher's name being used or reported. I will not use your name, your teacher's name, or your school's name in my reports. You can also discuss this study with your parents or guardian or with your teacher if you have any questions or concerns.
If you haven't already given your parental consent to your teacher, please hand it to me.

Do you have any questions about the study?
Please sign below.

I agree to participate in the study investigating teaching and student learning in middle school science.

____________________	____________________	____________________
Student Name	Signature	Date

Table D.1. Interview Schedules
(Number in parentheses is length of the interview in minutes)

Teacher A	Teacher B	Teacher C	Teacher D
10/30/2007 (49)	11/02/2007 (61)	1/10/2008 (38)	2/28/2008 (90)
12/07/2007 (35)	1/11/2008 (48)	1/11/2008 (30)	3/13/2008 (20)
12/13/2007 (20)	1/29/2008 (10)	1/14/2008 (35)	3/19/2008 (10)
12/20/2007 (25)	2/16/2008 (37)	1/29/2008 (32)	3/20/2008 (22)
1/28/2008 (33)	4/4/2008 (33)	2/29/2008 (34)	4/24/2008 (46)

Table D.2. Content Representations (CoRes) (Adapted from Loughran *et al.* (2001), Loughran *et al.* (2004), and Mulhall *et al.* (2003))

TOPIC: ____________________
School ID:
Teacher ID:
Year Level:

	IMPORTANT SCIENCE IDEAS OR CONCEPTS			
	Big Idea #1	Big Idea #2	Big Idea #3	Big Idea #4
Why it is important/what is your understanding of this idea				
What you intend the students to learn about this idea				
Difficulties/limitations connected with teaching this idea				

Table D.2 Continued:

From the lessons you taught this week, what did you consider as you planned the lessons? ➢ Your students' prior knowledge? If so, how? ➢ Variations in students approach to learning? If so, how? ➢ Students' difficulties with specific concepts?				
Other factors that influence your teaching of this idea				
Teaching procedures and particular reasons for using them				
Specific ways of ascertaining students' understanding or confusion around this idea				

Table D.3. Manifestations of Pedagogical Content Knowledge

PCK component	What it would look like	Adapted from	Notes
Reasons/purposes of selecting and emphasizing particular concepts (What the teacher intends for students to learn about a concept/idea/topic/content; Why it's important for students to know X and Y)	Expression or demonstration of reasons/purposes of selecting and emphasizing a particular concept (e.g., "we need to talk about smog because it is a real problem here in Detroit…" or "we need to talk about smog because it is required in your curriculum…")	Mulhall *et al.* (2003)	This gets at teachers' goals or beliefs for teaching a particular subject/topic and about science in general. Goals and beliefs are believed to influence teachers' use of instructional strategies (e.g., Cronin-Jones, (1991), Mitchener & Anderson (1989) and Olson (1981) all cited in Magnusson *et al.* (1999, p. 111)
Reasons/purposes of selecting and emphasizing particular skills (What the teacher intends for students to learn about a concept/idea/topic/content)	Expression or demonstration of reasons/purposes of selecting and emphasizing a particular skill (e.g., "it is important to learn how to classify because that is part of being a scientist…or because you need this skill if you want to be a biologist…")	Mulhall *et al.* (2003)	This gets at teachers' content/subject matter knowledge, that is, are the skills emphasized appropriate for the content/subject taught? Many studies indicated that PCK is influenced by content/subject matter knowledge (although the reverse is not necessarily true) (Hashweh, 1987; Magnusson et al., 1999; Sanders *et al.*, 1993; D. C. Smith & Neal, 1989; D.C. Smith & Neale, 1991)

Table D.3 Continued:

