AN EXPLORATORY STUDY OF THE IMPACT OF TWO VERSIONS OF
INQUIRY-BASED SCIENCE PROGRAM PROFESSIONAL DEVELOPMENT
ON TEACHERS' PERCEPTIONS OF THEIR PEDAGOGICAL
CONTENT KNOWLEDGE

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# TABLE OF CONTENTS

Abstract .............................................................................................................. vii

List of Tables ...................................................................................................... viii

List of Figures ..................................................................................................... ix

List of Abbreviations .......................................................................................... x

Chapter 1: Conceptualization of the Research Problem ..................................... 1

  Professional Development ............................................................................... 3
  Purpose of the Study ......................................................................................... 5
  Conceptual Framework ...................................................................................... 6
  Importance of the Study ................................................................................... 8
  Research Questions ........................................................................................... 9
  Definitions and Terms ...................................................................................... 10

Chapter 2: Literature Review ............................................................................. 12

  Professional Development .............................................................................. 12
  Need for Well-designed Professional Development ...................................... 13
  Characteristics of Effective Professional Development ............................. 14
  Models of Professional Development ............................................................ 17
  Assessment of Professional Development ..................................................... 20
  Conditions of Impact ....................................................................................... 22
  Summary of Professional Development Review and Implications ............... 24
  The Evolution of Pedagogical Knowledge and Content Knowledge ............. 24
  Schulman’s Paradigm ....................................................................................... 25
The Final Science Classroom Instructional Survey .......................... 64
Conducting the Two Different Delivery Approaches ...................... 65
Administration of Pretest and Posttest Surveys ............................ 65
Data Analyses ........................................................................... 66
Factor Analysis .......................................................................... 66
Descriptive Statistics ................................................................. 67
Examining Changes in Individual Scores Over Time ....................... 67
Examining Posttest Means Between Groups .................................. 67
Limitations of the Study ............................................................. 67
Chapter 4: Results .................................................................... 69
Descriptive Results of Pretest ..................................................... 69
Results of Posttest ...................................................................... 72
Within Group Comparison of the Changes in PCK By Construct ......... 74
Comparison of Posttest Means of Two Treatment Groups ............... 76
Discussion of Results ................................................................. 77
Evaluation of Model .................................................................... 79
Chapter 5: Conclusions, Recommendations, and Implications .......... 82
Analysis of Constructs and Instrument .......................................... 82
Alignment of PCK Constructs and FAST PD ................................. 84
The Research Question ............................................................... 88
Implications ............................................................................... 89
Suggested Further Study ............................................................. 90
References ............................................................................... 91
Appendices. .................................................................101

Appendix A: Schedule of 5-day institute. ..............................102

Appendix B: Schedule of 10-day institute. ..............................103

Appendix C: The Science Classroom Instructional Survey. ..........104
Abstract

This study compares two models of professional development (PD) for middle-school science teachers and the effect upon their self-reported Pedagogical Content Knowledge. The first model consisted of five days in laboratory, multi-media support and an on-line class. The second model consisted of ten days in the laboratory and telephone follow-up support. This study reviews the roots of research of Pedagogical Content Knowledge and existing models. For the purpose of the evaluation of the professional development, a new model was developed. The new transactional model is based upon nine underlying constructs. A survey instrument was developed and piloted on 51 teachers experienced with the content and methods taught in the professional development institutes. The instrument was revised to 43 items and given as a pretest and a posttest to 37 teachers participating in the institutes. In the shorter, enhanced version of the PD (Treatment 1) there were 20 participants, and in the original longer version of PD (Treatment 2), there were 16 participants. The pretest was administered the first day of the institutes and the posttest one semester later. Analysis of the data was done by the use of multiple-group structural equation modeling. By comparing the factors with this method, there was adjustment for errors in each item. Analysis suggests no difference in effect between treatment groups. There was significant difference (p < 0.10) between pretest and posttest means on two constructs for treatment group. Further study for the refinement and expansion of instrument and the editing of the professional development scheduled topics are suggested.
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Internal consistency of 6 factors defining PCK.</td>
<td>64</td>
</tr>
<tr>
<td>4.1</td>
<td>Pretest Means.</td>
<td>70</td>
</tr>
<tr>
<td>4.2</td>
<td>Posttest Means.</td>
<td>72</td>
</tr>
<tr>
<td>4.3</td>
<td>Comparison of Pretest Means of Two Treatments Controlling for Pretest</td>
<td>75</td>
</tr>
<tr>
<td>4.4</td>
<td>Within-Group Comparisons of the Changes in PCK by Construct</td>
<td>77</td>
</tr>
</tbody>
</table>
FIGURES

Figures page
1. The Integrative Model showing the Intersection of Subject Matter, Pedagogical and Contextual Knowledge. ....................................................... 33
2. The Transformative Model showing the amalgam of Subject Matter, Pedagogical and Contextual Knowledge. ........................................... 35
3. Side View of Hierarchical Model showing the foundations of PCK as Content Knowledge and Knowledge of Students. .............................. 37
4. The Research Design of this Study. ...................................................... 53
5. The Transactional Model showing Nine Constructs of PCK. ................ 59
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAAS</td>
<td>American Association for the Advancement Science</td>
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<tr>
<td>CLES</td>
<td>Constructivist Learning Environment Survey</td>
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<td>CoRe</td>
<td>Content Representations</td>
</tr>
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<td>CRDG</td>
<td>Curriculum Research &amp; Development Group</td>
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<td>CTOI</td>
<td>Constructivist Teacher Observation Instrument</td>
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<tr>
<td>ECIA</td>
<td>Education Consolidation and Improvement Act</td>
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<tr>
<td>ENC</td>
<td>Eisenhower National Clearinghouse</td>
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<tr>
<td>FAST</td>
<td>Foundational Approaches in Science Teaching</td>
</tr>
<tr>
<td>LIFE</td>
<td>Project Laboratory Investigations and Field Experiences</td>
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<tr>
<td>NCEE</td>
<td>National Committee on Excellence in Education</td>
</tr>
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<td>NRC</td>
<td>National Research Council</td>
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<td>PaP-eRs</td>
<td>Pedagogical and Professional-experience Repertoires</td>
</tr>
<tr>
<td>PCK</td>
<td>Pedagogical Content Knowledge</td>
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<tr>
<td>PD</td>
<td>Professional Development</td>
</tr>
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<td>SCIS:</td>
<td>Science Classroom Instructional Survey</td>
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<td>ScUP</td>
<td>Scaling Up Project</td>
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<td>SEM</td>
<td>Structural Equation Modeling</td>
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<td>SPSS</td>
<td>Statistical Package for the Social Sciences</td>
</tr>
<tr>
<td>STOI</td>
<td>Science Teacher Observation Instrument</td>
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<tr>
<td>TPPI</td>
<td>Teachers Pedagogical Preference Inventory</td>
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</tbody>
</table>
CHAPTER I

CONCEPTUALIZATION OF THE RESEARCH PROBLEM

The goal of improving public education in the United States has represented a continuing challenge for policymakers and educators since its beginnings (Tyack & Cuban, 1995). A call for improved science and math education in the United States was evident following the Soviet launch of Sputnik in 1957 (DeBoer, 2000; Freyd, 1964; Hurd, 1958; Raizen, 1997; F. J. Rutherford, 1997). This call for program development was quickly answered. Between 1956 and 1974 over 200 new math and science curriculum programs were developed (Lockard, 1975). New curricular programs sought to upgrade both the content taught to students as well as to introduce a more active, discovery-oriented approach to teaching.

In the 1950s and 1960s, curricular innovation followed a rational theoretical model where proposed programs began with a research and development phase, then a dissemination phase and, finally, a local utilization (Firestone & Corbett, 1988). This type of simplified model, however, underestimated the difficulty of implementing changes at the local level. In many cases, for example, minimal time was spent on explaining the theories underlying their development, and teachers were provided a limited amount of time to listen to presentations about what they should do in their classrooms. With this minimal instruction, teachers returned to the classrooms to begin to implement the new curricula.

During the 1970s, quantitative research began to document the challenge of implementing programs in the same way across different sites, and ethnographic studies emphasized local conditions that enhanced or inhibited change (Firestone &
Corbett, 1988; Fullan, 1987; Sarason, 1971). Researchers and evaluators considered explanations such as faulty program theory, lack of fidelity of implementation, failure to consider teachers' existing knowledge, attitudes and beliefs, and failure to consider the culture of the classroom. Other explanations included failure to convince teachers to “buy into” the program and failure to provide administrative support on the school level. Also, the culture of the school may have been incongruent with the change (Firestone & Corbett, 1988; Vesilind, 1998). Regardless of the cause or causes, numerous failed implementations were documented (DeBoer, 2000; Gross, Giacquinta, & Bernstein, 1971; Sarason, 1971; van Driel, Beijaard, & Verloop, 2001).

The curriculum experimentation of the 1960s and 1970s gave way to a concern with improving the quality of educational outcomes during the 1980s. The release of *A Nation at Risk* in 1984 with its indictment of the failure of American public schools compared with other developed nations, particularly in mathematics and science education, focused national attention on the topic (National Commission on Excellence in Education, 1984). For science education, more specifically, the press for reform during the decade resulted in the publication of *Science for All Americans* (American Association for the Advancement of Science, 1989). This publication preceded other documents such as the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1989) and *Blueprints for Reform* (American Association for the Advancement of Science, 1998). These publications sought to upgrade standards for science education by guiding educators in developing their own curricula and programs. The benchmarks specify how students should progress toward science literacy, recommending what they should know and what
they should be able to do by the time they reach specified grade levels (American Association for the Advancement of Science, 1993).

Demands for educational improvement in the nation grew even stronger during the 1990s. In 1989, President Bush endorsed a vision of stronger educational standards in the Educate America 2000 Act. In 2001, the introduction of No Child Left Behind (NCLB) emphasized the expanded federal involvement in ensuring student learning in the classroom, upgrading professional standards, and strengthening school accountability. In particular, NCLB drew attention to the considerable numbers of teachers who were inadequately prepared to teach science and math in the classroom. Similarly, the publication of the National Science Education Standards (NSES) (National Research Council, 1996) delineated not only what should be taught, but also standards for teaching, assessment, professional development programs and systems. The resulting teaching standards highlighted how science should connect with mathematics and emphasized understanding though inquiry. The NSES also specified that students should have equitable access to resources in a safe, supportive school environment. The NSES emphasized schools must support science reform, establish participatory decision-making structures about school needs, and provide teachers with time to discuss science education reform strategies.

Professional Development

One response to demands for improved student learning is to increase attention on the preparation of new teachers and the professional development of
experienced teachers. Not only must teachers have the necessary skills to teach in the classroom, but also they must have adequate preparation in science content knowledge. The number of teachers teaching out of field (Tobin, Tippins & Gallard, 1994) and lack the requisite content knowledge contribute to the difficulty of this task. Fenstermacher and Berliner (1983) define professional development as, “the provision of activities designed to advance the knowledge, skill and understanding of teachers in ways that lead to changes in their thinking and classroom behavior” (p. 4). Loucks-Horsley (1998) emphasizes that professional development for teachers must ultimately “... improve their effectiveness in their classrooms and organizations” (p. xiv).

Professional development is a primary means for changing teaching behavior in the classroom, but research over several decades has highlighted the difficulties in designing, implementing, and evaluating professional development for teachers. In one early study, Gross, Giacquinta and Bernstein (1971) describe several reasons for teachers’ failure to implement innovations. These include a lack of clarity of the desired new behavior or role, a lack of the necessary skills and knowledge to carry out the proposed change, insufficient support materials and equipment to facilitate implementation, and rigid organization procedures and existing policies which are incongruent with the planned changes. Similarly, Young and Odell (1991) note that successful professional development programs should (a) address the necessary training of the teachers in the skills and knowledge to bring about the change, (b) the identification of key local leaders and opinion setters in the school community that can facilitate desired changes, (c) the need for clarity in adapting the proposed change
to the local school setting, (d) the need to focus changes not only on the school as a whole, but also on how the individual teachers perform in the classroom, and to (e) emphasize actual changes in behavior as opposed to relying solely on participants’ reported changes.

These examples of previous research emphasize the need for professional development programs to adapt to characteristics and needs of teachers, their curriculum and classroom teaching expertise, and their local site contexts (e.g., administrative support, resources for professional development). As Fullan (1993) concluded, however, despite the fact that it has long been recognized that grounded knowledge and expertise are key factors in successful change efforts, surprisingly little focus has been aimed at understanding and improving efforts beyond short staff development sessions and isolated training away from the school site. The challenge, therefore, within a context of increased demands for teacher improved effectiveness in the classroom and typically limited resources allocated for staff development, is to determine whether short-term professional development activities can be packaged in alternative ways that result in increased professional knowledge and classroom skills.

Purpose of Study

The purpose of this exploratory study is to examine whether the length of time teachers are involved in a packaged professional development program for science teachers makes a difference in their perceptions about their acquisition of specific pedagogical knowledge and skills. The study also attempts to describe teachers’ perceptions of their professional development over the long term, examining their
self-reported ratings of their teaching on an instrument administered one semester after the implementation of the professional development program. More specifically, the study contrasts an established two-week professional development institute (i.e., 10-day, 65 contact hours) with a shortened one-week institute. The longer professional development institute includes electronic mail support from a program specialist for the teachers implementing the program (Brandon et al., 2007). The shortened one-week institute includes a redesign of the “face-to-face” institute, support materials (i.e., DVD-ROM), and an online course.

A primary reason for the development of a shorter institute was to provide the opportunity for increased participation in the professional program, as the traditional two-week institute had become less accessible to many busy educators during the summer. It was based on the belief that the shorter contact time would be easier to schedule and implement as increased pressure on teacher time and shortened summer vacation periods had diminished many teachers' ability or willingness to engage in professional development. Evidence of the efficacy of the longer program in changing teacher classroom behavior has been established through previous research (Brandon et al., 2007; Supovitz & Turner, 2000). A remaining need, however, is to establish whether the shortened institute provides similar benefits in terms of improving teachers' perceptions of their professional practice.

**Conceptual Framework**

In the dissemination and professional development phase of a new proposed science program, much attention is typically given to the presentation of content
knowledge to teachers, often referred to as “subject matter knowledge.” It is often assumed that practicing teachers have at least some and, hopefully, high levels of this type of knowledge. In recent years, researchers and policymakers have raised questions about districts’ policy of employing teachers in subject areas outside of their preparation and certification. Most importantly, these types of teachers lack adequate content knowledge (Tobin, Tippins and Gallard, 1994). Elementary teachers may also be deficient in content knowledge required for certain subjects (primarily science or math), as their degree requirements frequently emphasize Language Arts or Social Studies rather than science. Because of this, professional development programs must include necessary content knowledge and provide sufficient time for teachers to assimilate this knowledge into their classroom teaching practices.

