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ABSTRACT

The purpose of this study was to determine the effects of an implementation plan that would support middle school science teachers as they integrated a specific technological tool, Calculator-Based Laboratory (CBL) probeware. The final goal of the implementation process was pedagogical and curricula transformation by the participants. The implementation plan used for the study was the ST3 AIRS Model, which consists of eight steps developed to overcome contextual barriers to technology integration. Five teachers, who taught in grades six through eight, participated in this empirical multiple-case study using a qualitative and quantitative approach. Simultaneous data collection and analysis were accomplished through data reduction and interpretation. Construct validity was accomplished by triangulation of multiple sources of data. External validity of the data analysis and findings was accomplished by correlation of findings with middle school science teachers who participated in a separate program involving this technology. The inductive findings of the study indicated that 80% of the participants conceptually had short-term pedagogical and curricula transformation, as they successfully integrated CBL in their curriculum. With the support of the ST3 AIRS Model framework, the teachers overcame contextual barriers that included learning to use the technology, adequate staff development, and pedagogical support. (Contains 74 references.) (PVD)

A Model for Pedagogical and Curricula Transformation for the Integration of Technology in Middle School Science

by

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Abstract

The purpose of this study was to determine the effects of an implementation plan that would support middle school science teachers' as they integrated a specific technological tool, Calculator-Based Laboratory (CBL) probeware. The final goal of the implementation process was pedagogical and curricula transformation by the participants. The implementation plan used for the study was the ST^3AIRS Model, which consists of eight steps developed to overcome contextual barriers to technology integration. Five teachers, who taught in grades six through eight, participated in this empirical multiple-case study using a qualitative and quantitative approach. Simultaneous data collection and analysis were accomplished through data reduction and interpretation. Construct validity was accomplished by triangulation of multiple sources of data. External validity of the data analysis and findings was accomplished by correlation of findings with middle school science teachers who participated in a separate program involving this technology. The inductive findings of the study indicated that 80 % of the participants conceptually had short-term pedagogical and curricula transformation, as they successfully integrated CBL probeware in their curriculum. With the support of the ST^3AIRS Model framework, the teachers overcame contextual barriers that included learning to use the technology, adequate staff development, and pedagogical support.

Introduction

The purpose of this study was to investigate the factors that influenced five middle science teachers as they implemented and integrated a specific type of instructional technology Calculator-Based Laboratory (CBL) probeware in their curriculum. Along with determining what effects the implementation and integration of this instructional technology tool had on their pedagogy and curricula. The study involved empirical research with both qualitative and quantitative data. Data analysis included a cross-case analysis of multiple case studies (Yin, 1994). Data were gathered August 1999 through December 1999. This time period was selected because it was the first opportunity for the participants to implement and integrate CBL probeware in their curriculum, as well as, the opportunity to test the ST^3AIRS Model in a school setting from beginning of implementation and integration of a new technology.

The research data were collected through interviews, questionnaires, anecdotal records, and observations of teachers. Triangulation of data reduced researcher bias, along with contributing to increased reliability and validity of the study. Findings of the research present a holistic view of the factors that influenced these teachers and the ST^3AIRS Model. The holistic approach to this study presents a view of influences on teacher level of technical proficiency with CBL probeware, level of actual use during integration in their curricula, changes in pedagogy, changes in organizational culture and climate, and curricula transformation related to the integration of the CBL probeware.

Problem

The availability of instructional technology for teachers is increasing in middle school science to meet societal demands and goals. Society's goals include the use of instructional technology as part of everyday instruction in school science to prepare children to meet the needs of an increasing technological dependent culture (ISTE, 1998). These goals include the implementation and integration of instructional technology to facilitate the teaching and learning process through curricula transformation. However, teachers have not rushed to change their classroom instructional strategies or shift their pedagogical practices to include instructional technology. This transpires in spite of increased accessibility to better hardware and software, along with an increase in staff development opportunities (U.S. Congress, Office of Technology Assessment, 1995). Teacher resistance to change is primarily due to their concerns regarding the influence of instructional technology integration on their preparation, beliefs, and values. These concerns include teacher technical ability and proficiency with instructional technology, along with organizational culture and climate influences that are beyond the control of the teachers (Dexter, Anderson, & Baker, 1999). These concerns include the influence of their school climate and culture facilitating or presenting barriers as they implement an innovation within their curriculum (Becker & Riel, 1999a; Salpeter, 1998; O'Neil, 1995; U.S. Congress, Office of Technology Assessment, 1995; Becker, 1991).