Knowledge of student learning or understanding and linking it to teaching	Expressed or demonstrated recognition/knowledge of students' prior knowledge and linking it to teaching content Expressed or demonstrated recognition/knowledge of strengths and weaknesses of students and how the teacher used this knowledge to improve students' learning Expressed or demonstrated recognition/knowledge of students' learning styles and how different learning styles are incorporated into the lessons/activities Expressed or demonstrated recognition/knowledge of content areas that are confusing/difficult for students and ways to address it – how did the teacher respond to students' misconceptions or difficulties?	Magnusson *et al.* (1999) Lee *et al.* (2007) Mulhall *et al.* (2003) Wilson (2006) Grossman (1990) Meijer *et al. (1999)*	
Ways used to overcome barriers or constraints in teaching context (Difficulties/limitations connected with teaching an idea/concept/topic/content)	Expressed or demonstrated ways to address challenges/difficulties/barriers in teaching context (e.g., structuring class activity in a particular way because of small classroom, lack of materials, or limited time; changing structure/organization of class due to outside noise or any other type of disturbance; adapting class structure and organization to different needs of students (e.g., ESL students, special education students); administrative support; general school environment or environment within a particular unit of the school)	Lee & Luft (2005) Mulhall *et al.* (2003) Wilson (2006)	

Table D.3 Continued:

Reasons/purposes of using particular approaches, methods, or instructional strategies	Expression or demonstration of reasons/purposes of using particular approaches and/or methods – what does a particular method hope to achieve? (e.g., "delivery of facts-based information is very important for me…I believe students need correct information in order to make decisions, hence my focus is to give them correct information" or "I really think group work as a form of collaborative learning helps students develop social skills and communication skills. About half of my students have difficulty communicating and don't feel very comfortable working with others, so I do a group activity as often as I can.")	Magnusson *et al.* (1999) Lee *et al.* (2007) Mulhall *et al.* (2003) Wilson (2006) Grossman (1990) Meijer *et al.* (1999)	
Reasons/purposes of using particular activities (e.g., problems, demonstrations, simulations, investigations, and experiments)	Expression or demonstration of reasons/purposes of using particular activities – what does an activity hope to achieve? (e.g., "today we are going to watch a video in order to broaden your knowledge about marine invertebrates, which you have learned from our discussion earlier. Then after that you are going to take a video quiz in order for me to assess whether you paid attention or not.")	Magnusson *et al.* (1999)	
Knowledge of curriculum and how it is incorporated into content (How does the teacher make connections among scientific concepts, units, and even other subjects?)	Expressed or demonstrated knowledge of school curriculum and linking it to teaching content (e.g., "in 5th you learned about X…in 6th grade you learned about Y. in 7th grade you need to learn about Z. this is what we're going to focus on in the next two weeks because in order for you to do G, you need to know Z first."	Magnusson *et al.* (1999) Lee *et al.* (2007)	

Table D.3 Continued:

Activities or examples that connected well with students	Activities or examples that got students excited – they were actively involved in the discussion, or performing the activity, or asking sensible questions; they were not drawing on the board or talking to their neighbor, or doodling, or doing anything else besides being engaged	Magnusson *et al.* (1999)	According to Magnusson *et al.* (1999), use of particular examples is part of knowledge of topic-specific strategies.
Community resources used and why	Expression or demonstration of knowledge of community resources, use of, and reasons/purposes for using (e.g., knowledge of nature center in and around the school community, use of it, and reason/purpose for using that particular nature center)	Lee *et al.* (2007)	
School resources used and why	Expression or demonstration of knowledge of school resources, use of, and reasons/purposes for using (e.g., knowledge of compost project in the school, using that project in teaching, and reason/purpose for using that project; knowledge of a school pond, using it in teaching, and reason/purpose for using that pond)	Lee *et al.* (2007)	
Order of subjects/content to teach	Expressed understanding of the importance of carefully choosing/ordering content to teach based on prior knowledge of students, or what they need to know first, second, third, etc.		

Table D.4. Teacher and School Profiles

Teacher	A (County X)	B (County Y)	C (County Z)	D (County Z)
Gender	M	F	M	F
Age at the time of the study (in years)	32	57	59	33
Length of teaching experience at the time of the study	3	23.5	22	8
Majors/ minors	Cell and Developmental Biology/ Biology and Chemistry Education Pursuing an MA in Physical Science Programs for Teachers at the time of the study	Special Education and Early Childhood Education MA in Science for K-8 Teachers	Secondary Physical Education/ History, Social Studies Completed an MA in Science Education	Elementary Education/Math, Science, and French MA completed but major not provided
Grade level	7th, 4 class groups plus one homeroom class and one tutorial class (help with homework)	7th, 4 class groups but also taught one 6th grade class (Reading) at the time of the study	6th, 5 class groups	5th, one class group only
Topics taught during observations and interviews	• Air Pollution • Water Pollution	• Classification of Organisms	• Forces & Motion	• Agents of Erosion • Rocks & Minerals