A second knowledge underlying the development and implementation of a professional development program for science teachers is pedagogical content knowledge (PCK). In contrast to the more general concept of science content knowledge, Hashweh (1987), for example, differentiates pedagogical content knowledge as “more than a knowledge of the concepts, principles and topics in a discipline — it includes knowledge of how to teach particular topic” (p. 2). Moreover, Mason (1988) reported that beginning teachers who were assessed and found to have adequate content knowledge in their subject areas were frequently unable to apply this content information in their teaching situations. He concluded that there is a need to instruct teachers how to merge the information about pedagogy covered in teachers’ preparatory education courses with their specific content areas.
The literature on PCK suggests a set of knowledge, skills, and attitudes teachers need to be effective in the classroom. These are often grouped into three clusters: knowledge of content, knowledge of pedagogy, and knowledge of the student learning context (Gess-Newsome & Lederman, 1999; Veal & McKinnester, 1999). Within science, more specifically, one conceptual framework includes knowledge of science, knowledge of inquiry, knowledge of curriculum materials, making connections to the real world, assessment of learning, goal setting and planning, the teacher as facilitator, cooperative and collaborative learning strategies, student discussion, and questioning strategies (Veal & McKinster, 1999).

Because previous research suggests the more effective teachers exhibit this knowledge (Hassard, 2005), teachers' increased use of PCK should be one important component in assessing the effectiveness of professional development programs. It follows that a strong professional development program should make a positive impact on levels of teachers' PCK. The construct of PCK is used in this study as an important basis for modeling the behaviors of effective teaching (Cochran, 1992; P. L. Grossman, Wilson, & Shulman, 1989; Shulman, 1986).

**Importance of the Study**

Globalization, the movement of the United States from a production-based to an information-based economy, and increased competition from developing nations all underscore the importance of American students being well-prepared and competitive in science. Furthermore, professional development is a resource-intensive endeavor and in education, there is increasing competition for scarce resources, both
in time and money. In the current era of mounting accountability, schools and school districts are under scrutiny to justify expenditures, both in terms of teacher productivity and student growth. Therefore, it is critical that administrators, school board members, and policy makers have reliable, research-based information upon which to base their allocation of resources. This specific study, therefore, was prompted by a need to gain a clearer understanding of how the delivery of professional development experiences for science teachers may affect their perceptions of their evolving professional knowledge and competence. If the same level of teacher perceptions about their utilization of the professional development experiences investigated in this study is confirmed in the shorter delivery model as in the more lengthy delivery, a cost-effective advantage may be realized.

**Research Questions**

The study addresses two research questions. First, is there a change in the teachers’ perceived pedagogical content knowledge after participation in the profession development? Compared with their pretest scores, participants should experience an increase in their pedagogical content knowledge after participating in the professional development program. Second, is there a difference related to the length of delivery of the professional development program on teachers’ perceptions of their pedagogical content knowledge? It is expected that each approach should be effective; that is, no difference in the post-test scores of participants in either delivery approach is expected.
The comparison of delivery approaches on participants' pedagogical content knowledge represents an attempt to expand the scope of past studies on teacher professional development in several ways. First, the study defines and examines a multivariate model of pedagogical content knowledge using longitudinal data collected on several different participant cohorts. This approach should provide more accurate estimation of possible differences in participants' perceptions of pedagogical content knowledge than studies that use a single scale or studies of professional development that are conducted at only one point in time. Second, the study considers possible changes due to professional development delivery on a wider range of participant outcomes. Third, by considering differences in methods of delivery, the study may provide a glimpse of how limited school resources can be used to support efforts to improve teacher knowledge and performance in the classroom.

Definition of Terms

Professional Development. In this study the term refers to the provision of activities designed to advance the knowledge, skill and understanding of teachers in ways that lead to changes in their thinking and classroom behavior (Fenstermacher & Berliner, 1983).

Content Knowledge. In this study this term refers to a teacher's specific substantive knowledge of a content area. This is what may be learned in classes of the teacher's major, such as biology, physics or other science classes.
Pedagogical Knowledge. In this study, this term refers to a teacher’s knowledge of instructional strategies, conceptual models, or activities that may be used in the classroom.

Scaling Up. This term is used to describe the dissemination of a program that has shown effectiveness in a smaller venue, such as a school or district, that developers wish to expand to a wider area. The process of preparing for and enacting this expansion is called scaling up. It may include professional development, dissemination, and evaluation procedures.

Self-efficacy. In the context of teacher professional development, it is the teachers’ beliefs that they have the ability to control the motivation of their students, are able to create productive learning environments, promote learning and academic progress.
CHAPTER II
LITERATURE REVIEW

The following review of the literature is separated into two sections. The first section examines studies of professional development including definitions, the need for professional development, defining effective professional development, and the design of professional development. The second section is about pedagogical content knowledge (PCK) and use of it as a paradigm to improve teaching.

Professional Development

Indeed research suggests that the role of professional development, in the light of the national education standards movement and increased number of state initiatives, needs to be more focused and aligned (Guskey & Huberman, 1995; Shaha, Lewis, O'Donnell, & Brown, 2004). "Effective professional development is considered the center of educational reform (Lowden, 2005)." Professional development must address not only what teachers are expected to do, but it must also provide them with knowledge and strategies to implement these techniques in their classrooms. Teachers must be given the guidance to enable them to change their thinking as well as their behavior with the classroom. In discussing the role of professional development Loucks-Horsley stated:

Recognition of what our classrooms should look like and what our students should be able to do does not automatically translate into changes in the classroom or with our students. This is due, in part, to a lack of information. However, knowing what needs to be done does not mean knowing how to do
it. This is where the critical role of professional development comes in...

Unless teachers are being able to practice new ways of learning, teaching and leading, this reform will fall short of its potential (Rhoten & Bowers, 2001 p. i).

Fenstermacher and Berliner (1983) define professional development as, “The provision of activities designed to advance the knowledge, skills, and understanding of teachers in ways that lead to changes in their thinking and classroom behavior.” (p. 4)

Need for well-designed professional development

Fullan (1993) cites the need for well-designed and implemented professional development. Teachers exposed to poorly designed and clumsily implemented programs reject them and may express contempt. A systematic approach to both school and system related professional development leads to acceptance of new ideas and approaches. Effective professional development is fundamental to change.

Fenstermacher and Berliner (1983) note that professional growth in teachers is needed, “As criticism of public schooling increases in scope, and as standardized tests lay bare the apparent shortfall in expectations for schools, thoughts turn to what is wrong.” (p. 1) Fullan (1993) states that even though it is well accepted that teacher skill and knowledge are essential, “it is surprising how little attention we pay to it beyond one-shot workshops and disconnected training.” (p. 16)

Effective professional development is viewed as the center of educational reform and is critical for teacher growth and student achievement (Lowden, 2005). In the current
era of national reform, and the new millennium, evidence that programs make a real
difference is imperative (Shaha et al., 2004). Considering the cost of professional
development, there is a definite need to consider what teachers actually learn in
professional development (Lamb & Tschillard, 2005).

Characteristics of effective professional development

Guskey (2003) studied the characteristics of effective professional
development. He conducted a meta-analysis in which he reviewed 13 studies of
professional development from U. S. Department of Education, national education
associations, teacher associations and researchers. From these studies he gleaned a
total of 21 characteristics of professional development. The top characteristics as
determined by frequency of inclusion were not always consistent across the studies,
thus a rank ordering of characteristics was done. The characteristics he identified
were as follows:

(a) The program enhances teachers’ content and pedagogic knowledge by helping
teachers understand the content they teach more deeply and the ways that students
learn.

(b) Effective programs provide sufficient time and other resources that enable
teachers to have a deeper understanding of the program, analyze student work, and to
develop new instructional approaches. (Even though most of the reports reported this
as a positive characteristic, two reports stated that it had no influence or a negative
influence on the effectiveness of the program.)
(c) The program promotes collegiality and collaboration among the teachers and provides the opportunity to work together, reflect on practices and build sense of community.

(d) The program includes procedures for program evaluation.

(e) The program aligns with other reform initiatives and is not a stand-alone presentation.

(f) The program models high quality instruction. The presenters are experienced and professional.

Guskey also stated in his analysis that most of the successful studies were school or site-based. However, he cites one study that found that teachers might not see value in school-based programs not grounded in the research of larger district or state programs. Guskey also reports that there seems to be balance needed between programs developed from research and the school-based programs that takes into consideration the specific needs and local perspectives. The analysis also contends that successful programs build leadership capacity within the organization and develop strong instructional leaders at the school level. They also respond to the specific needs of the teachers, although teachers frequently are unable to identify these needs.

In his attempt to glean the characteristics of effective professional development, Guskey (2003) raised this issue about assessment of professional development:

First, there appears to be little agreement among professional development researchers or practitioners regarding the criteria for "effectiveness" in
professional development. Some define it in terms of teachers' self-reports of professional development features that influence increases in their knowledge and changes in their instructional practices. Others look for consensus in the opinions of professional development writers and researchers. While lists of the characteristics of effective professional development based on such diverse criteria are valuable, they provide only a starting point in efforts to improve the quality of professional development programs and activities. (p. 8)

Also about successful professional development, Gess-Newsome wrote, "The characteristics outlined below are among those that appear consistently in the literature and positively impact teachers' professional development efforts" (Gess-Newsome, 2001 p. 94). She presented six characteristics:

(a) The program includes sustained support that follows the teacher back to the classroom. This support should provide assistance to teachers as they confront personal changes and offer contact with others who support the change.

(b) The professional development must also fit the personal needs of the individual teacher whether they are early in their career, in their midyears or late in their careers.

(c) The professional development is connected to classroom practice and directly linked to student learning.

(d) The professional development challenges pedagogic beliefs and practices. Programs that effectively model appropriate teacher behavior and are effective in changing teachers' classroom behavior, will lead to change in beliefs.
(e) Effective programs promote incremental change within which teacher can make changes in their teaching without totally abandoning the instructional strategies that give them security. The instructional strategies, with which teachers have had success, need not be thrown out with the bathwater.

(f) Although classroom teaching is a solitary activity, teachers need a venue in which to collaborate and seek support for program change.

Gess-Newsome (2001) also stated, “Professional development programs that are clearly connected to the classroom, model appropriate classroom teaching practices, and result in significant increase in student learning will clearly be more effective than those that do not” (p. 95).

Guskey and Gess-Newsome agree that professional development should include the modeling of expected teacher behavior. This exemplar serves as a template and is to be emulated by the participants within their own classrooms. Teachers assimilate this ideal pedagogical model into their own instructional strategies.

Models of Professional Development

Firestone and Corbett (1988) call the dissemination of knowledge-based programs a policy tool for organizational change. They suggest that such programs are effective when they provide the knowledge required for change and teachers are willing to make such changes. Programs must, however, also meet the requirements of being necessary, practical, and possessing clarity. The authors claim that
professional development models that support these requirements would be more successful than those that do not.

Mason (1988) studied beginning and prospective science teachers and found little relationship between their understanding of science and their ability to communicate this knowledge to their students. Mason (1988) concluded that there is a need to show teachers how to merge content knowledge with effective teaching strategies.

There is substantial literature to suggest that if professional development is to improve student achievement, it must impact the beliefs of teachers. The focus of professional development is the expansion and elaboration of teachers' knowledge and beliefs (Borko & Putnam, 1995; Gross et al., 1971; Loucks-Horsley et al., 1998). Guskey and Huberman (1995) state that if professional development is going to improve teaching, it must approach the common features that seem to be associated with successful principles of teaching, learning, and learning to teach derived from cognitive psychological research. As to the change in beliefs, Fullan (1993) proposes that the actual behavior of teachers in the classroom can be changed. Once the change shows evidence of success in the classroom, the teachers then make changes in attitudes and beliefs to accommodate the change.

In summary, the growing importance of professional development underscores the need to design and implement the best means for using the available time, fiscal, and material resources to achieve the greatest impact. The various literature (Gess-Newsome, 2001; Guskey, 2003; Guskey & Huberman, 1995; Loucks-Horsley et al., 1998) suggests the following characteristics of successful programs:
(a) Long-term design plans rather than “quick-fix” solutions. Any program designed for less than three years is myopic or short sighted.

(b) Teachers must understand the need for program prior to inception. Early acceptance of and commitment to the program is essential. Involving teachers in the planning is of deep importance. This is introduction at the teacher level.

(c) Administrative support and consistency of expectations are needed to keep the program progressing.

(d) Although it may be one of many types, it must have clear focus and design. Programs may promote immersion into inquiry, or immersion into the science itself. They may be designed around curriculum replacement or adaptation. They may replace or modify an instructional strategy or delivery of the program. Still another type of development is based on group work doing case studies, study groups or networking. A more use of “curriculum mapping” is as an approach to professional development. Whichever of the designs is selected, the design must match with the perceived need.

(e) They have congruence with the school’s culture. Some teachers may not be comfortable with study groups whereas others may prefer this approach. There is not a single approach that is most effective for all.

(f) Review and validation are critical. This part is often ignored. Once a program is implemented, there is a tendency to consider the task done. If it is to remain viable, continuous refreshing and reviewing are needed.
Assessment of Professional Development

The measurement of the impact of professional development has taken different approaches. The Laboratory Investigations and Field Experiences (LIFE) project conducted a three-year assessment of the impact of the implementation of a state initiative driven professional development reform (Radford, 1998). The study measured the content knowledge, process skills and attitude toward science teaching of 90 teachers. The PD included a three-week summer course, independent science research projects, classroom follow-up of the teachers’ process skills, attitudes toward science and classroom teaching behaviors. It also included instruction in cooperative learning models and problem-centered learning. The learning model employed in the study was based upon the three-step model of exploration, concept development and concept application (Karplus & Thier, 1967). The assessments used for data collection included attitude surveys, journals, learning logs, written tests and on-site observations.

The results indicated a significant impact ($p > .01$) upon the students' science attitudes and process skills as compared with a control group of students. Teachers who participated in the professional development scored higher on science content, process skills and science attitude than the teachers who did not. The positive results of the project led Radford to suggest a model of professional development for life-science teachers having the following characteristics:
(a) The science content, the process skills and the teaching methodologies are closely integrated and are team taught by scientists in the field, a science educator and a science teacher.

(b) The instruction in the institute models the reform methodologies that include an inquiry-based and student-centered approach.

(c) Participants provide daily feedback through journals and learning logs which leads to improved communication among participants and researchers.

(d) Cooperative learning groups are used with participants.

(e) Participants conduct long-term investigative activities to further their understanding of the scientific process.

(f) Alternative types of assessments are included in the institute.

(g) The staff of the institute models the assessment and adapts instruction to adjust for students' prior knowledge.

(h) The participants are immersed in the role of being a scientist and writing about science.

(i) Teachers are given time for reflection with activities such as reunion workshops, journals, and planning sessions.

(j) Program materials are inexpensive and accommodate schools' small budgets.

(k) Funds are provided for teacher for supplies and materials.

(l) Long term follow up activities are included, such as, newsletters, visits, and the development of local leadership teams.
Conditions of Impact

Other research of the effectiveness of professional development for science teachers found similar results even though it looked at different characteristics of impact. Supovitz and Turner (2000) used data from the National Science Foundation Teacher Enhancement Program called the Local Systemic Change Initiative. They used a self-report survey to measure the impact of professional development on 3464 teachers and cross-linked this with responses from 666 principals. The teachers in this study did not participate in a single professional development program, as did those in the Radford (1998) study. Rather, they received professional development as part of different projects within the initiative. The amount of professional development, measured in hours, ranged from zero to more than 160 hours. The results of the survey were analyzed using hierarchical linear modeling. The study examined the relationship between the professional development programs and the developers' vision of teaching practice. A strong relationship was found between the amount and quality of professional development, the culture of inquiry-based teaching and an investigative classroom culture. They also found that teachers with greater preparation in content knowledge had a positive impact on the teaching and the support of the principal had less of an impact than the socioeconomic status of the students. The results indicated a strong link between high quality professional development and the teaching strategies and activities advocated by science curriculum reformers such as AAAS and NRC. It also found that teachers with
positive attitudes toward the reform demonstrated higher measures of inquiry-based practice and an investigative culture in their classrooms (Supovitz & Turner, 2000).