Research by the U.S. Congress' Office of Technology Assessment (1995) indicated that many of these influences present barriers to teachers. These barriers include time to learn, access to equipment, adequate staff development, technical support, a shared vision of the appropriate use of instructional technology by schools and teachers, planning time for integration, teacher apathy due to conflicting vision/goals of school systems, and adequate funding (U.S. Congress, Office of Technology Assessment, 1995). Although there is an increased emphasis by school systems to support their teachers, the mere presence of instructional technology in the classroom is not an assurance that science teachers will integrate the technology in their curriculum (Ravitz, Wong, & Becker, 1999).

Becker and Riel's (1999a) research found that the work of integrating instructional technology strategies into practice is a complex process and that teachers encounter either a bureaucratic culture or a professional culture in their school. Bureaucratic cultures tend to give teachers autonomy in their classrooms, but restrict their participation in curricular and organizational decisions. The bureaucratic culture hinders innovative practice and collaboration among teachers. In contrast, professional cultures support innovation and collaboration among teachers. In this culture, decisions are based on a guiding philosophy about teaching and learning and sensitivity to the learning needs of students.

In previous research, Becker (1991) found that only 5 % of technology implementation programs succeed beyond a three-to-five-year period in schools. Research by Eastwood, Harmony, and Chamberlain (1998) continue support for Becker's findings. Additionally, their findings were that apathy, technical, cultural, and climate influences present barriers to teachers as they attempt to implement an innovative technology program. Teachers' pedagogy, as related to instructional technology, reflects their beliefs and values. Nevertheless, their practices, and to a lesser extent their philosophies, are subject to influence based on their experiences in teaching, along with expectations transmitted to teachers through formal rules, procedures, and school norms by school administrators (Glazer, 1999). Despite all the promises that instructional technology brings to the science classroom to transform teaching and learning, the U.S. Congress' Office of Technology Assessment's (1995) research findings indicated that little change in teachers' pedagogy occurs due to these factors:

- Most teachers learned their teaching practices during the period of time prior to current instructional technology availability and practices.
- Teachers have not received adequate pre-service preparation despite the importance of technology in teacher education and it is not central to their preparation in most colleges.
- Teachers report not having adequate inservice staff development to prepare them to use technology effectively in teaching opportunities.

Background

CBL probeware technology was selected for this study because it was a new innovation for middle school science in Virginia. The Virginia Department of Education (1997) spent $16.5 million for graphing calculators and CBL probeware hardware for both high schools and middle schools, which was a new innovation for middle school science. The purpose of the Graphing Calculator and Scientific Probe Initiative (VDOE, 1997) was to reform and transform science teaching in middle school science by providing an instructional technology tool for collecting real-time data using scientists' investigative techniques. Distribution was based on the number of middle school students enrolled in Algebra classes. The total number of CBL probeware systems distributed by the VDOE exceeded 6,000. The desired ratio was four graphing calculators to one CBL probeware system received by each middle school, although each school could vary this ratio. Of the number of CBL probeware systems provided, 70 % were purchased from Texas Instruments while the remaining 30 % where purchased from Casio (VDOE, 1997).

CBL probeware was provided by the VDOE (1997) for integration in middle school mathematics and science curricula as a method of implementing an affordable technological real-time data collection system for students, as well as supporting the Virginia Standards of Learning (SOL) (Board of Education Commonwealth of Virginia, 1995). The Virginia SOL prescribed the role of instructional technology in science education to include CBL probeware, along with other instructional technology tools (Board of Education, Commonwealth of Virginia, 1995, p. 34).

The middle school in this study was one of the 70 % of schools that had selected Texas Instruments CBL probeware, placing the school in the category having the type of CBL hardware selected by the majority of the school systems in the state. Therefore, this study allowed the findings to focus on the CBL probeware that is most commonly used in Virginia middle schools. However, most factors that influenced the implementation process by middle school science teachers in this study are common to both Texas Instruments and Casio, even though both Texas Instruments and Casio probeware system types have their own unique hardware and software specific influences.

Significance of the Problem

Educational institutions must produce technologically capable students who will live, learn, and work in an ever-increasing technologically complex and information-rich society. Students need to have effective technology skills when they enter the work force. Within a sound educational setting, instructional technology can enable students to achieve societal goals (ISTE, 1998): capable information technology users; problem solvers and decision-makers; creative and effective users of productivity tools; use of content specific tools, such as probeware and graphing calculators, in exploratory environments to support learning and research by the users; and users select and use appropriate tools and technology resources to accomplish a variety of tasks and solve problems.