Table D.4 Continued:

Number of students in the class included in the study	27	28	23	25
Roles/tasks besides teaching	Basketball Coach Track Coach Tutor – help with homework	Recycling Coordinator in the school building Department Chair for Science Department School Improvement Committee Retention Committee Member of Michigan Science Teachers Association Technology Committee District Committee on Strategic Planning	Science Curriculum Committee Member of Michigan Science Teachers Association MEAP Committee Department Chair for Science Department	Data not available

Table D.4 Continued:

School type	Public, non-magnet	Public, non-magnet	Public, non-magnet	Public, non-magnet
School community	Metropolitan rural	Small town	Urban fringe within a mid-size city	Small town
MEECS units trained	None	Ecosystems and Biodiversity Water Quality Air Quality Land Use	Water Quality	Land Use
MEECS units currently used (at the time of data collection)	Not using any at all	Not using this year	Not using this year	Land Use (parts of)
Subjects currently taught (at the time of data collection)	Science	Science Reading	Science	Environmental Science Language Arts/English Mathematics Social Studies/Social Science

APPENDIX E:

CONDING INSTANCES AND INCONSISTENCIES IN TEACHER DATA

Table E.1. Variables of Interest and Number of Instances and Inconsistencies in Coding of Teacher Data

Ins = No. of instances coded; Inc = No. of inconsistencies in coding

Class Observations	**Teacher A**		**Teacher B**		**Teacher C**		**Teacher D**	
Variable of interest	Ins	Inc	Ins	Inc	Ins	Inc	Ins	Inc
1) Goals and beliefs	3	1 (33%)	3	0	11	1 (9%)	3	0
2) Pedagogical approaches	n/a (instead of no. of instances, amount of time an approach was used was calculated)							
3) Instructional methods	472	6 (1.3%)	676	0	173	3 (1.7%)	547	0
4) Skills exposed to students	32	0	80	0	49	1 (2%)	74	2 (2.7%)
5) Representations of PCK	48	1 (2.1%)	49	0	28	0	55	0
6) Action Competence	97	1 (1%)	3	0	0	0	142	3 (2.1%)

Interviews	**Teacher A**		**Teacher B**		**Teacher C**		**Teacher D**	
Variable of interest	Ins	Inc	Ins	Inc	Ins	Inc	Ins	Inc
7) Goals and beliefs	12	0	8	0	30	2 (6.7%)	15	0
8) Pedagogical approaches	63	2 (3.2%)	39	0	60	0	50	0
9) Instructional methods	43	0	68	0	95	0	78	0

Table E.1 Continued:

10)Skills exposed to students	18	0	8	0	66	1 (1.5%)	23	0
11)Representations of PCK	46	0	39	0	40	0	58	1 (1.7%)
12)Action Competence	40	0	19	0	0	0	29	0

Content Representations	**Teacher A**		**Teacher B**		**Teacher C**		**Teacher D**	
Variable of interest	Ins	Inc	Ins	Inc	Ins	Inc	Ins	Inc
13)Goals and beliefs	5	0	3	0	3	0	6	0
14)Pedagogical approaches	6	0	16	0	11	0	63	2 (3.2%)
15)Instructional methods	13	0	16	0	15	0	95	0
16)Skills exposed to students	1	0	4	0	7	0	10	0
17)Representations of PCK	15	0	10	0	5	0	105	2 (1.9%)
18)Action Competence	12	0	0	0	0	0	15	0

Table E.1 Continued:

Survey	Teacher A		Teacher B		Teacher C		Teacher D	
Variable of interest	Ins	Inc	Ins	Inc	Ins	Inc	Ins	Inc
19)Goals and beliefs	4	0	6	0	3	0	1	0
20)Pedagogical approaches	4	0	12	0	6	0	7	0
21)Instructional methods	6	0	13	0	6	0	11	0
22)Skills exposed to students	0	0	3	0	0	0	1	0
23)Representations of PCK	0	0	0	0	0	0	2	0
24)Action Competence	0	0	4	0	0	0	0	0