There has been conflicting results on the relationship of duration and good effects of PD. Garet et al. (2001) reported that if the PD is sustained over time, is of higher quality, and was of a substantial number of hours, it has a substantial positive effect upon the coherence of the PD and upon the opportunities for learning. It also had a moderate effect upon the emphasis on content knowledge. However, Desimone, Porter, Garet, Yoon, and Birman (2002) in a longitudinal study, found no effect of the number of PD hours upon the use of higher order teaching practices, use of alternative assessment practices, and use of technology.

Loucks-Horsley, in her work with the Eisenhower National Clearing House (ENC) and the National Institute for Science Education’s Professional Development Project, delineated strategies for effective professional development (Loucks-Horsley, Hewson, Love & Stiles, 1998). The project strongly recommends a strategy for professional development in science is immersion into science. It is an intensive experience in which the teachers must make meaning of the activities by actually collecting and organizing data, defending explanations and dealing with skepticism. When they return to their classrooms they implement the science program as an experienced learner.

First by becoming a learner of the content, the teachers broaden their understanding and knowledge of the content they are addressing with the students. Second, by learning through inquiry — putting the principles of inquiry-based science or mathematics teaching and learning into practice and
experiencing the process for themselves — teachers are better prepared to implement the practices in their classrooms. (p. 49)

The teachers immersed in this type of professional development approach gain content information and are exposed to an instructional model that may be new to them. An approach of this kind may call for a restructuring of their cognition about instructional strategies thus, promoting change in way teachers work with students in their classrooms (Tillema, 1995).

**Summary of Professional Development Review and Implications**

The literature makes clear the importance of well designed and well implemented professional development as the center of the improvement of our education system. Programs designed around one of the established models, such as immersion in science, have a better chance of success in changing teachers' attitudes, beliefs, behavior in the classroom and improving student learning. Also, a program that provides teachers with the content knowledge, pedagogical strategies and affect the attitudes of the teachers will be conducive to improvement.

**The Evolution of Pedagogical and Content Knowledge**

Shulman (1986) suggested that if we were to take a historic look at the assessment of teachers' knowledge, the teacher board exams of the 1800s would probably be a good place to start. These exams were prepared by the boards of education of progressive states and attempted to measure the fitness of a person to teach. The teacher was expected have the knowledge of basic mathematics, american
history, civics, physical anatomy, geography and correct grammar usage and the like. The earliest assumptions were that if you had comprehension of the content, you could teach the content. However, school boards began to realize that normal schools had to be created to develop teachers' pedagogical skills along with content knowledge. And, this knowledge should be able to be measurable.

Shulman refers to early teacher exams where teachers were asked to tell how they would approach the instruction of spelling and how they would motivate students to learn. The validity of these exams was probably never established, yet the fact that they were created demonstrates that educators and policymakers believed that teacher preparation should focus not only in the content of the subject matter but in pedagogical skills as well.

**Shulman's Paradigm**

Given the assumption of the two types of knowledge, that of the knowledge of the subject matter and that of the knowledge of general pedagogical skills and techniques, Shulman (1986) proposed that there might be a third type of knowledge, knowledge specific to the subject matter to be taught. He proposed a type of knowledge, different from, yet intertwined with the other two. It does not denigrate content knowledge, or the need for general pedagogical knowledge. It is synthesized from the two with the addition of an understanding of what makes learning of specific topics easy or difficult.

At the root of this concept was Shulman's research with the Knowledge Growth and Teaching Project at Stanford University. In this research, Shulman and
his colleagues studied college students in their transition from expert students to novice teachers (Brandt, Shulman, & Colbert, 1988). In depth interviews and analysis of the performance of a cadre of student teachers provided the foundation for this theoretical framework.

Shulman (1986) proposed that pedagogical content knowledge (PCK) consists of the most powerful analogies, illustrations, and examples that represent or make the subject comprehensible to the student. This collection is generally built upon experience and may come from research in the field of study or from the wisdom of practice. It is also built upon the knowledge of the conceptions and frequent misconceptions of learners. A teacher with PCK understands the learner’s preconceptions, knowing that students are without prior knowledge. The teacher is able to assess the students’ preconceptions to determine which of them are misconceptions, and create learning situations and opportunities to help students analyze, synthesize, and ultimately to overcome any misconceptions. Although it was not necessarily Shulman’s intent at the time, this new term he coined, pedagogical content knowledge, initiated and propagated many studies, especially in science education.

Gundmundsdottir (1987) building upon Shulman’s work, added that PCK "is what makes science teachers rather than scientists" (in Cochran 1992 p. 4). To be effective, teachers must organize their knowledge for the purpose of teaching, not as it may be organized for conducting research in the content area.

With respect to teachers’ knowledge, Wilson, Shulman and Richert (1987) quoted a biology teacher who reflected on the knowledge needed for teaching. “When
you learn it to teach, you have to be able to handle ... 150 different approaches to it because you have to handle every different student’s approach." (p. 104) It is this ability to approach the subject matter from different perspectives that enables a teacher to convey the subject to most of their students. Wilson (Wilson et al., 1987) argued that a set of generic pedagogic principles along with content knowledge is not sufficient for effective teaching. What is needed, they suggested, is pedagogical content knowledge.

The definition of PCK has evolved as different researchers have placed their slant on this term. This consistency of definitions is illustrated in a publication of the American Association of Colleges for Teacher Education.

The ability to transform subject matter knowledge requires more than knowledge of the substance and syntax of one’s discipline; it requires knowledge of learners and learning, of curriculum and context, of aims and objectives, of pedagogy. It also requires a subject-specific knowledge of pedagogy. By drawing on a number of different types of knowledge and skills, teachers translate their knowledge of subject matter into instructional representations (Grossman et al., 1989, p. 32).

Cochran (1992) echoed the definition by saying, “Pedagogical content knowledge is a type of knowledge that is unique to teachers, and is based on the manner in which teachers relate their pedagogical knowledge (what they know about teaching) to their subject matter knowledge (what they know about what they teach)” (p. 4).
In reference to PCK, van Driel, Beijjard and Verloop (2001) wrote, “it is developed through an integrative process rooted in classroom practice implying that prospective or beginning teachers usually have little or no PCK at their disposal” (p 143). These researchers coined another term from the study of teachers, calling it “practical knowledge.” The features of practical knowledge were defined as being:
(a) action oriented knowledge acquired without the help of others, (b) personal and context bound, (c) for the most part implicit or tacit knowledge, (d) integrated with norms, values and experiential knowledge, (e) and that teachers’ beliefs play an important role in its development. There is some overlap with the previous definitions of PCK. Both PCK and "practical knowledge" are content bound are intertwined with experience. The teachers’ instructional strategies incorporate the specific subject matter in different ways across the different content areas. A difference may be the statement that "practical knowledge" is acquired without the help of others.

Recently, Loughran, Berry and Mulhall (2006) defined PCK as being:
“..rooted in the belief that teaching requires considerably more than delivering the subject content knowledge to students, and that the student learning is considerably more than the absorbing information for later accurate regurgitation, ...PCK is the knowledge that teachers develop over time, through experience, about how to teach particular content in particular ways in order to lead to enhanced student learning... PCK is not a single entity that is the same for all teachers of a given subject area, but that the expert teacher’s PCK reflects the particular expertise with individual differences that are influence by the context...It may be possible to see how a knowledge
of pedagogy and knowledge of content combine to shape the amalgam

Components of Pedagogical Content Knowledge

Guskey and Huberman (1995) presented a broader view, delineating the four elements, or qualities, of pedagogical content knowledge. These are (a) pedagogical content knowledge as overarching conception of teaching, (b) a subject knowledge of instructional strategies and representations, (c) knowledge of students’ understandings and potential understandings and (d) knowledge of curriculum and curricular materials.

Gess-Newsome and Lederman (1999) suggest that there are five component parts of PCK. They are (a) the science curriculum, (b) student understanding of specific science topics, (c) assessment, (d) instructional strategies and (e) the teacher’s orientation toward science teaching.

Veal and MaKinster (1999) identified the following components of PCK: (a) Context, (b) Environment, (c) Nature of Science, (d) Assessment, (e) Pedagogy, (f) Curriculum, (g) Socio-culturalism, (h) Classroom Management, (i) Knowledge of Students, (j) Content Knowledge. The first eight components, from a through k, are referred to in the text as the embedded attributes; that is, they are in the top hierarchical level of the pyramidal model of PCK and are interconnected with each other.

Loughran, Berry and Mulhall (2006) present still another approach to PCK. Similar to Veal and MaKinnester (1999) they believe that teachers must have a strong
conceptual understanding of their subject matter in order to recognize and develop their own PCK. However, based on research done with pre-service teachers over fifteen years, they have developed a complex model that requires new teachers to engage in a lengthy reflective process. This process helps teachers understand the concept of PCK and their role in promoting their own professional growth.

To define and delineate PCK, Loughran et al. (2006) present a framework for concrete examples of PCK. The first part of the framework is Content Representation (CoRe). This is concerned with how the teacher conceptualizes the content of the given subject matter. To elicit this concept the teacher may first be asked to express the major idea of the content. An example may be, “Matter is made up of small bits called particles.” Another may be, “Frictional forces are caused by distortion of two surfaces sliding over each other.” This series of “big ideas” is then sequenced. Under each of these ideas, the following questions are proposed to make a two-dimensional array.

- What you intend the students to learn?
- Why is it important for students to know this?
- What else do you know that you do not intend students to know yet?
- What difficulties or limitations are connected with the students learning this?
- What knowledge do you have about students’ thinking that influences your teaching of this?
- What are the other factors that influence your teaching of this idea?
- What teaching procedures will be used are and why?
What are the specific ways in which students’ understanding or confusion can be ascertained?

The second part of the framework is the Pedagogical and Professional-experience Repertoires (PaP-eRs). It is defined as “a narrative account of a teacher’s PCK that highlights a particular piece, of aspect, of science content to be taught.” Also, the Pedagogical and Professional-Experience Repertoires are “intended to represent the teacher’s reasoning, that is the thinking and actions of a successful science teacher in teaching specific aspects of science content” (Loughran, Berry, & Mulhall, 2006 p. 24). This series of Pedagogical and Professional-Experience Repertoires are designed to link with an aspect of the Content Representation (CoRe). Examples of Repertoires are shown in the entries of teachers’ journals.

Loughran, et al. (2006) identify the Resource Folio as the depository of the CoRe, the two dimensional “worksheet,” and the teacher’s journal containing the narratives of the reasoning and actions of the teacher. The actions include the “unpacking” of the instructional strategies such as the use of concept-mapping, the use of Venn diagrams, role-playing, or interpretive discussion. They suggest that using the Resource Folio will enable teachers to construct their PCK. It will then be a “powerful, accessible and useful representation of PCK and in theory is responsive to practice and in practice is important to theory” (p. 26).

Loughran, et al. (2006) delineated PCK in this way (PaP-eRs, CoRe) to help pre-service teachers create a scaffold upon which to develop their PCK. The use of Repertoires, Content Representation and the Resource Folio shows value. Used as a tool, it encourages the novice teachers to reflect first upon the content that they label
"big ideas" in the Content Representation (CoRe). The process also calls for detailed narration of the instruction strategies, or pedagogy, they label PaP-eRs. Thus, the time commitment to collecting data is substantial but may be appropriate for pre-service teachers enrolled in a methods class that may continue for multiple semesters. The design has promise for teacher training. However, because of the necessary longevity of the folio model, it has limitations for shorter-term professional development programs.

A Continuum of PCK Models

The development PCK models can be viewed on a continuum. On one end is the early Integrative Model that interprets PCK not as a domain of knowledge itself, but only existing at the intersection of the three types of knowledge. This model proposes that the locus of effective teachers' instruction occurs at intersection of content knowledge, pedagogical knowledge and contextual knowledge. Next on the continuum is the Transformative Model. This incorporates the same three elements as the Integrative Modes and introduces a new category, pedagogical content knowledge, which is distinct from the original three. Finally, the third model, the Hierarchical Model, expands the other models by ascribing levels of importance for the original elements. The following section discusses the three models in more detail.
**Integrative Model**

The Integrative Model so named and described by Gess-Newsome and Lederman (1999) suggests that the knowledge of subject matter (content knowledge), contextual knowledge and the knowledge of pedagogy are developed separately and that they integrate during the act of teaching (See Figure 1).

![Integrative Model Diagram](image)

*what is needed for teaching

**Figure 1. The Integrative Model showing the intersection of Subject, Pedagogical and Contextual Knowledge.**

The integration of the three types of knowledge is necessary for successful teaching. In this model there is still a separation of subject matter, pedagogy and context and one does not change the other. The teacher selectively draws upon each knowledge base and integrates them as needed to create learning opportunities. This integrative model was presented by Cochran, King and DeRuiter (1991). The expert teacher smoothly moves from one knowledge base to the other when teaching. This model aligns well with the description of PCK by Loughran, Berry and Mulhall (2006).
Gess-Newsome and Lederman (1999) warn that teachers "may never see the importance of knowledge integration and continue to emphasize the importance of content over pedagogy, resulting in transmission modes of teaching with little regard for content structure, classroom audience or contextual factors (Gess-Newsome & Lederman, 1999 p. 12)." The model implies that PCK does not exist as a separate knowledge but is an amalgam of subject matter knowledge, pedagogical knowledge and contextual knowledge. Gess-Newsome and Lederman also suggest that traditional teacher preparation programs separate content knowledge from pedagogical knowledge instruction and little, if any, attention is given to the importance of contextual knowledge. They believe that this causes a potential deficit for novice teachers in the classroom.

**Transformative Model**

The Transformative Model (See Figure 2) is presented with subject matter knowledge, pedagogical knowledge and contextual knowledge, as does the integrative model, however it proposes a synthesis with the formation of PCK. The three sources are not in themselves productive. It is only when the three are synthesized that the latent resources become viable. In alignment with the transformational model, Magnusson, Krajcik and Borko (1999) state:

In our view, the defining feature of pedagogical content knowledge is the conceptualization as a result of a transformation of knowledge from other domains (p. 96).
They also present a conceptualization of PCK as what a teacher possesses that discriminates from that of content specialist. Planning and teaching requires that the teacher apply knowledge from multiple domains when designing and guiding learning experiences.

Figure 2. Transformative Model showing the amalgam of Subject Matter, Pedagogical and Contextual Knowledge.

Gess-Newsome's (1999) criticism of this model is it underemphasizes the specifics of the teaching situation and the characteristics of the students. The PCK is the product produced and is dependent upon the situational and student characteristics. The PCK synthesized is not transferable across contexts. For example, the PCK synthesized for teaching fourth graders in an energy unit are not the same as would be appropriate for tenth graders. Although the subject matter knowledge or
content may be the same and the general pedagogy may be the same, because of the context, the PCK would be different because the context is different and pedagogy would be different.