While International Society for Technology in Education's (1998) goals for students are not all-inclusive, instructional technology has strongly influenced the nature of science and human society. The use of technology in science education has grown out of the personal experiences of scientists as they investigate the properties of objects and use technological tools for manipulating variables during investigations. Technological tools, such as probeware, provide scientists' real-time eyes and ears for data collection. These tools are essential for purposes of accurate measurement, data collection, and computation. As technology advances, new instruments and techniques are developed through the technological applications in science that make it possible to advance scientific research (National Research Council, 1996; American Association for the Advancement of Science, 1989).

Virginia's CBL Probeware Implementation

Middle school science teachers in Virginia received CBL probeware systems from the VDOE (VDOE, 1997) for implementation and integration in their science curricula. VDOE's purpose was the transformation of curricula to include more technology through the implementation of CBL probeware, along with computer-based instructional technology. Although the VDOE provided the hardware to the school systems, the schools systems were given the responsibility for staff development. As with any new innovation, middle school science teachers encountered little support for and many barriers to implementation of this technology. The challenge to middle school science teachers was that their prior knowledge and experience with instructional technology was computer-based, whereas CBL probeware is graphing calculator-based. These teachers do not typically use graphing calculators in middle school science. Even with the distribution of CBL probeware by the VDOE (1997), little or no staff development opportunities were provided for the these middle school science teachers (Wetzel, 1998; VDOE, 1998a; VDOE, 1998b; Wetzel, 1997).

After providing CBL probeware to schools, VDOE provided a televised course on the basic operation of the Texas Instruments (TI)-82 graphing calculator. This staff development was not adequate for the graphing calculators provided to school systems, because VDOE provided TI-83 and Casio graphing calculators. While TI-82 and TI-83 graphing calculators are similar

(Texas Instruments, 1994; VDOE, 1998a), there are enough differences to cause confusion among teachers unfamiliar with the technical aspects of graphing calculators. The majority of staff development was mathematics teacher specific, with only a minor part designed for science teachers. As a result, staff development concentrated on mathematics implementation with little focus on science teachers (VDOE 1998a). Again, the staff development responsibility for science teachers was given to school systems (VDOE, 1998b).

Realizing the problems that were associated with TI-82 versus TI-83 graphing calculator staff development, VDOE provided a new televised training program using the TI-83 graphing calculator in January-February 1999 (VDOE, 1999). They also provided televised staff development for science teachers using the CBL probeware system. Although this staff development focused on high school teachers, middle school science teachers could participate in the sessions. High school teachers, not middle schools teachers, conducted the CBL probeware staff development, and all laboratory activities were designed for high school science (VDOE, 1999). The teachers involved in the study had not had the opportunity to view these VDOE staff development sessions. Therefore, the teachers in this study were unprepared to use implement and integrate probeware in their curricula.

What is CBL Probeware?

CBL probeware is a system that is composed of sensor probes, a CBL System or data collecting device, and a graphing calculator. Sensor probes can be used to electronically collect real-time data for temperature, motion, voltage, and light. The second component of the system is the CBL data-collecting device, which executes the program data collection rate and number of samples to be taken. The third part of the CBL probeware system is the graphing calculator. The graphing calculator has three functions that include the operation of the program that controls the CBL data collection device, storing data for manipulation, and presenting graphical displays of data. The CBL system probeware sensors transform a graphing calculator into a mini-science laboratory system (Texas Instruments, 1994). Figure 1 presents the major components of a CBL probeware system (Texas Instruments, 1994).

Literature Review

Review of the literature found that previous research concerning Calculator-Based Laboratory (CBL) probeware concentrated on high school science and mathematics teachers. Additional research regarding the related Microcomputer-Based Laboratory (MBL) probeware involved high school science and mathematics teachers, along with elementary science teachers (Rogers, 1997; Settlage, 1995; Krajcik & Layman, 1989; Linn, Layman, & Nachmias, 1987). The limitation of published research concerning CBL probeware implementation and integration with middle school science teachers in a school setting sets the stage for this study to be unique in relation to previous research.