There are several commonalities in the literature between the two models. Both express a focus on the concern with how the teachers use knowledge of the content area, knowledge of the students within context and the application of pedagogical skills. Much of the current research using both models considers the development and application of PCK as the dominant way in which the teacher organizes the structure, content, skills and activities within the classroom to provide for the best conditions and opportunities for student learning. A difference is that in transformative model, PCK is a product of the three components.

Hierarchical Model

Veal and MaKinnster (1999) arranged the components of PCK they selected in a taxonomy. In defining taxonomy, they refer to Krathwohl, Bloom and Masia (1964) and the original Taxonomies of Educational Objectives: “A true taxonomy is a set of classifications which is ordered and arranged on the basis of a single principle on the basis of a consistent set of principles (p 11).”
Veal and McKinster (1999) identified ten components of PCK and arranged them in hierarchical layers. At the top level are the first eight components. As a base for this level, and the intermediate level, is the Knowledge of Students component. This is the teacher's understanding of possible student errors and misconceptions.

The foundation of this the model is Content Knowledge. This knowledge consists of the empirical descriptive data, the assumptions and theoretical conceptions. The researchers postulated that this foundational level may be general, domain-specific or topic specific and is essential to the development of PCK.

In this model, Content Knowledge is the foundation, and most important level. The second most important level is the Knowledge of Students. Veal and Makinister (1999) state that "only after a teacher understands or realizes the importance of his/her students can the other attributes of pedagogical content knowledge be developed" (p. 16). However, they also state, "The Taxonomy of PCK Attributes does
not imply a linear progression of knowledge or development. Rather, the taxonomy represents a multi-faceted and synergistic developmental relationship between the various attributes" (p. 10).

**Approaches to the Measurement of Pedagogical Content Knowledge**

Various approaches have been used to measure PCK. Even though a variety of studies have used PCK as a construct, most have been limited to small samples of teachers or student teachers. One study, however, The Salish I Research Project (Vopava, Spector, & LaPorta, 1997a) was unusually large and complex being three years in duration and measuring both teacher and student measures. The research assessed five elements of pre-service teachers through the first years of teaching. These elements were (a) the teacher preparation of secondary high school science and mathematics teachers, (b) new teacher knowledge, (c) new teacher beliefs, (d) performance in the classroom, and (e) student learning outcomes.

The complexity and extensiveness of the study required the construction of new instruments as well as adaptation of some existing instruments. The Constructivist Learning Environment Survey (CLES) was designed to assess the classroom environment with respect to six constructs relevant to a "constructivist learning environment." The survey was developed by Taylor, Fraser and White (1991) at the Curtin University of Technology and has been used frequently in research about the learning environment (Bettencourt 1988; Luft 2001). The instrument consists of a survey in two forms, one for teachers and one for students in the subject areas of mathematics and science. The CLES assesses six constructs:
Personal Relevance, Scientific Uncertainty, Critical Voice, Shared Control, Student Negotiation and Attitude. The teacher form consists of 42 items presented in a Likert-type five-point scale. The categories of the scale are “almost always,” “often,” “sometimes,” “seldom” and “almost never.”

Seven items of the Personal Relevance Scale measure the teacher’s perception of how the students relate to what takes place within the school laboratory and the student’s life outside of school. From the constructivist perspective, there should be congruence between the two worlds. This congruence gives a meaningful context for learning. Of the seven items, five are stated in a positive manner thus positively scored, and two are negatively scored.

The next construct of the CLES is the Scientific Uncertainty Scale. This is based on the concept that science is an uncertain and evolving activity, influenced by culture and by human values. The teachers report the extent to which students perceive this about science as such and are critical and skeptical. Of the seven items, five are positive and two are negative.

The Critical Voice Scale examines how teachers view their students’ perceptions of the classroom atmosphere as it promotes a social climate in which the students’ voice may contribute toward plans for conducting the class assessments of impediments to learning. The opposite of this would be a strict adherence to “covering the curriculum content.” In this section, there are seven items of which six are positive.

The Shared Control Scale assesses the extent teachers involve their students in the management of the classroom learning environment. It assesses the participation
of students in the designing and managing learning activities, determining assessment
criteria and setting the social norms for the classroom. Seven items, all stated
positively, measure this construct.

The Student Negotiation Scale is based on the idea that students should be
given the opportunity to explain and justify their ideas in an open forum where
students can reflect on the viability of others’ and their own ideas. The construct
stands in opposition to student isolation and the textbook as the arbiter of knowledge.
Again, this construct is assessed using 7 positively stated items.

The final construct, the Attitude Scale, looks at how students’ attitudes toward
anticipated activities contributed to their understanding. The scale is also used in the
CLES as a measure of the concurrent validity. The instruments are administered to
both the students and the teachers. The surveys provide information about the
students’ perception of the learning experience and the teacher’s perspective of the
classroom.

The Salish I Research Project (Vopava, Spector, & LaPorta, 1997b) was a
unique exploratory study. It produced a variety of procedural recommendations,
questionnaires, rating scales and interview questions that can be used to study the
growth of a beginning teacher over a series of years.

In another study, this one with a small sample size, Luft (2001) looked at the
impact of an inquiry-based professional development program on beginning and
experienced science teachers. The participants were six induction (beginning)
teachers and eight experienced teachers. They participated in a six-day program in
which they began by observing lessons of extended inquiry by mentors and then were
trained in the observation of their peers. This part of the program was followed by observations of lessons they taught and feedback from the program director or coordinator in a clinical supervision format. Later a follow-up session addressed concerns and finally provided a network in which the teachers could share experiences and discuss issues with other program participants. In the analysis, a simultaneous mixed methodology was used.

Luft (2001) constructed an instrument to examine eight categories. They were (a) Cooperative learning, (b) Teacher as guide, (c) Assessment, (d) Student communication and action, (e) Inquiry questioning, (f) Designing and conducting scientific investigations, (g) Gathering and analysis of data, and (h) The sharing of extended investigations. Luft also used a modified form of the Teachers’ Pedagogical Philosophy Interview (TPPI) from the Salish Project (Vopava et al., 1997b) into 45 minute long participant interviews.

Luft (2001) found that such a program design could be successful in changing teachers practices and beliefs if it gives attention to the diverse behaviors and beliefs of the participants. First, the program should provide a venue appropriate to their instructional needs and learning styles. Second, it should contain follow-up experiences that provide for multiple ways to interact. And third, the program staff (instructors and facilitators) must provide a stimulus to cause the teachers to reflect upon their beliefs and participants must view the reform-based practices positively. However, with the small sample, these recommendations are not generalizable.
Convergent and Inferential Techniques

Based on a synthesis of previous studies, Baxter and Lederman (1999) described convergent and inferential techniques of evaluating PCK. The instruments were multiple-choice forms, self-report inventory and short-answer format. Representative teaching events were formulated into statements, questions or pictorials to which the teacher responds. This response may be a rating scale, a written short answer, or a choice selected from among multiple answers.

Baxter and Lederman (1999) cited only one study that used multiple-choice format. They reported that the main problem with constructing such an instrument was the difficulty in developing the questions. A lengthy explanation is often necessary to convey the context of the question. The narrative explaining the instructional episode has to be complete to insure the reader understands the situation. In multiple-choice tests, distracters have to be written in addition to the correct response. If the distracter is too far off the desired response, it becomes obvious and of no value. If it is too close to the desired response, it may be defensible as a correct answer. The use of the multiple-choice approach may not validly capture the instructional episode and the behavior of the teacher.

In contrast to this, an advantage of using a Likert type self-report is that the teacher can respond to a question on a scale, as opposed to generating only one response. The scale will report a value. Also, an underlying assumption of the multiple-choice format is that as set of right answers does exist while the scale allows for a range of variance.
Baxter and Lederman (1999) critique the multiple-choice technique. They cite "criticisms of these tests for poor criterion-related validity, failing to measure many critical teaching skills and their adverse impact on minority representation in the teaching profession" (p. 151). As to the short answer technique, they cite Kagan (1992) that the technique "runs the risk of obtaining bogus data because standardized data may mask a teacher's highly personalized perceptions and definitions" (p. 426). Although they mention the Likert-type self report in their review of inferential techniques, they make no critique.

**Assessment Using Concept Mapping**

The use of concept mapping, card sorts and pictorial representations is a newer technique in assessing teacher PCK although Novak and Gowin (1984) proposed the use of concept maps to assess student learning in the 1980s. Concept mapping has been used for a variety of tasks to establish the perceived cognitive structure or relationship between key terms and items in one area of knowledge (Novak, 1990; Novak & Gowin, 1984; Ruiz-Primo, Schultz, & Shavelson, 1997; Ruiz-Primo, Schultz, Li, & Shavelson, 2001). In this method, the subject is asked to generate words or phrases and then link them together to form a map to illustrate the relationship between or among the items. The primary assumption is that the concept maps reflect how the information is organized within the long-term memory of the subject. The usual scenario in concept mapping is to have the subject link graphically the key terms in a way that reflects the subject's understand of the relationship. This
assumes the maps represent the organization of information as is appears in the subject’s long-term memory.

Morine-Dershimer (1989) conducted a study of eight university students in a seven week teacher preparation course. Using concept mapping in a pretest and post-test format, she found a shift in the students' perception of pedagogy and content. In the post maps there was an increase of frequency of references to goals, skills, evaluation and instructional strategy that seemed to be directly related to the seven-week course.

Gess-Newsome (1999) criticized the concept mapping technique, claiming it offers a limited set of terms and presents a static, two-dimensional relationship. The strength of the analysis is based upon the number and complexity of connections. However, two subjects with equal knowledge may pictorially represent the knowledge differently. One subject may relish graphically representing the relationships but the other may be reticent and prefer to use another method of representation. This technique has no external reference, thus interpretation is more subjective.

Although Gess-Newsome (1999) criticizes this technique, several studies reported on the validity of the use of concept mapping for assessing knowledge with students as was done by Ruiz-Primo and colleagues (Ruiz-Primo, Schultz, Li, & Shavelson, 1999; Ruiz-Primo et al., 1997; 2001). They reported differences in validity among the varied techniques used. They used “construct-a-map,” “fill-in-the-lines,” and “low-directed” techniques and compared them to a criterion map. They
found "fill-in-the-lines" and "construct-a-map" techniques had a higher magnitude of correlation to the criterion map.

Multi-method Assessment

The third technique to assess teacher PCK is called multi-method evaluation. It is the most time consuming and detailed process, and uses methods such as interviews, video-prompted recall, as well as concept maps. Results are then triangulated to infer a profile of the subject. These techniques produce a large quantity of data but are cumbersome and difficult to administer. Interviews alone are suggested to last for thirty to forty minutes.

An example of multi-method was a study by McClure, Johnson, Jackson, and Hoff (2000). During the 1998-1999 school year, Minnesota’s Teacher Resource Network worked on developing a battery of instruments to measure and evaluate the level and quality of constructivist teaching within science classrooms. The first instrument used was a modified form of the Constructivist Learning Environment Survey (CLES) which has been used in other studies (Bettencourt, 1988; Fraser, 1994; Luft, 2001; Vopava et al., 1997a). The original CLES (Taylor & Fraser, 1991) had 28 items in four scales: prior knowledge, negotiation, student-centeredness and autonomy. Later, the form was modified to 30 items in five scales. The five new scales were personal relevance, uncertainty, critical voice, shared control, and student negotiation.

In addition to the CLES, the Teacher Resource Network also developed the Constructivist Teacher Observation Instrument (CTOI), which was a result of the
alignment of constructs of a learner centered instructional model and the CLES. Using the CTOI, the evaluator ranked the teacher on a scale of one to four using a rubric provided. The instrument provides a format for an observer to assess six characteristics of the classroom and the teacher’s behavior. These characteristics were:

- **Foundation Knowledge/Student Involvement in Learning** (structure of content/concepts, inquiry, teacher seeks student input, student needs drive curriculum, connection to student experiences, life, other disciplines and the future)
- **Classroom Climate** (mutual respect, student involvement in solving classroom climate issues, handling of fairness, judicial, restitution, safe environment)
- **Learner Diversity/Multiple Perspectives** (student and multiple perspectives are presented, learning process is valued, adaptations, fairness, multi-modal instruction)
- **Communication** (questioning, learner-to-learner interaction, multiple cues, principles of speech and writing)
- **Assessment** (frequent formal and informal feedback during learning process, adjustment of instruction, self and peer assessment)
- **Promoting Thinking** (engagement in higher order thinking, active learning and student responsibility for learning)

The study does not establish the time needed to use the instrument or effectiveness of the instrument other than to say that in the study pre and post-
observation sessions were needed to determine if the lesson fit into the format of the instrument.

McClure et. al. (2000) found that while the CLES focused on teacher philosophy and intent, it did not reflect what an evaluator may see when observing the classroom. A new instrument, the Science Teacher Observation Instrument (STOI) was created to compensate for this. It was useful in cases where a small number of subjects were to be studied, but for larger groups it was unwieldy and time consuming.

Rowan, Schilling, Ball, Miller, Atkins-Burndett, Camburn, et al. (2001) used a survey method to assess teachers’ pedagogical content knowledge in the areas of reading comprehension and mathematics. In the mathematics curriculum, measurement was made in what Rowan referred to as two facets of PCK. The first was content knowledge and the second was “knowledge of students’ thinking.” The teacher’s content knowledge was assessed using 32 multiple-choice items while “knowledge of student thinking” was assessed with a 29-item instrument. The survey presented a series of scenarios in which the teacher was asked to conjecture why a student answered a question in a particular way or gave a particular response. Rowan referred to the topics in the questions as being “fine-grained” as they related to very small, specific examples of a behavior or teacher knowledge. They asked about one event or response. For instance, for the topic “number concepts,” three scenarios were presented with 10 items. For the math concept of “operations,” there was one scenario and one item.
Rowan, et al. (2001) concluded that much effort was needed in the development of sufficient item banks. They reported that the items failed to discriminate the levels of knowledge of the teachers. The items also did not possess enough clarity for teachers to demonstrate their knowledge through the instrument.

The Task of Measurement

The construction of an instrument to assess teachers’ PCK is not an easy task. A researcher developing one should have a vision of how PCK might appear in diverse examples. How would PCK exhibit itself differently in the novice and experienced teacher? There are some experienced teachers with little pedagogical content knowledge, but for our purposes here, we will assume that they have developed this knowledge. The task is to discriminate the level of PCK of a teacher and the change in PCK.

Novice teachers may demonstrate a superficial or incomplete knowledge of pedagogical content knowledge if they depend upon subject matter knowledge straight from the book (Borko & Livingston, 1989). This may be presented “as is” as it exists in text or as it was understood when the teacher “took the course.” Here, the book is the authority.

An example used is the mathematics majors who decide to teach mathematics but have no understanding of the common misconceptions of students. In the teachers’ prior experience with the material, the content seemed logical and new knowledge was easily assimilated. The novice teachers will assume that the students will find the content as interesting and as logical as they did (P.L. Grossman, 1989). Yet, the
students struggle to acquire this knowledge. After a student informs the teacher that he does not comprehend the concept, the teacher may attempt to re-teach using the same procedure as before, and having the same result. They lack multiple approaches to the demonstration of a specific concept (Magnusson et al., 1999).

Novice teachers may over emphasize trivial content in lieu of overarching concepts. Quizzes and tests are based on low level recall and material is learned for the test and not for application. Memorization of parts and terms become the objective. When a teacher asks a student for a definition, the teacher expects a verbatim response, just as it appeared in the book, not paraphrased, or their interpretation. For these novice teachers, the book is the content and the objective is to know the book. There is no discrimination between curriculum and text. Parents frequently share this perspective and are pleased to see the large size of the textbook, which to them signifies a good course.

Novice teachers may relish the amount of content knowledge they possess and await a student’s question so that they can show the class that they know the answer. This attitude is not present only in novice teachers, but may also be found in other experienced teachers lacking pedagogical content knowledge. Knowing “the correct answer” is a point of pride.

When asked for explanations of concepts, novice teachers may reply that the answer is “in the book.” One teacher was being observed and the supervisor commented that when a student asked about a question that was on an assignment, the teacher turned the pages in student’s book to show the student where the answer was
in the book. The novice teacher could not comprehend any problem with this behavior. After all, the student “got” the answer.

The novice teacher is the sole assessor of knowledge in the classroom laboratory. The teacher informs the students when they “know” the material. Most experienced teachers have knowledge of different curriculum materials and know that the book is not the course and finishing the book is not the goal.

Effective, experienced teachers find ways of creating a structure of the content that is logical to the student (Morine-Dershimer, 1989). They use metaphors, similes and examples so the students can assimilate the content (Livingston & Borko, 1989). They assess prior learning, ability and student learning and consider them in making decisions about teaching. Effective teachers know that student interactions within groups enhance and facilitate learning.

Effective, experienced teachers critically reflect and tailor materials to individuals or groups. They reflect on a daily lesson and on where it fits into their long-range planning (Livingston & Borko, 1989). They make real-world connections between what is being taught and “real life situations.” Effective teachers make smooth logical transitions between lessons and activities.

Effective, experienced science teachers use questioning as a teaching and as a learning technique, not as a tool for interrogation (Rowe, 1973). I once observed a high school science teacher question a student and provided less than a second before asking the next student the same question. This teacher had taught for several years, yet persisted in using an ineffective instructional strategy.
The effective, experienced teachers see the value in and use problem-based learning. They provide opportunities for students to determine the validity of their own constructions. The classroom laboratory of the experienced science teacher is interactive, collaborative and cooperative (Magnusson et al., 1999).

Effective experienced teachers know that learning is a social-psychological phenomenon. They know that they are facilitators for learning. They are not pillars of knowledge. This point is captured in the expression, "the sage on the stage," versus "the guide on the side." As a facilitator of learning, the teacher elicits responses, helps in the research to gather data but does not give answers (Young & Pottenger, 1992). They know that responding to a student's question, "I do not know. What do you think?" is not an admission of ignorance, but a facilitative technique. After asking students a question, they frequently follow the student response with, "Why do you think so?" Students are held accountable in the classroom laboratory to give evidence and reasons for decisions and conclusions.

Conclusion of Literature Review

The coining of the term Pedagogical Content Knowledge by Schulman offered a new cognitive model of teacher knowledge. The value of the model for research the question was posed: Is this the "missing program in educational research" that discriminates the quality of teaching? (Gess-Newsome & Lederman, 1999) Or, is the term a non-issue, and just a catch phrase? It has been suggested that PCK may be able to bridge the gap between the content knowledge and pedagogical knowledge in science teacher preparation (Anderson & Mitchener, 1994).
If PCK is a useful paradigm, we should be able to use it to assess the behaviors of teachers in the classroom. If the professional development provided to the teachers is effective, the behavior of the teachers should be changed. Professional development that enhances a teacher’s development of PCK is of substantive value and reflects effective professional development.
CHAPTER III
DESIGN OF THE STUDY

This chapter presents the method used to implement the study testing the differential effects of the two models of professional development.

Research Design

The study uses a quasi-experimental design that compares the pretest and posttests of the Pedagogical Content Knowledge (PCK) constructs across the two treatment groups without random assignment (Shadish, Cook, & Campbell, 2002). The participants were randomly selected, but not randomly assigned to, two delivery approaches that were offered in three locations. To solicit participants, information describing the program was sent to middle schools in three school districts. As an incentive the teachers were offered the opportunity to participate in the professional development institute without cost. In addition, they were offered a classroom set of student materials and teacher materials.

<table>
<thead>
<tr>
<th>Observation 1</th>
<th>X₁</th>
<th>Observation 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation 1</td>
<td>X₂</td>
<td>Observation 2</td>
</tr>
</tbody>
</table>

Figure 4. Quasi-experimental pretest and posttest design.
The subjects were 36 middle-school teachers, 27 females and 9 males, assigned to one of the two treatment conditions by location. The first group (N=16), consisted of those people participating in a one-week professional development program with enhanced follow-up support. The second group (N = 20) was comprised of teachers who took part in the traditional two-week professional development program with minimal follow-up support. The teaching experience of the subjects ranged from one year to 32 years of experience. The mean years of teaching experience for first group was 9.9 years, while the mean experience of the second group was quite similar (9.1 years).

**Professional Development Program**

**The ScUP Project**

“The Effects of Professional Development and Long-term Support on Program Implementation and Scaling Up,” (Brandon et al., 2007; Lawton, 2005) referred to as the ScUP Project, was a two-year study conducted by Curriculum Research & Development Group (CRDG) of the University of Hawai‘i under an Interagency Educational Research Initiative (IERI). The program designed an enhanced one-week version of an introductory PD institute to be compared with the original two-week version of the program that has been used for over twenty years. The support system for the one-week version included Web-based services, telephone support and supplementary material, including computer software resources.
The FAST Program

The ScUp Program selected Foundational Approaches in Science Teaching (FAST) as the program for use in the study. The FAST program was developed at the University of Hawai‘i’s Curriculum Research & Development Group in the 1970s. Over the decades of use, it has been revised and modified to keep current with the times. Resource materials, such as the reference books, are revised to reflect current data. Since its inception, the program has been disseminated to 36 states and to ten foreign countries (Young & Pottenger, 1992). It has received recognition as an exemplary science program by the National Diffusion Network and by the US DOE Expert Panel on Mathematics and Science Education.

The FAST program is based on the disciplines of knowledge as delineated in King and Brownell’s *The Curriculum and the Disciplines of Knowledge* (King & Brownell, 1966). The course aims to prepare students to become active role players in a scientific and technologically based society. The assumption of this instructional approach is that the discipline of science should be taught in ways similar to the way the discipline exists in society. The assumption also states that the primary role of education is the development of the intellectual capacities of the students and to satisfy their need to know, thus enhancing students’ ability to engage in a changing society. It is noted that human knowledge is based on the theoretical disciplines, and an understanding of the disciplines is essential to the understanding of society (Young & Pottenger, 1992).
The FAST professional development model has been used for over 30 years to prepare teachers using the disciplines of knowledge as its basis. Teachers are immersed in the principles and activities of the program. The disciplines of knowledge model states that a discipline is a defined area of study, the network of facts and writings, and the corps of human beings who share the commitment to this community. To become part of this community, and not being observers, one needs to have a commitment to the discipline, which includes an acceptance of the guiding practices and an acceptance of the role as participant within the community. This immersion model approach of professional development meets the disciplines of knowledge framework. It gives teachers the experience of being a learner in the classroom laboratory. In turn, the teachers return to their classrooms to recreate this community. It should also be noted that this immersion into inquiry science is cited by the Eisenhower National Clearing House on Mathematics and Science Education (1999) and Loucks-Horsley et al (1998) as a successful strategy for professional development.

Operationalizing the PCK Instrument

As presented in Chapter 2, there are different ways in which researchers have modeled PCK. There is the Integrative Model, in which a simple Venn diagram expresses the model (Gess-Newsome & Lederman, 1999). According to this model, the intersection of adequate pedagogical knowledge, contextual knowledge and subject matter knowledge is required for effective classroom teaching. This model does provide a simple, descriptive definition of PCK. In trying to give a simplified
view of PCK, however, it lacks detail and precision, and it does not articulate the
intricacies necessary to enhance student learning. Gess-Newsome and Lederman’s
(1999) Transformative Model provides a more thorough definition of PDK
components and the interrelationships among the components.

Similarly, Veal’s Hierarchical Model (1999) breaks down the PCK into
smaller units and also states a hierarchy relative to importance or foundational value
of two components. In contrast, the three circles of the Integrative Model are of the
same size, implying equality of the components. The Transformative Model also
implies an equality of the components. The Hierarchical Model, by using three
dimensions, separates the components on vertical dimension, implying the
foundational importance of content knowledge and knowledge of students.

Both the Integrative and Transformative models do function to show the
components and the interaction among the components. For the measurement of PCK
with in-service teachers, the following appears to extend the PCK construct in more
depth than the other two models. This model does cluster the sources of PCK into
Content Knowledge, Contextual, and Pedagogy. Each of these clusters contains
specific constructs that interact with and contributes to PCK. The model used in this
study serves the task of clearly identifying constructs that may be impacted by
professional development.

Proposed Transactional Model

The Transactional Model used in this study is based upon the literature on
Professional Content Knowledge (Cochran, 1992; Gess-Newsome & Lederman,
1999; Shulman, 1986) and the literature on national standards and effective teaching (Biological Science Curriculum Study, 1995; National Research Council, 1996; Stronge, 2002) that suggested the following constructs:

1. Nature of Science
2. Knowledge and use of Inquiry
3. Knowledge of Curriculum Materials
4. Teacher-as-Facilitator
5. Student Discussion and Questioning
6. Cooperative Learning, Student Collaboration and Environmental Support
7. Connections or Relevance to Real World
8. Assessment of Learning
9. Goal Setting and Planning

One primary use of the model is descriptive. It shows the nine factors of PCK and how they can be arranged into three clusters. A second use of the model is to illustrate the dynamic interactions of the constructs. In this model, as the pedagogical content knowledge is developed, there is a necessary transaction that takes place within the individual in terms of content knowledge, pedagogical knowledge, and contextual knowledge. A third use of this model is to facilitate the definition of necessary components of PCK and their corresponding measurement (i.e., through survey items) over a period of time and with respect to different PD experiences.
Content Knowledge

Within the first cluster, Content Knowledge, there are three constructs. The first construct is that of the (1) Nature of Science. The teacher must develop an understanding of science. Science is more than a collection of facts and principles. The body of scientific knowledge is always fluid and is changing as technology changes. The development of an understanding of this knowledge impacts a teacher's PCK. As the teachers apply this knowledge in the classroom, it increases their own
understanding of this knowledge. The second (2) is the Knowledge of Inquiry. Pre-service and novice science teachers may underestimate the importance of this construct. Rutherford states, “Until science teachers are able to view scientific inquiry as part of the content of science – and until teachers become well grounded in the history and philosophy of science – they cannot be educated to teach science as inquiry” (1964, p. 80). As teachers gain this knowledge of inquiry and use this knowledge in the classroom, the process modifies their experiences and comprehension. The third construct in the Content cluster is (3) Knowledge of Curriculum Materials. As the teacher gains familiarity with the variety and structure of curriculum materials, the teacher can make choices on the selection of materials and make more efficient use of specific materials. The use of different curricular materials broadens the teacher’s understanding of the advantages and disadvantages of different programs and materials, enabling the teacher to make better decision.

Pedagogy

The second cluster, Pedagogy, contains the construct of (4) Teacher-as-Facilitator. The task of the teachers is to facilitate learning. Effective teachers know that they are not the sole source of knowledge. As teachers have the students present evidence to support findings, they accept new ideas and data (Young & Pottenger, 1992). They may learn how the role of teacher-as-facilitator functions by observing a colleague demonstrating this pedagogical strategy. While the teachers may have a rudimentary understanding of the process, it is not, however, until after the teachers
apply the process that they have a full comprehension the intensity of this strategy.
The next construct in the Pedagogy Cluster is (5) Student Discussion, which includes
the power of effective questioning strategies. Although teachers may have a
comprehension of the process, it is not until practiced that teachers develop an
understanding at the application level of how Socratic dialogue and scaffolding foster
understanding. The teacher has the students present evidence to support findings and
encourages students to present their ideas for proposed investigations, explanations of
phenomena and anomalies. They may also ask for clarification of others’ ideas,
explanations and designs.

The third construct in Pedagogy Cluster is (6) Cooperative Learning,
Collaboration and Environmental Support. The teacher creates an environment
conducive to student intercommunication and supportive of varying viewpoints.
Group activities are arranged to facilitate exchange of ideas and data. There are a
number of cooperative learning strategies that the teacher chooses from, but it
requires application and practice before a teacher’s understanding of this strategy is
refined.

**Contextual Knowledge**

Knowledge of Context is the third cluster. The first construct in this cluster is
(7) Connections or Relevance to the real world. The teacher must develop an in-
depth knowledge that enables him or her to make the connections between the
classroom and the world outside. A teacher may have learned about the influence of
socio-economic status and cultural influences during teacher training, but it is the
interaction with their students that develops this ability to draw analogies and the best examples that relate what is being learned in the classroom with the students’ life outside the classroom. The next Contextual construct is (8) Assessment. Frequently viewed as summative function by novice teachers, effective assessment is used for improving teaching and learning. Both formative and summative assessments interact with planning, discussion and inquiry. The last construct is (9) Goal Setting and Planning. The teacher sets appropriately high, but achievable goals for the students. Goal setting interacts with the teacher’s appropriate use of assessment tools that provides feedback of students’ progress, and from this may suggest adjustment of goals.

An example of the transaction among the components is when a teacher uses assessment, the information gathered by the assessment contributes to the PCK. This new information in the PCK influences the planning and goal setting. If the assessment reveals that students are not reaching reflected goals, goals may be changed or the teacher may apply different pedagogical strategies. The teacher may increase or refine the discussion or questioning. These changes result in a stronger PCK.

Another example of the transaction may be that if a teacher increases knowledge of inquiry and the nature of science, perhaps by researching actual historical scientific events, this gained knowledge will influence the teacher’s role as facilitator. The teacher will want to create an appropriate environment for the students to construct the knowledge for themselves. Thus, PCK is not stagnant but is being influenced by changes and interaction among the components.
Instrument Development

The instrument used in the study was developed using the Transactional Model. It is based on the premise that effective professional development should have a positive impact on teachers’ Pedagogical Content Knowledge. To assess this knowledge the instrument should address these nine constructs that comprise PCK.

Based on the constructs, 72 test items were created. The items were in the form of statements such as, “I provide examples of how science concepts apply to daily life.” And, “I change my science teaching based on assessment results.” The 72 items were paired with a five-point Likert-type scale (Likert, 1932). The indicators were Never, Rarely, Sometimes, Often and Always.

Pilot Testing

The instrument was pilot-tested with 51 teachers who were previously trained and are currently using the FAST program. The responses from these experienced teachers were analyzed using the Statistical Package for Social Sciences (SPSS) (Nie, Bent, & Hull, 1970). Data reduction with factor analysis was used to establish the items that best measured each construct. Cronbach’s alpha (Cronbach, 1950), a measure of internal consistency across subjects was low (<0.4) for three of the nine constructs.