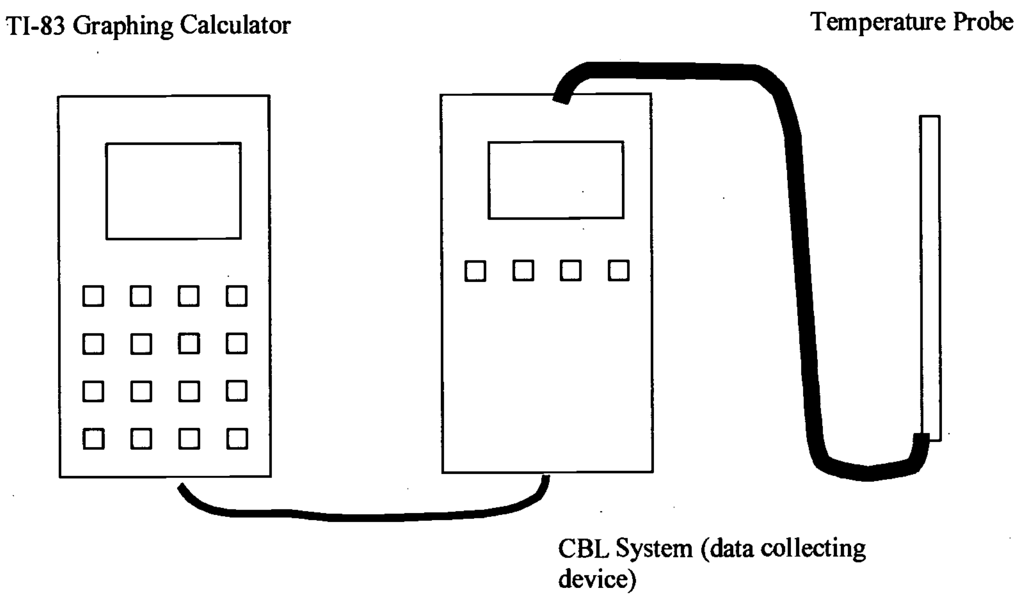


Figure 1. Calculator-based laboratory (CBL) probeware system.

The literature regarding implementation, integration, and transformation is broad-based with respect to instructional technology. Since CBL probeware is a specific instructional technology tool, the broad-based literature does not adequately represent the specific underlying concerns and changes teachers make in the integration and the ultimate transformation of their pedagogy. The findings of this study provide supporting research in this area with an in-depth analysis of factors that influenced five middle school science teachers.

Applying the Literature to a Specific Technology

For teachers to successfully implement and integrate instructional technology, they need to take ownership in the process. Change is difficult and the process may span a period of years (Fullan, 1991; Loucks, 1983). Those concerned with the implementation of a new instructional technology tool must recognize the teachers' role in this process (Becker & Riel, 1999b). For sustained change by teachers, they need emersion in new instructional strategies related to a new technological tool. Also, the imposition of instructional technology innovations on teachers, without adequate attention to pedagogical underpinnings and consideration of classroom organization does not always result in classroom change. Additional previous research by Bowers (1988) found that teachers are reluctant to change established classroom practices in response to expectations to use innovative materials and electronic devices. They must first be convinced that new approaches are efficient and effective with their students.

Middle school science teachers have many demands on them during the course of a school day. They have little or no time allotted to explore new innovations, to collaborate with other teachers regarding new teaching strategies, and to integrate instructional technology in curriculum. Unless there are significant changes in a school's organizational procedures and goals to provide more time for teachers to learn and explore new strategies, this barrier will remain the most difficult to overcome (Ravitz, Wong, & Becker, 1999). As with any profession, staff development time must be invested by school systems' to allow their teachers time to operate and integrate a new hardware or software innovations (Becker & Riel, 1999b). The review of the literature is divided into three areas: the culture of instructional technology and science education; teachers' beliefs and change regarding instructional technology; and contextual factors that influence the use of instructional technology by teachers.

The Culture of Instructional Technology and Science Education

Instructional technology and science education are almost like two ships that pass in night. They silently pass without communicating with each other or about their relationship since they have evolved into two different cultures, technology education and science education. In fact, technology and science education paths diverged due to specialization (Lux, 1984). The cultural environment of technology and science teachers perpetuates this artificial separation of technology and science for their students. Philosophers and educators, such as Dewey (1925) and Snow (1959), recognized the error of this path early on and often argued against, particularly from an educational point of view, the separation of technology and science. Today we are still faced with the same dilemma. This artificial separation leaves us all with an incomplete and less sophisticated understanding of interrelationships and functioning of instructional technology and science (Zuga, 1991).

The integration of instructional technology in schools is a fact of life in American education. Along with integration, the ability of students to use instructional technology is recognized as an essential skill by society. Recognizing the responsibility to prepare students to work and live in a technological society, national education standards recommend integration of instructional technology in teaching science. These standards include the *National Science Education Standards* (NRC, 1996), *National Education Technology Standards for Students* (ISTE, 1998), and *National Education Technology Standards for Teachers* (ISTE, 2000). These three standards advocate the use of instructional technology by teachers to encourage students to become active participants in the learning process and to use the standard methodology of scientists. Examples of these standards for students are the use of CBL probeware to collect real-time data, organizing sets of data, and analyzing graphs of complex data to understand scientific phenomena (ISTE, 1998; Bowman & Davis, 1997).