Given this low reliability, the decision was made to delete these three constructs from the present investigation. The two constructs deleted from the Content Cluster were Knowledge of Science and Knowledge of Curriculum Materials. Therefore, only one construct, Knowledge of Inquiry, is used to define the
Content cluster. One construct was also deleted from the Contextual Cluster (Goal Setting and Planning). The remaining constructs had more acceptable alphas ranging from 0.61 to 0.78, as shown in Table 4.1.

Table 3.1. Internal consistency of 6 factors defining PCK

<table>
<thead>
<tr>
<th>Factor</th>
<th>Alpha</th>
<th>Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Assessment</td>
<td>.72</td>
<td>Contextual</td>
</tr>
<tr>
<td>2. Collaboration</td>
<td>.78</td>
<td>Pedagogy</td>
</tr>
<tr>
<td>3. Discussion</td>
<td>.69</td>
<td>Pedagogy</td>
</tr>
<tr>
<td>4. Facilitation</td>
<td>.73</td>
<td>Pedagogy</td>
</tr>
<tr>
<td>5. Inquiry</td>
<td>.67</td>
<td>Content</td>
</tr>
<tr>
<td>6. Relevance</td>
<td>.61</td>
<td>Contextual</td>
</tr>
</tbody>
</table>

The Final Science Classroom Instructional Survey

The remaining 43 items were placed into the final survey instrument, Science Classroom Instructional Survey (SCIS). The title selected for the instrument was to be generic sounding and not explicitly revealing that the survey as a pretest and posttest to evaluate possible behavioral and attitudinal changes in the teachers. This was done in an effort to minimize the chances of socially correct responses.
Conducting the Two Different Delivery Approaches

There were three instructors who conducted the professional development institutes within the two delivery approaches. The first instructor conducted one section of the first approach (shortened delivery) and one section of the second approach (traditional two-week training) in Hawai‘i. The second instructor conducted a section of the first approach in Illinois, and the third instructor conducted a section of the second approach in Maine. All three of the instructors were trained in conducting the institutes and were certified by CRDG as qualified instructors. All three instructors also were required to follow the scope and sequence of the course as prescribed in the syllabus and schedule (see appendix).

Administration of Pretest and Posttest Surveys

The first treatment was the newly designed one-week PD institute with DVD enhancement and web and media training. The SCIS was administered as a pretest to this treatment group of 16 teachers on the first day of the institute prior to instruction beginning. The SCIS was also administered on the first day of the two-week long professional development institute to the second treatment group of 20 teachers enrolled. This two-week institute has been the traditional design of the professional development institutes used by the FAST program for over twenty years. At the end of the first semester after participation in either professional development delivery approach, the SCIS was mailed to all participants as the posttest. The responses were collected during the second semester of program implementation, giving participants additional time to implement the program.
The overall response rate of participants on the posttest surveys was 72.2 percent (i.e., 26 of the 36 participants). More specifically, of the 16 teachers in first treatment group, 12 teachers responded. In the second group of 20, 14 responded. Follow-up efforts indicated attrition of participants was due to teachers leaving the profession, maternity leave, and relocation.

To ensure anonymity of each participant, a person was hired to score surveys and for data entry. The data were recorded by the participant number. The pretest and posttest survey data were transferred to a coding sheet. Negatively scored items were rescored prior to data entry into the statistical package for analysis.

The data collected were arranged for analysis by treatment group as well as by construct. Each of the individual items on the survey was coded to the relevant construct. Each individual teacher responses was also coded as to the treatment received, and the location of the institute. The teaching experience and gender of each participant was also coded.

**Data Analyses**

**Factor Analysis**

Preliminary analyses were conducted to align each of the six constructs comprising PCK with the items in the survey.

**Descriptive Statistics**

Next, descriptive statistics are presented to examine statistics from the pretest administered to the teachers prior to the professional development sessions to
determine their levels of pedagogical content knowledge (PCK). It also compares the
two groups’ pre-treatment levels of PCK.

Examining Changes in Individuals’ Scores Over Time

The next analysis examines possible pretest to posttest changes in PCK for
each treatment group. Structural equation modeling is used to equate each group’s
pretest factor score and posttest factor score to the same metric for comparing each
construct. The six constructs are compared separately because of sample size
limitations.

Examining Post-Test Means Between Groups

The final analysis compares means for the posttest administered to the
teachers to determine the differential effects of the two treatment models (after
controlling for their pre-test levels). Again, structural equation modeling is used to
define a common metric to compare each group’s factor scores.

Limitations of the Study

This study has several limitations. The small sample size of 36 participants
has limited generalizability. It was designed to be limited in scope. It is aimed only at
the impact, or lack thereof, of specific professional development programs on the
teachers’ perceptions of their PCK, not on student achievement or other variables.
The researcher is cognizant of possible researcher bias. The researcher has extensive
knowledge of the FAST program having taught it in the classroom. The researcher
has also been contracted as an institute specialist, that is, an instructor for the FAST professional development institutes and as a staff developer to train institute specialists. Most recently, after this study the researcher was conducted hired by CRDG.
CHAPTER IV

RESULTS

This chapter presents the results of the study. The first section presents and discusses the descriptive statistics from the pretest administered to the teachers prior to the professional development sessions to determine their levels of pedagogical content knowledge (PCK). It also compares the two groups' pre-treatment levels of PCK. The next section presents the means for the posttest administered to the teachers to determine the differential effects of the two treatment models. It presents the differences between the individual construct means as well as the aggregated post group means. The next section analyzes the pretest and posttest means for each treatment group to determine whether there were any significant changes within groups between the pretests and posttests. The final section examines the data in the context of the Science Classroom Instructional Survey to determine the strengths and weaknesses of the instrument in answering the research questions that guided the study.

Descriptive Results of Pretest

The first step of the study was to assess the PCK of the teachers as they entered the professional development. Because of the small sample size, the six constructs were compared separately using multiple-group structural equation model (SEM)(Muthén, 1984). The advantage of using SEM was that it allowed the groups to be compared on the basis of the items (the questions posed to teachers) that compose
each construct instead of just the constructs themselves. That is, each item was
compared with each other item instead of comparing the mean of the construct.
Because the strongest items were used in defining the constructs when the instrument
was piloted and developed, we are assured that the error was well accounted for.

Table 4.1, the Pretest Means, shows the teachers’ pretest scores on the
individual items within the constructs, as well the means of each group on all of the
constructs. The overall mean score for the teachers on the constructs was 3.73 on a
five-point Likert-type scale, where one was low and five high. For Treatment Group
1, the mean was 3.75, whereas for Treatment Group 2, it was 3.72. These scores were
relatively high, which is not surprising considering the fact that the teachers were
quite experienced. Group 1 had an average of 9.93 years and Group 2 an average of
9.11, thus a mean of 9.5 years of classroom experience for the teachers.

Table 4.1 Pretest Means*

<table>
<thead>
<tr>
<th>Construct 1 (Assessment)</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 3</td>
<td>3.81</td>
<td>3.85</td>
</tr>
<tr>
<td>Item 16</td>
<td>4.20</td>
<td>4.00</td>
</tr>
<tr>
<td>Item 19</td>
<td>4.60</td>
<td>4.40</td>
</tr>
<tr>
<td>Item 32</td>
<td>4.69</td>
<td>4.65</td>
</tr>
<tr>
<td>Item 35</td>
<td>4.25</td>
<td>4.10</td>
</tr>
<tr>
<td>Item 39</td>
<td>3.25</td>
<td>3.15</td>
</tr>
<tr>
<td>Item 42</td>
<td>3.69</td>
<td>3.70</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Construct 2 (Collaboration)</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 4</td>
<td>4.06</td>
<td>4.00</td>
</tr>
<tr>
<td>Item 23</td>
<td>4.00</td>
<td>3.80</td>
</tr>
<tr>
<td>Item 24</td>
<td>3.57</td>
<td>3.70</td>
</tr>
<tr>
<td>Item 25</td>
<td>4.13</td>
<td>3.95</td>
</tr>
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</table>
Table 4.1 (continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 26</td>
<td>3.93 (.207)</td>
<td>4.15 (.587)</td>
</tr>
<tr>
<td>Item 28</td>
<td>3.86 (.864)</td>
<td>3.89 (.809)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Construct 3 (Discussion)</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 5</td>
<td>4.06 (.680)</td>
<td>4.05 (.826)</td>
</tr>
<tr>
<td>Item 12</td>
<td>3.50 (.966)</td>
<td>3.47 (.772)</td>
</tr>
<tr>
<td>Item 14</td>
<td>3.56 (.814)</td>
<td>3.50 (.607)</td>
</tr>
<tr>
<td>Item 34</td>
<td>4.13 (.885)</td>
<td>4.40 (.598)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Construct 4 (Facilitation)</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 21</td>
<td>4.13 (.915)</td>
<td>4.25 (.639)</td>
</tr>
<tr>
<td>Item 31</td>
<td>3.50 (.816)</td>
<td>3.65 (.813)</td>
</tr>
<tr>
<td>Item 33</td>
<td>4.56 (.512)</td>
<td>4.55 (.510)</td>
</tr>
<tr>
<td>Item 37</td>
<td>3.88 (.806)</td>
<td>3.55 (.759)</td>
</tr>
<tr>
<td>Item 38</td>
<td>3.87 (1.125)</td>
<td>3.90 (.912)</td>
</tr>
<tr>
<td>Item 40</td>
<td>3.56 (.964)</td>
<td>3.75 (.851)</td>
</tr>
<tr>
<td>Item 43</td>
<td>3.44 (1.153)</td>
<td>3.80 (.696)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Construct 5 (Inquiry)</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
<td>3.88 (.806)</td>
<td>3.80 (.696)</td>
</tr>
<tr>
<td>Item 6</td>
<td>2.87 (1.147)</td>
<td>3.40 (.883)</td>
</tr>
<tr>
<td>Item 7</td>
<td>3.13 (.957)</td>
<td>3.20 (.616)</td>
</tr>
<tr>
<td>Item 8</td>
<td>3.50 (.966)</td>
<td>3.37 (.684)</td>
</tr>
<tr>
<td>Item 9</td>
<td>3.56 (.814)</td>
<td>3.37 (.761)</td>
</tr>
<tr>
<td>Item 10</td>
<td>2.93 (.704)</td>
<td>2.95 (.705)</td>
</tr>
<tr>
<td>Item 22</td>
<td>4.00 (.845)</td>
<td>3.79 (.713)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Construct 6 (Relevance)</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 2</td>
<td>3.88 (.719)</td>
<td>3.95 (.510)</td>
</tr>
<tr>
<td>Item 15</td>
<td>3.07 (.829)</td>
<td>3.32 (.749)</td>
</tr>
<tr>
<td>Item 30</td>
<td>3.93 (.730)</td>
<td>3.84 (.688)</td>
</tr>
<tr>
<td>Item 36</td>
<td>4.13 (.806)</td>
<td>3.85 (.587)</td>
</tr>
<tr>
<td>Item 41</td>
<td>3.69 (1.014)</td>
<td>3.75 (.639)</td>
</tr>
</tbody>
</table>

*Note. 1 = low and 5 = high
Results of Posttest

The next step was to measure the PCK of the teachers a semester after they participated in the professional development institutes. Table 4.2 presents the posttest means and the standard deviations for each item in each of the six constructs as measured by the SCIS. The means and standard deviations of Treatment Group 1 are compared with the corresponding means and standard deviations of Treatment Group 2. As Table 4.2 indicates, the teachers' scores were higher than average on all six constructs. In addition, the item standard deviations were relatively low, suggesting that there was not a great deal of variance among the teachers' responses on each question. Again, this is not surprising, given the experience level of the teachers.

Table 4.2 Posttest Means*

<table>
<thead>
<tr>
<th>Construct 1: Assessment</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 3</td>
<td>3.73</td>
<td>3.93</td>
</tr>
<tr>
<td>Item 16</td>
<td>4.08</td>
<td>3.86</td>
</tr>
<tr>
<td>Item 19</td>
<td>4.50</td>
<td>4.50</td>
</tr>
<tr>
<td>Item 32</td>
<td>4.75</td>
<td>4.71</td>
</tr>
<tr>
<td>Item 35</td>
<td>4.25</td>
<td>4.00</td>
</tr>
<tr>
<td>Item 39</td>
<td>3.50</td>
<td>3.29</td>
</tr>
<tr>
<td>Item 42</td>
<td>3.50</td>
<td>3.50</td>
</tr>
</tbody>
</table>

Table 3 continued

<table>
<thead>
<tr>
<th>Construct: 2: Collaboration</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 4</td>
<td>3.75</td>
<td>3.93</td>
</tr>
<tr>
<td>Item 23</td>
<td>4.08</td>
<td>3.71</td>
</tr>
<tr>
<td>Item 24</td>
<td>3.75</td>
<td>3.36</td>
</tr>
<tr>
<td>Item 25</td>
<td>4.36</td>
<td>4.31</td>
</tr>
<tr>
<td>Item 26</td>
<td>4.17</td>
<td>4.29</td>
</tr>
<tr>
<td>Item 28</td>
<td>4.08</td>
<td>3.93</td>
</tr>
</tbody>
</table>

72
Table 4.2 (continued)

<table>
<thead>
<tr>
<th></th>
<th>Treatment 1</th>
<th>SD</th>
<th>Treatment 2</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct 3: Discussion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 5</td>
<td>4.20</td>
<td>.632</td>
<td>3.79</td>
<td>1.051</td>
</tr>
<tr>
<td>Item 12</td>
<td>3.75</td>
<td>.754</td>
<td>3.71</td>
<td>.611</td>
</tr>
<tr>
<td>Item 14</td>
<td>3.83</td>
<td>.835</td>
<td>3.57</td>
<td>.646</td>
</tr>
<tr>
<td>Item 34</td>
<td>4.42</td>
<td>.515</td>
<td>4.21</td>
<td>.699</td>
</tr>
<tr>
<td>Construct 4: Facilitation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 21</td>
<td>4.33</td>
<td>.492</td>
<td>4.29</td>
<td>.914</td>
</tr>
<tr>
<td>Item 31</td>
<td>3.83</td>
<td>.577</td>
<td>4.00</td>
<td>.877</td>
</tr>
<tr>
<td>Item 33</td>
<td>4.33</td>
<td>.651</td>
<td>4.50</td>
<td>.519</td>
</tr>
<tr>
<td>Item 37</td>
<td>3.83</td>
<td>.718</td>
<td>3.71</td>
<td>.611</td>
</tr>
<tr>
<td>Item 38</td>
<td>4.00</td>
<td>.853</td>
<td>4.07</td>
<td>1.072</td>
</tr>
<tr>
<td>Item 40</td>
<td>4.00</td>
<td>.739</td>
<td>3.92</td>
<td>.494</td>
</tr>
<tr>
<td>Item 43</td>
<td>3.83</td>
<td>.718</td>
<td>3.43</td>
<td>.756</td>
</tr>
<tr>
<td>Construct 5: Inquiry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 1</td>
<td>3.73</td>
<td>.467</td>
<td>4.00</td>
<td>.679</td>
</tr>
<tr>
<td>Item 6</td>
<td>3.50</td>
<td>.707</td>
<td>3.29</td>
<td>.825</td>
</tr>
<tr>
<td>Item 7</td>
<td>3.50</td>
<td>.707</td>
<td>3.29</td>
<td>.726</td>
</tr>
<tr>
<td>Item 8</td>
<td>3.45</td>
<td>.522</td>
<td>3.50</td>
<td>.855</td>
</tr>
<tr>
<td>Item 9</td>
<td>3.67</td>
<td>.651</td>
<td>3.21</td>
<td>.893</td>
</tr>
<tr>
<td>Item 10</td>
<td>3.09</td>
<td>.701</td>
<td>3.07</td>
<td>.829</td>
</tr>
<tr>
<td>Item 22</td>
<td>4.08</td>
<td>.793</td>
<td>3.71</td>
<td>.825</td>
</tr>
<tr>
<td>Construct 6: Relevance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 2</td>
<td>3.73</td>
<td>.786</td>
<td>3.86</td>
<td>.770</td>
</tr>
<tr>
<td>Item 15</td>
<td>3.17</td>
<td>.577</td>
<td>3.29</td>
<td>.914</td>
</tr>
<tr>
<td>Item 30</td>
<td>3.91</td>
<td>.701</td>
<td>3.93</td>
<td>.829</td>
</tr>
<tr>
<td>Item 36</td>
<td>4.00</td>
<td>.603</td>
<td>3.57</td>
<td>.646</td>
</tr>
<tr>
<td>Item 41</td>
<td>4.00</td>
<td>.894</td>
<td>3.93</td>
<td>.829</td>
</tr>
</tbody>
</table>

*Note. 1 = low and 5 = high*
Within-Group Comparison of the Changes in PCK by Construct

First, analyses are presented to determine whether individuals’ perceptions of their pedagogical content knowledge in each of the six domains changed over time regardless of which type of delivery approach they received. In these analyses, the individuals’ pretest factor scores were defined as 0.0 to set a metric to compare the post-test factor score using structural equation modeling. The results are presented in Table 4.3.

As Table 4.3 indicates, Treatment Group 1 had an increase from pretest to posttest on five of the six constructs. The only construct demonstrating a decrease was Inquiry. In Treatment Group 1, two constructs, Collaboration and Discussion showed an increase that was significant at the p < .10 level. Given the small sample size, this represents an encouraging preliminary finding. It suggests the instrument can pick up a difference in two of the specific domains comprising PCK. This result can be considered as better than chance. Although Treatment Group 2 had higher posttest scores on five of the six constructs, none of the differences was large enough in this small sample to be statistically significant.1
Table 4.3 Within-Group Analyses of the Changes in PCK Over Time by Construct

<table>
<thead>
<tr>
<th></th>
<th>t-ratio</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Pre-post Assessment</td>
<td>1.130</td>
<td>&gt; .10</td>
</tr>
<tr>
<td>2. Pre-post Collaboration</td>
<td>1.756*</td>
<td>&lt; .10</td>
</tr>
<tr>
<td>3. Pre-post Discussion</td>
<td>1.884*</td>
<td>&lt; .10</td>
</tr>
<tr>
<td>4. Pre-post Facilitation</td>
<td>0.148</td>
<td>&gt; .10</td>
</tr>
<tr>
<td>5. Pre-post Inquiry</td>
<td>-0.208</td>
<td>&gt; .10</td>
</tr>
<tr>
<td>6. Pre-post Relevance</td>
<td>0.394</td>
<td>&gt; .10</td>
</tr>
<tr>
<td><strong>Treatment 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Pre-post Assessment</td>
<td>0.869</td>
<td>&gt; .10</td>
</tr>
<tr>
<td>2. Pre-post Collaboration</td>
<td>0.504</td>
<td>&gt; .10</td>
</tr>
<tr>
<td>3. Pre-post Discussion</td>
<td>1.411</td>
<td>&gt; .10</td>
</tr>
<tr>
<td>4. Pre-post Facilitation</td>
<td>1.056</td>
<td>&gt; .10</td>
</tr>
<tr>
<td>5. Pre-post Inquiry</td>
<td>0.907</td>
<td>&gt; .10</td>
</tr>
<tr>
<td>9. Pre-post Relevance</td>
<td>-0.250</td>
<td>&gt; .10</td>
</tr>
</tbody>
</table>

* p < .10
Comparison of Posttest Means for Two Treatment Groups

Finally, possible differences between the means of the two treatment groups on the posttest were compared using structural equation modeling. In this approach, the first group's construct is set to a mean of 0.0 to provide a common metric to compare the factor scores. This analysis most directly relates to the broad question of whether there is any difference in perceptions of subjects' PCK levels across the two different delivery versions of the professional development program. Since the pretest scores for the two groups were not equal, they were included as covariates in the analysis.

Table 4.4 shows the between group differences on the posttest. There was no significant change among any of the six constructs from pretest to posttest. Treatment Group 2, the group with two weeks of PD, had slightly higher posttest gains on 4 of the 6 constructs. In the content cluster, the knowledge of inquiry was higher. In the contextual cluster, the assessment construct was higher. And, in the pedagogy cluster, discussion and collaboration were higher.

Although this may seem to suggest that the Treatment Group 2 derived greater benefit from having a two-week experience, the differences are not significant so it is difficult to conclude whether the changes were actually due to the model of the institute or merely chance.
Table 4.4 Comparison of Posttest Means of Two Treatments Controlling for Pretest Scores

<table>
<thead>
<tr>
<th>Construct</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
<th>t-ratio</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Assessment</td>
<td>0.0</td>
<td>0.169</td>
<td>0.273*</td>
<td>&gt; .10</td>
</tr>
<tr>
<td>2. Collaboration</td>
<td>0.0</td>
<td>0.044</td>
<td>-0.075*</td>
<td>&gt; .10</td>
</tr>
<tr>
<td>3. Discussion</td>
<td>0.0</td>
<td>0.034</td>
<td>0.054*</td>
<td>&gt; .10</td>
</tr>
<tr>
<td>4. Facilitation</td>
<td>0.0</td>
<td>-0.540</td>
<td>-0.715*</td>
<td>&gt; .10</td>
</tr>
<tr>
<td>5. Inquiry</td>
<td>0.0</td>
<td>0.250</td>
<td>0.365*</td>
<td>&gt; .10</td>
</tr>
<tr>
<td>6. Relevance</td>
<td>0.0</td>
<td>-0.032</td>
<td>-0.058*</td>
<td>&gt; .10</td>
</tr>
</tbody>
</table>

* p > .10 two-tailed

Discussion of Results

The study compared the possible differential effects of the two approaches to the professional development of science teachers and could be approached by a comparison of the posttest scores of the two groups however, the Science Classroom Instructional Survey provided additional information. By the detailed description of Pedagogical Content Knowledge, and the identification of the embedded constructs, it was possible to dissect the two types of PD of institutes and examine the individual
differences by these constructs. This was done by the analysis of each of the six constructs for both groups at two points in time, prior to participation in the institutes, and a semester later, giving the participants an opportunity to implement what they had learned.

Looking at the scores of the two groups prior to the institutes, it was evident that the groups were not equal, however, not greatly dissimilar. Scores on the individual constructs were similar. The aggregate mean for all the teachers on all of the items on the pretest for Group 1 was slightly higher than Group 2 but less than .1 on the five-point Likert-type scale.

The posttest scores were, as expected, higher than the pretest scores. For Group 1, all of the posttest means of the six constructs were higher than the pretest means of the same construct. Again, in Group 2, there was an increase from pretest to posttest. There was one anomaly as there was a slight decrease, less than 0.1 on the Likert-type scale, in the mean for the relevance construct.

It was expected that some constructs would have greater change if that construct is focused upon in the PD institute. This change may occur if they have a low value on the pretest, and the teachers choose to apply the gained knowledge to their classroom instruction. An example of this was with Group 1. The constructs collaboration and discussion had differences between the pretest and posttest scores large enough to be notable, suggesting that these two constructs in Group 1 were different. It should be noted also that in Group 2, the construct with greatest difference was also discussion, although less than in Group 1.
All of the constructs are not found equally in all of the teachers prior to the institutes. All of the constructs are not given equal instructional emphasis in the institutes. Not all of the constructs are equally embraced by the teachers and assimilated into their instruction. The implications of this are discussed in chapter 5.

**Evaluation of the Model**

The Transactional Model was selected because of the need for a model that was aligned with the purpose of the study, which was to assess professional development. The model served as the foundation for the development of the SCIS instrument. Previous models did not exhibit the detail that would enable a more detailed assessment that was needed in this study.

The Integrative, Transformative and Hierarchical Models are functional for the discussion of the paradigm of PCK, but lack the functionality of the Transactional Model. The Integrative and Transformative Models approach PCK holistically. The Hierarchical Model does detail some components of PCK but separates them from Content Knowledge and Knowledge of Students.

The Transactional Model identifies the constructs but not in a hierarchal sequence. Each of the three clusters is of comparative weight in the model, as are each if the nine imbedded constructs. The reason for this delineation is to better identify the change, or lack of change within each construct.

Professional development is designed to improve instruction by providing skills and knowledge within the categories of pedagogy, content and context. To be constructive, an evaluation needs to assess in greater detail the influence of the
professional development. To over-generalize, the participant could be asked, “Was it
good?” To diagnose the strengths and weaknesses of professional development,
specific information must be ascertained.

The SCIS derived from the Transactional Model was designed for this
function. It provided a richer description of the event of professional development as
in the following: The Relevance construct refers to relating what is learned in the
classroom to the world of the student outside of school. The teacher should make
these connections explicit as to enhance the meaningfulness of the learning. In the
comparison of the pretest and posttest mean for this construct, the $t$-ratio for Group 1
is 0.394 and for Group 2, -0.250. If only a T-test was done, it would appear that the
instructor did not excel in improving the teachers’ rating on this construct. However,
by looking at the pretest scores it is noted that Group 1 had high pretest scores,
indicating that the participants rated themselves high prior to the professional
development and high on the posttest one semester later.
End Notes for Chapter IV

1. For this small N size, the t-ratio for significance at the < .05 level is 2.064 and for < .10 is 1.711, and none of the values reached this level.
CHAPTER V

CONCLUSIONS, RECOMMENDATIONS AND IMPLICATIONS

The importance of effective and efficient professional development is, and will continue to be, an issue in education. The proliferation of standards, benchmarks and exit testing intensifies the need to develop quality professional development experiences for teachers that will help them improve their effectiveness in the classroom. Furthermore, the changing school calendars and increased demands on teachers underscore the need for professional development opportunities of shorter duration than in years past.

The initial purpose of this study was to assess the differential effect of two versions of professional development on the teachers’ pedagogical content knowledge. At first the task seemed elementary. All that was needed to be done was to define Pedagogical Content Knowledge, find an instrument that measures PCK and assess the impact of PD. However, the review of the literature resulted in multiple definitions from many sources and multiple models. None of the models fit the task given; thus, a new model was developed. PCK instruments were found, but none fit the definitions and model. Thus, a new instrument was developed.

Analysis of Constructs and Instrument

Revision of the instrument at the point of pilot testing produced a fairly reliable instrument with relatively high correlations between constructs and items. The Likert-type instrument was on a five-point scale. A difficulty arose when the
pretest scores were high. At this time, a seven-point scale may be been more suitable and discriminating, giving the teachers wider range of choices.

As stated before, the Transactional Model was developed because of the need for a model that was aligned with the purpose of the study, which was to assess professional development. The model served as the foundation for the development of the SCIS instrument. The previous models did not exhibit the detail that would enable a more detailed assessment of each construct that was needed in this study.

The Integrative, Transformative and Hierarchical Models are useful for the discussion of the paradigm of PCK, but lack the functionality of the Transactional Model. The Integrative and Transformative Models approach PCK holistically. The Hierarchical Model does detail some components of PCK but separates them from Content Knowledge and Knowledge of Students.

The Transactional Model identifies the constructs but not in a hierarchal sequence. Each of the three clusters is of comparative weight in the model, as are each if the nine imbedded constructs. The reason for this delineation is to better identify the change, or lack of change, within each construct.

Professional development is designed to improve instruction by providing skills and knowledge within the categories of pedagogy, content and context. To be constructive, an evaluation needs to assess in greater detail the influence of the professional development. To over-generalize, the participant could be asked, “Was it good?” To diagnose the strengths and weaknesses of professional development, more detailed information must be ascertained.
The SCIS instrument was based upon the constructs that are found in the Transactional Model. This was to provide a richer description of the events of professional development as in the following: The Relevance construct refers to relating what is learned in the classroom to the world of the student outside of school. The teacher should make these connections explicit as to enhance the meaningfulness of the learning. In the comparison of the pretest and posttest mean for this construct, the t-ratio for Group 1 is 0.394 and for Group 2, -0.250. If only a T-test were done, it would appear that the instructor did not excel in improving the teachers’ rating on this construct. However, by looking at the pretest scores it is noted that Group 1 had high pretest scores, indicating that the participants rated themselves high prior to the professional development and high on the posttest one semester later.

**Alignment of PCK constructs and FAST PD**

To discuss the relationship of what the Science Classroom Instructional Survey measured and the scope, content and sequence of the two institutes, it is necessary to assess the alignment of the PCK constructs the institutes.

The Science Classroom Instructional Survey instrument was developed from the literature and research done in the assessment of PCK. PCK seems to be congruent with the qualities of what some view as the experienced effective teacher (Livingston & Borko, 1989; Magnusson et al., 1999; Morine-Dershimer, 1989; Rowe, 1973; Stronge, 2002; Young & Pottenger, 1992). It was not written as a specific assessment tool for all of the objectives of the FAST institutes but specifically the influence of the PD upon the self-reported PCK of the teachers. It was developed
because previous instruments, such as the CTOI, CLES and Loghran’s Resource folio’s containing CoRe and PaPeRs, were not functional with the FAST PD designed.

In the one-week institute, all six of the tested constructs show gains from pretest to posttest, although small. In the two-week sessions, five of the six had small gains. A careful reading of the schedules of the two treatments, found in Appendix A and B, shows that both institutes have instructional time dedicated to assessment. In this institute time, models of evaluation instruments are presented and teachers actually assess themselves on the content presented over the first three days.

Sessions on Grouping and Questioning Strategies are found on the schedules for both the treatments. These topics align well with the Collaboration (which includes cooperative techniques) construct in the PCK model. This may contribute to significant differences in score for Collaboration and Discussion.

There is no instructional time shown on the schedule for Inquiry. However, the training itself models the role of the teacher as facilitator and the use of inquiry. The skill of the institute presenter on this particular construct may vary. The impact of knowledge of inquiry may need to be better defined within the activities of the institute.

The results show no significant differences between the two treatments on the measure of self-assessed PCK. In the comparison of the means of the two groups across the six constructs, it seems that there is not an advantage of one treatment over the other. This, however, does not completely explain the results.
The relationship of the two different schedules to the six constructs tested needs to be addressed. A major difference between the two treatments schedules was the time spent on the science content knowledge and the actual conducting of investigations. Treatment 1 covers Physical Science investigations 17 of the 40 investigations. Treatment 2 covers all forty investigations. In the Ecology strand, of the 32 investigations, the shortened treatment covers seven investigations. The third strand of the program is the Relational Study. In the original two-week schedule, about four hours are scheduled for this topic. In the shortened schedule, less than one hour is on this topic. The participants in the shortened session have much less familiarity with the investigations. The purpose of the DVD resource was to alleviate the lack of time spent on the investigations by providing a resource of information for the teacher. The extent to which the participants actually use the multi-media DVD for support was not measured and may have had an influence. Lawton (2005) cites this as an issue in his study of self-efficacy in the ScUp Project.