Instructional technology and science may be expressed in basic terms of technology being viewed as a human endeavor to modify one's environment and science as a human endeavor to explain one's environment (Lux, 1984). Each is a human activity, directed by humans to fulfill wants and needs. Therefore, we control technology and science. The distinction is made merely as a means of distinguishing the role of each in a complex pattern of relationships. Whether we chose to modify our environment slightly or alter it radically in order to live within it, technology is a fundamental value chosen by society (Ihde, 1990).

The separation of technology and science for purposes of study and the tendency to blur the distinctions between technology and science by practice is evident in our school curricula. Education created separate curricula for technology and science education that are on unequal footing. Moreover, this is an unrealistic representation of the role of technology and science in our society and the relationships between technology and science (Zuga, 1991).

The artificial separation of technology and science for the purposes of analysis and study does not exist in real-world applications. The relationship between technology and science is symbiotic; both are necessary for advancement of knowledge in human endeavor. Today, the relationships between the activities of scientists and technologists are established and modified faster than science teachers can identify and describe them. The key concern for these teachers is how to best unify the teaching of science and technology. Science education literature is filled with the call for integration of these two subjects, but the execution has not been widespread (AAAS, 1989).

Teachers' Beliefs and Change Regarding Instructional Technology

Although teachers have the advantage of an unprecedented amount of instructional technology for use in their classrooms and schools, little evidence indicates that teachers systematically integrate technology in their classroom curriculum (Eastward, Harmony, & Chamberlain, 1998). Several factors erode efforts by school districts or schools as they make an effort to sustain an effective technology program. Factors that influence their efforts include a focus on hardware rather than on implementation processes, a weak implementation planning process that fails to meet the needs of teachers, and little or no professional staff development (Eastward et al., 1998). To be successful with technology implementation, teachers need to change their pedagogy. This teacher change is a process that requires a shift in a teacher's paradigm as he or she implements a new innovation that has an influence on their pedagogy (Dexter, Anderson, & Becker, 1999; Fullan, 1991; Honey & Moeller, 1990).

Change is a process that may span a period of years and the recognition of this process by those concerned during the implementation of a new instructional strategy or technological tool is important (Fullan, 1991). Individual teachers can accomplish change, but only when these teachers take ownership in a new instructional strategy or technological tool will sustained change take place. Fullan's (1991) research findings were that this change may take two to three years for a new technology tool to be fully implemented and integrated within a curriculum. Some teachers will adapt the use of a new technological tool quicker than other teachers, while others resist the change altogether.

Teacher Change

Change is a personal human experience that needs to be considered by school systems and change facilitators when implementing a new program. To successfully implement the integration of a new technological tool, consideration of what the implementation will mean to teachers' personal beliefs and values is of great concern. How will it affect their current classroom practices, preparation time, beliefs regarding technology, and values? What factors directly and indirectly influence teachers' integration of instructional technology (Dexter, Anderson, & Becker, 1999; Knapp & Glenn, 1996; Honey & Moeller, 1990; Hall, 1974)?

Teachers' beliefs and values regarding change that are incompatible with the implementation and integration of a new instructional technology tool are a major obstacle (Anderson et el., 1994). For these teachers to accept change in their pedagogy to adapt a new technological innovation, they must first experience conflict within their expectations. For teachers to conceptually change their teaching strategies and techniques, they need to (Posner, Strike, Hewson, & Gertzog, 1982): become dissatisfied with their existing conditions; view change as intelligible; view change as plausible; and find change useful in a variety of new situations.

Effective change must address implementation and integration in concrete and practical terms to reduce the inherent human nature of resistance to change. The novelty or uniqueness of a new technological tool alone will not produce the desired change, only when teachers' change their epistemology does change take place. To be successful in the implementation of change, policy makers need to pay attention to teacher needs, recognize that change takes time, understand that teachers tend to demonstrate growth in relation to their personal feelings and skills, and that change is not an event. Change is a process (Hord, Rutherford, Huling-Austin, & Hall, 1987).

Through time teachers have developed resilient teaching practices, due to ever shifting goals and policies that influence their pedagogy. To accommodate this process, teachers look for and use reliable teaching strategies effective with large groups of students in small places. They must be convinced that new strategies are efficient and effective (Bowers, 1988). Because of this, most change and innovation in education does not reach institutionalization or stabilization in schools.

To effectively understand the process of teacher change, one must adhere to the premise that a teacher becomes a learner. Teachers who want to change are teachers who want to grow and do not believe in the status quo. Teachers who are reflective are continually trying to do what is best for their students. Schubert and Ayers (1992) contended that only reflective teachers continuously grow.

Wittrock (1974) found that teachers construct or generate meaning though sensory input. Wittrock's findings are similar to Piaget's (1978) findings that individuals construct knowledge as they act on objects while trying to make sense of what they have discovered. The generative view of learning influences teacher beliefs and values as they implement and integrate new innovations as they construct meaning through their sensory input that may be contradictory to their current contextual influences (Osborne & Wittrock, 1983). The generation of a new teaching method or strategy is based on teachers' existing ideas and sensory input, which often causes a shift in their beliefs and values (Osborne & Wittrock, 1985).

Based on their review of case studies of how teachers implemented new programs in their classroom, Tobin and Fraser (1990) concluded that teachers' beliefs regarding how students learn and what they should learn appear to have the greatest impact on teacher change. When discussing teacher change, Richardson (1990) cited both teacher change literature and learning to teach literature. Learning to teach focuses more on individual teacher's cognitions, beliefs, and mental processes than on behaviors. She further explained that the two main components of teachers' way of knowing appear to be based on experience and the teacher herself/himself.

In their research involving 608 teachers, Buck and Horton (1996) found that teachers believed their teaching had been transformed by the incorporation of instructional technology in their classroom. These teachers perceived changes in their pedagogy that were threefold. First, they believed that they expected their students to study more complex material and that they taught concepts they had never considered teaching prior to using instructional technology. Second, the teachers believed they were able to meet the individual needs of their students. The third change was a shift from the traditional teacher-centered to a student-centered learning environment. These findings suggested that when teachers incorporate instructional technology in their curriculum there was pedagogical and curricula transformation to improve their students' learning of science concepts.

Teacher Beliefs and Values

A teacher's epistemology is a product of his/her own prior knowledge, development, and experience as teacher. Each teacher's teaching style is influenced by personal factors, including his/her personality and belief system. But all teachers' styles are influenced by the context of the organizational structure in which they teach. Teachers may profess valuing independent student accomplishment and successful collaboration among their peers, but statistical records of teachers' behavior typically report that these same teachers still use teacher-centered pedagogy (Brooks & Brooks, 1993). Brooks and Brooks (1993) found that teachers are predominately teacher-centered and generally behave in a didactic manner, disseminating information to students. This is due to teachers' beliefs that behavioral control is their biggest problem and that teacher-centered whole-class lessons are most conducive to quiet classrooms (Becker, 1991). For instructional technology to be successfully implemented, teacher beliefs and values need to shift. If not, the desired implementation and integration of instructional technology in education will not occur on a broad scale. Brooks and Brooks (1993) found that when teachers shift to an interactive manner, they are facilitating student learning. This becomes apparent when instructional technology is implemented in the classroom.

Teacher beliefs are critical to the success of any new innovation in education. All teachers have implicit and explicit beliefs regarding teaching and learning (National Research Council, 1996). Any change in pedagogy can only happen with a corresponding change in teachers' beliefs regarding the appropriateness of an innovation. Isenberg's (1990) research found that teaching and learning had shifted focus from the observable teacher behaviors to teacher beliefs and their impact on teacher behaviors. This research differs from earlier research that viewed teachers as technicians delivering a prepackaged curriculum. Researchers now acknowledge the powerful influence teachers have on curriculum innovations (Cronin-Jones, 1991).

For implementation of an innovation to be successful, teachers must believe that the innovation is not just an "idea of the month" that will disappear after two or three years. They must believe that their time and energy invested will improve their teaching and student learning. Teachers must be allowed to experiment with the innovation in a low risk environment and receive constructive feedback. Innovators and researchers must not ignore the complexity of relationships between a belief system and practice. Reform efforts must be grass roots not top-down or quick fixes (Clark & Peterson, 1986). This is due to the range of methods and approaches and the theories of teaching and learning demand extensive intellectual preparation and continual learning on the part of the teachers (Wiske, 1998).

From a Vygotskian perspective, humans develop and change as they interact with others and learn to make use of a culture's tools, both physical and psychological. So the constructions that humans make in their minds originate in interchanges with people and influence their beliefs and values. The transformation from the inter-psychological to intra-psychological takes place within a person's "zone of proximal development (ZPD)" (Vygotsky, 1978). Because the teacher is a learner when implementing and integrating an innovation, the teacher who is an expert becomes a novice. In learning new teaching strategies, a teacher's ZPD is concentrated learn new things that may conflict or support their beliefs and values. Teachers need to be reflective individuals to effectively, implement, change, and interact with colleagues and students (Martin, 1993). Since much of teacher change is revolutionary, teachers need time to reinforce and deter resistance to change. Martin (1993, p. 84) argued that "Without time and support for constructive interaction, there is no chance that the teacher will appropriate the new information."