Besides addressing constructs that may apply to being a good teacher, the FAST PD was designed to build upon the knowledge of science and knowledge of the investigations that constitute the program. It is not expected that the PD will have instant impact upon the teachers and their classes but lay the foundation for future growth.

It is important to consider the objectives of the two institutes. According the FAST Institute Course Syllabus, the objectives are as follows:

The FAST teacher institutes are designed to prepare teachers to successfully teach the program in their classrooms by developing in participants
1. a thorough knowledge of the program’s philosophy and objectives,

2. an ability to use the variety of instructional strategies that are inherent in FAST,

3. an understanding of the content of physical, biological and earth science, and technology in FAST, and

4. an excitement and enthusiasm for teaching science at the middle/junior high school level (Young & Pottenger, 1997).

It can be said that the PCK constructs fit primarily within the first two objectives. There is however, the third objective that focuses on the content knowledge that was not assessed either within the FAST or the ScUp Project. Also, particular attention should be paid to the knowledge of inquiry and the structure of science. I return to the quote, “Until science teachers are able to view scientific inquiry as part of the content of science — and until teachers become well grounded in the history and philosophy of science — they cannot be educated to teach science as inquiry” (Rutherford, 1964 p. 80).

Large increases from pretest scores to posttest scores were not anticipated. The impact of a short PD will not be dramatic over a semester. However, hopefully the presentation of the constructs inherent in this model of PCK will produce knowledge of the characteristics of expert teachers and set forth a pattern of growth.

It may also be surmised that since the teachers in this study had a mean of over 9 years teaching experience, they may already have a higher level of Pedagogical Content Knowledge; in which case, the professional development may have little or no effect upon the constructs tested. Many of the previous studies have
focused on teachers just entering the profession of teaching (Loughran, 1999; Rowan et al., 2001; Vopava et al., 1997a). It may be assumed that these pre-service and beginning teachers have a lower beginning level of PCK.

In the four institutes presented in this study, three specialists were used. One specialist conducted one session of each treatment in Hawai‘i. Each of the other two specialists conducted one each of the treatments. One was in Maine and the other in Illinois. The effect of the specialist upon the scores is not known.

The Research Question

The original research question was, "is there a difference in the two models of the professional development and the impact upon their self-reported Pedagogical Content Knowledge?" The results do not indicate that there is not a difference between the two professional development models. However, this study has postulated other questions along the way.

Is PCK a viable paradigm or another buzzword? This researcher believes that even though researchers have not always agreed upon exactly what constitutes PCK, it seems that there is a common belief that expert teachers possess this knowledge. It is believed that effective teachers use this knowledge to improve student learning. Therefore, for the purpose of designing and developing situations in which teachers can enhance their knowledge, the term Pedagogical Content Knowledge is useful for dialogue. It may be more useful with pre-service teachers and novice teachers. This is because in the early years of teaching, teachers may not yet be aware of the variety of knowledge, skills and techniques available to improve teaching. In this study,
however, the mean teaching experience was over nine years. The participants may have begun the study at a higher level of PCK.

Two products resulted from this study. First, a new model of PCK was developed that is applicable to assessment of professional development. Secondly, an instrument was developed that has an acceptable level of construct validity.

Implications

The developers of the FAST professional development are concerned with the amount of time needed and the efficiency of the institutes for dissemination of the program. This study found no significant difference in the effect of the two treatments on teachers' perception of their PCK. And, since there is no difference, the lengthy PD can be replaced with the shorter, enhanced version if the primary purpose is developing PCK. This, however, should be done with caution. Teachers' PCK is not the only objective of the institutes. As cited previously, the list of objectives show content knowledge as well as the experience with the program to successfully implement the program as being primary. The content presented, that is, the actual investigations presented in the shorten schedule, cover less than half of the school year. To provide the teachers with the knowledge of these investigations not covered in the institute, the electronic resource material was provided. How much the resource will be used as well as the effectiveness of the resource to answer questions the teachers may have had not been assessed. Lawton (2005) cites this as a concern in his study on the effects of the two models on the teachers' self-efficacy.
Suggested Further Study

This study looked at only a small sample of teachers and only at their self-reported perceptions of their PCK. There are multiple avenues for future study. The term "PCK," this researcher believes, is a viable paradigm and current studies have not exhausted possible research.

The instrument in this study should be revisited and piloted with a larger population to refine its validation. This would enable the recovery of the three constructs not included in the final instrument.

The SCIS instrument might be administered to pre-service science teachers, pre and post student teaching, to assess change in their PCK. Principals or curriculum supervisors could use the SCIS instrument with novice teachers during their initial years of teaching to measure the growth of PCK. And, the instrument could be administered to veteran teachers as a reflective tool to assess their PCK development.

Data from the administration of the instrument to these three groups could be compared to better determine the relationship between years of experience and PCK level, as well as the period of time when PCK develops most rapidly.

The PCK paradigm is currently being used within pre-service courses where it is serves as point around which teacher development can be discussed. A promising area of research is the longitudinal study of teachers entering the field and their development of PCK.

The professional development of the FAST program still has unanswered questions. First is the assessment of the effect of the professional development on the science content knowledge. Although originally part of the ScUp Project, the research
was not completed. Secondly, the effectiveness, efficiency, and use of the electronic resource need to be assessed. It is not known how, or if, the electronic resource was used, or its effect on teacher professional development. If the dissemination of this media is to continue, more should be known about the use.
REFERENCES


94


97


Influence on new teachers and their students. Final report to US department of Education. Iowa City, Iowa: Science Center, University of Iowa.


APPENDICES
### APPENDIX A
FAST One Week (5 day) Schedule (Treatment 1)

### FAST 1 The Local Environment

#### ONE-WEEK INSTITUTE SCHEDULE

<table>
<thead>
<tr>
<th>Day 1 AM</th>
<th>Day 2 AM</th>
<th>Day 3 AM</th>
<th>Day 4 AM</th>
<th>Day 5 AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to FAST</td>
<td>Collect \textit{E2} data</td>
<td>PS 8</td>
<td>E30 Mapping Class Study</td>
<td>Discussion Questioning Strategies</td>
</tr>
<tr>
<td>What is inquiry?</td>
<td>\textit{FAST} Overview</td>
<td>Cartesian Diver</td>
<td>Area</td>
<td>PS15 Bubbles and Gases</td>
</tr>
<tr>
<td>PS 1 Liquids and Vials</td>
<td>Science Standards</td>
<td>PS9 Density of Cartesian Diver</td>
<td>E26 Care of an Animal in the Laboratory (Talk)</td>
<td>PS16 Density of Gases</td>
</tr>
<tr>
<td>PS 2 Mass and Sinking Straw</td>
<td>Student Books</td>
<td>Grouping (Soap POE)</td>
<td>E6 Soil Composition</td>
<td>PS17 Weather Balloons</td>
</tr>
<tr>
<td>PS 3 Graphing Straw Data</td>
<td>E 27 Initial Survey</td>
<td>PS10 Density of Objects</td>
<td>E7 Comparing Soils</td>
<td>Project</td>
</tr>
<tr>
<td>PS 4 Mass &amp; Sinking Straw</td>
<td>E 28 Ecological Changes in Small Area</td>
<td>PS11 Density of Liquids</td>
<td>E8 Soil and Roots</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E 3 Propagating Plants</td>
<td>PS12 Buoyancy of Liquids</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>E 4 Oral Reports</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>E 5 Written Reports</td>
<td></td>
<td></td>
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<tr>
<td>PM</td>
<td>PM</td>
<td>PM</td>
<td>PM</td>
<td>PM</td>
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<tr>
<td></td>
<td></td>
<td>Evaluation Guide</td>
<td></td>
<td>Plans for follow-up</td>
</tr>
</tbody>
</table>

104
### APPENDIX B
FAST Two Week (10 day) Schedule (Treatment 2)

## FAST 1, The Local Environment

### INSTITUTE SCHEDULE

<table>
<thead>
<tr>
<th>DAY 1 AM</th>
<th>DAY 2 AM</th>
<th>DAY 3 AM</th>
<th>DAY 4 AM</th>
<th>DAY 5 AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registration</td>
<td>FAST OVERVIEW</td>
<td>PS 8 &amp; 9</td>
<td>Ecology 29 &amp; 30</td>
<td>Discuss QUESTIONING STRATEGIES in FAST</td>
</tr>
<tr>
<td>Introduction to FAST</td>
<td>Science Standards</td>
<td>Discussion on GROUPING</td>
<td>Field Mapping</td>
<td>PS 15, 16, &amp; 17</td>
</tr>
<tr>
<td>What is Inquiry?</td>
<td>Student Books</td>
<td>PS 10, 11, &amp; 12</td>
<td>Ecology 26</td>
<td></td>
</tr>
<tr>
<td>PS Problems 1-4</td>
<td>Ecology 27-28</td>
<td></td>
<td>Animal Care</td>
<td></td>
</tr>
<tr>
<td>LAB SAFETY</td>
<td>Ecology 4-5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral/Written Reports</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>PM PM</td>
<td>PM PM</td>
<td>PM PM</td>
<td>PM PM</td>
<td></td>
</tr>
<tr>
<td>Ecology 1 &amp; 2</td>
<td>PS 5, 6, &amp; 7</td>
<td>TEACHER'S GUIDE Format &amp; Content</td>
<td>PS 13 &amp; 14</td>
<td>Ecology 6, 7, &amp; 8</td>
</tr>
<tr>
<td>FLOW DIAGRAMS</td>
<td>CGS</td>
<td>EVALUATION Evaluation Guide</td>
<td>Balloons In Water Submarine</td>
<td>Soils</td>
</tr>
<tr>
<td></td>
<td>Assign Reading on GROUPING</td>
<td>PS Evaluation 3</td>
<td>Assign Reading on QUESTIONING STRATEGIES</td>
<td>Ecology 17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Assign PLANT PROPAGATION</td>
<td></td>
<td>Weather Station</td>
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<tr>
<td>PM PM</td>
<td>PM PM</td>
<td>PM PM</td>
<td>PM PM</td>
<td></td>
</tr>
<tr>
<td>THE FAST Instructional System</td>
<td>PS 23 - 28</td>
<td>Ecology 18 - 25</td>
<td>PS 34 - 40</td>
<td>Relational Study</td>
</tr>
<tr>
<td>Ecology 31 &amp; 32</td>
<td></td>
<td></td>
<td></td>
<td>Air Pollution</td>
</tr>
<tr>
<td>PS 18 &amp; 19</td>
<td></td>
<td></td>
<td></td>
<td>OR Water Resource Management</td>
</tr>
<tr>
<td>PM PM</td>
<td>PM PM</td>
<td>PM PM</td>
<td>PM PM</td>
<td></td>
</tr>
<tr>
<td>PS 20, 21, &amp; 22</td>
<td>Ecology 9 - 16</td>
<td>PS 29 - 33</td>
<td>Collect and analyze Seed Scarification Data</td>
<td>Summary of FAST 1</td>
</tr>
<tr>
<td>SUBMARINES</td>
<td></td>
<td></td>
<td>Plant Propagation Reports</td>
<td>Planning for the</td>
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<td>Academic Year</td>
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</tr>
</tbody>
</table>

105
### Science Classroom Instructional Survey

*Instructions:* Please reflect on the activities that you and your students do in your science classroom. For each item, circle the letter that best reflects your classroom.

<table>
<thead>
<tr>
<th>Item</th>
<th>Circle one response for each item.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Students in my science classes talk with each other about how to solve problems.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>2. Students in my science classes learn how science can be part of their daily lives.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>3. I write comments on students' science work.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>4. Students show respect for the ideas of others in my science classes.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>5. Students share knowledge in the classroom science laboratory.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>7. Students propose alternative explanations to phenomena in my science classes</td>
<td>N R S O A</td>
</tr>
<tr>
<td>8. My science students like to keep their data to themselves.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>9. Students in my science classes work best individually.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>10. Students in my science classes use mathematics to support convincing explanations.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>11. Students in my science classes are able to interpret graphs.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>12. Students in my science classes offer to explain their ideas to one another.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>13. A grade is sufficient feedback for my science students.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>14. Students in my science classes explain their ideas to each other.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>15. Students in my science classes discuss the connections between classroom learning and their daily lives.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>Item</td>
<td>Circle one response for each item.</td>
</tr>
<tr>
<td>---------------------------------------------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>16. I provide science students with needed feedback to improve their work.</td>
<td>Never</td>
</tr>
<tr>
<td>17. Science student time is best spent reading the book.</td>
<td>N</td>
</tr>
<tr>
<td>18. My primary assessment of students focuses on completion of work.</td>
<td>N</td>
</tr>
<tr>
<td>19. I use multiple science assessment types (e.g., quizzes, projects, reports, or lab practicals).</td>
<td>N</td>
</tr>
<tr>
<td>20. Quizzes are the best method for finding out what students understand in science classes.</td>
<td>N</td>
</tr>
<tr>
<td>21. Part of my job is to supply materials, tools, and resources for my science students.</td>
<td>N</td>
</tr>
<tr>
<td>22. New data from science investigations can change students' ideas.</td>
<td>N</td>
</tr>
<tr>
<td>23. My students feel safe in expressing themselves in science discussions.</td>
<td>N</td>
</tr>
<tr>
<td>24. My science students learn best when they work alone.</td>
<td>N</td>
</tr>
<tr>
<td>25. My science classroom supports collaboration among students.</td>
<td>N</td>
</tr>
<tr>
<td>26. My science classroom is arranged for interaction among students.</td>
<td>N</td>
</tr>
<tr>
<td>27. It is more important to teach for content than to teach for broad conceptual understanding.</td>
<td>N</td>
</tr>
<tr>
<td>28. In my science classroom, students must support statements with evidence.</td>
<td>N</td>
</tr>
<tr>
<td>29. In my science classes, learning science content is more important than learning science processes.</td>
<td>N</td>
</tr>
<tr>
<td>30. Learning science helps my students in their daily lives.</td>
<td>N</td>
</tr>
<tr>
<td>31. If students ask me if their data are correct, I answer yes or no</td>
<td>N</td>
</tr>
<tr>
<td>32. Teachers should use a variety of assessments in the science classroom</td>
<td>N</td>
</tr>
<tr>
<td>Item</td>
<td>Circle one response for each item.</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td>33. I commend students when they have done a good job.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>34. Students in my science classes have opportunities to talk to each other about their classroom work</td>
<td>N R S O A</td>
</tr>
<tr>
<td>35. I provide feedback to my science students.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>36. I provide examples of how science concepts apply to daily life.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>37. I ask students to evaluate their own data or conclusions.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>38. I like to keep science student desks in straight rows.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>39. I use item completion and fill-in-the blank assessments.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>40. I ask students in my science classes why they think their answers are correct.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>41. I encourage my students to master their science textbook.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>42. I change my science teaching based on assessment results.</td>
<td>N R S O A</td>
</tr>
<tr>
<td>43. I ask students if they agree or disagree with data presented by their peers.</td>
<td>N R S O A</td>
</tr>
</tbody>
</table>