Kuhn's (1970) model regarding changing paradigms in the concept of science teaching involves the belief that in the scientific community there are accepted examples of law, theory, application, and instrumentation. Kuhn's theory of paradigm shifts gives a rationale for changing teachers' beliefs and how these beliefs play a major role in their willingness and ability to change their practices. A change in teachers' practice is brought about through change in their beliefs in learning and teaching. When teachers are faced with disequilibrium in their understandings of teaching and learning, they strive for equilibrium. By sustained experiences with new ideas and collaboration with colleagues, teachers restore that equilibrium by constructing new understandings, and therefore new beliefs, through reflection (Piaget, 1978).

<u>Contextual Barriers to Change</u>

Senge, Kleiner, Roberts, Ross, Roth, and Smith (1999) identified ten challenges to initiating change. These challenges influence the growth process in an organization when implementing an innovation that combines inner shifts in teachers' values, aspirations, and behaviors along with outer shifts in processes, strategies, and practices. Senge et al. (1999) referred to this change as "profound change." With profound change, there is learning within the organization as it builds capacity for ongoing change. These ten challenges to profound change in a school organization are:

- Lack of time to implement the change.
- Adequate support for those implementing the change.
- Relevance of change to the curriculum.
- Administration being consistent and clear with goals and message regarding the change.

- Fear and anxiety for those regarding implementation.
- Assessment of progress that is disconnected from traditional forms of assessment.
- Isolation and arrogance between believers and nonbelievers of the new innovation.
- Organizational structure and policies that hinder change.
- Inability to transfer knowledge across departmental boundaries.
- Organizational strategies and intended focus that include change as a natural process of the organization.

A major challenge to educational innovation is assisting teachers in unlearning the beliefs, values, assumptions, and culture that underlie their school's standard operating procedures and practices (Dede, 1999). To be successful beyond initial implementation, school systems need to assist teachers in learning, but also aiding them in unlearning their standard organization's operating procedures. The goals of the innovation implementation must include organizational changes as teachers learn. A shift in organizational change will sustain change that can only be achieved when owned by teachers and not imposed or mandated (Dede, 1999).

Theoretical Framework

The framework for this study was the ST^3AIRS Model (Wetzel, 1999). Through this framework pedagogical support and technical assistance was provided during the study period. The ST^3AIRS Model (Figure 2) provided support during the implementation and integration of CBL probeware and consists of eight steps developed to overcome contextual barriers to the teachers as they integrated technology. These eight steps are staff development, time to learn, trainer that was qualified, transition time to implement technology, access to hardware and software, involvement by teachers in the process, recognition of teachers, and support for teachers. The ST^3AIRS Model focused on strategies for the use of CBL probeware by the teachers involved in the study to influence changes in their pedagogy, along with curricula changes related to the implementation and integration of this technology. Research by Dexter, Anderson, and Becker (1999) found that contextual barriers influence instructional practices, teaching strategies, classroom management, technical expertise, curriculum directives, and organizational support for teachers. Support for the teachers involved in the study included staff development sessions, technical assistance, support for modifications of laboratory lessons and techniques to improve student learning, and problem solving strategies and techniques to support integration of CBL probeware within their curricula.

Support for this framework was based on previous research conducted by Dexter, Anderson, and Becker (1999), along with Honey and Moeller (1990). Their research focused on the beliefs and values of teachers as they used technology within their curriculum. Findings by Dexter, Anderson, and Becker (1999) categorized teachers as being substantially constructivist, weak constructivist, or non-constructivist. The substantially constructivist teachers uses students-centered learning and successfully integrates technology, while a non-constructivist teacher is more teacher-centered and uses little technology. A weak constructivist teacher lies along the continuum. In another study conducted by Honey and Moeller (1990) found that teachers tend to fall into two categories, high-tech and low-tech. High-tech teachers are more student-centered using more hands-on, inquiry methods, and collaborative learning techniques with students.

While low-tech teachers are predominately teacher-centered and fear that using technology will undermine their authority in the classroom. Additional research by the U.S. Congress, Office of Technology Assessment (1995), Ritchie (1996), and Becker (1991) provide additional support for the research framework.

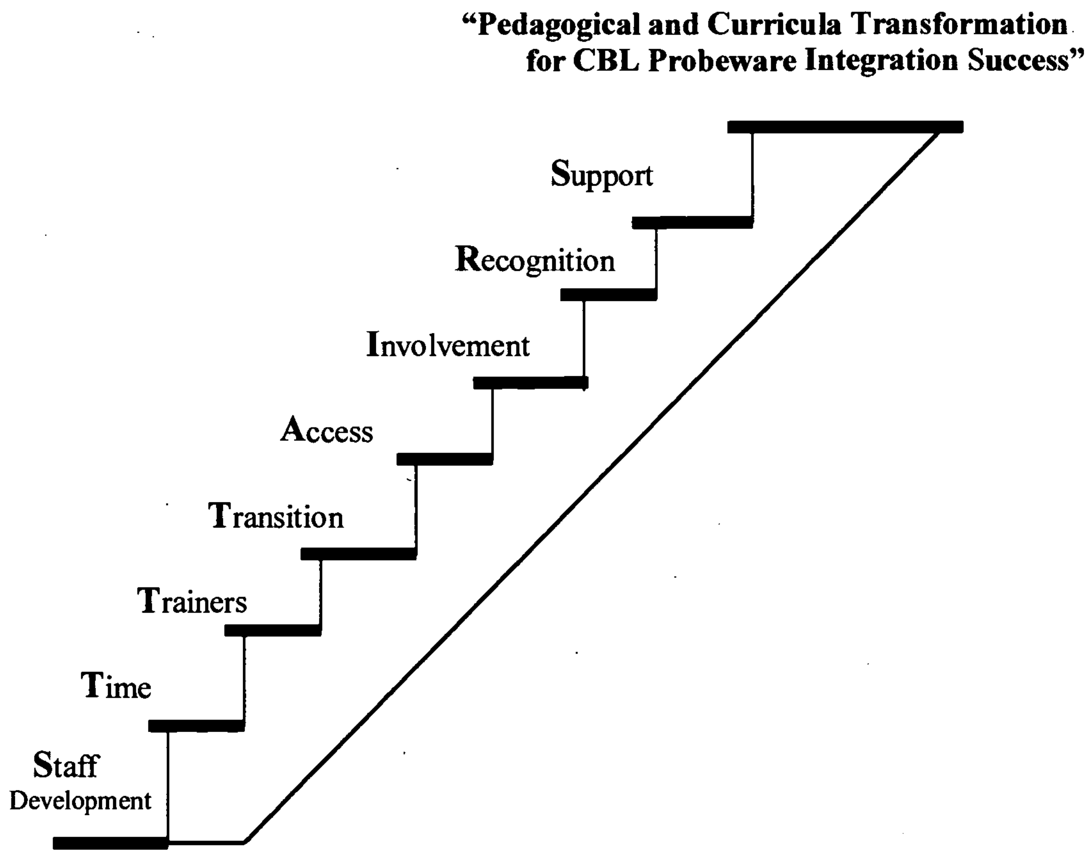


Figure 2. ST^{3}AIRS Model.

Methodology

The study was an empirical multiple-case design that used the dominant-less dominant qualitative-quantitative approach to eliminate misleading associations (Creswell, 1994). As part of this approach, descriptive numeric methods were used to analyze quantitative data. Following Maxwell's (1996) research design diagram, Figure 3 summarizes the components of the research design. Each of the five middle school science teacher was a case study, Figure 5. Cross-case analysis of the five teachers in this study, allow conclusions that are drawn from the findings in relation to the research questions and are constructed into a rich understanding of influences on these teachers from a personal perspective. Using larger numbers of teachers may replicate previous findings and add little beyond existing literature. Additionally, a larger number of teachers would limit the study's ability to conduct an in-depth analysis of influences that these teachers encountered as they integrated CBL probeware. Also, a larger group could limit the study's ability to obtain the teacher trust and confidence.

Overview of the Site and Sample

The teachers in the study were all in a middle school located in a suburban community of Virginia. The school was in a predominately middle to low socioeconomic setting. The school system was small having four elementary schools, one middle school, and one high school. The middle school's population was approximately 750 students ranging in from grades six through eight. Ethnic make up of the school was 70 % European American, 20 % African American, 5 % Hispanic, and 5 % other minorities. Approximately 30 % of students enrolled in the school were eligible for the free or reduced lunch program, and less than 10 percent of the school's student population was considered transient. All students were enrolled in science, which was one of the core content requirements for each respective grade level in the school.

Teachers

Stratification for specific teacher characteristics was used to select teachers with specific characteristics (Creswell, 1994). First, the teachers were employed at the research school and volunteered to be part of the study. Second, these teachers are middle school science teachers -- the target group for this study. Third, they were "novices" with regard to CBL probeware at the beginning of the implementation process. Finally, these teachers were selected to determine if their previous knowledge and experiences influenced their ability to implement and integrate CBL probeware in their curricula. Table 1 provides selected demographics of the participants.

The teachers involved in the study were science teachers either full or part-time, and only one was a science major. Mathematics was the second content subject taught by the teachers who were part-time science teachers. Science content consisted of sixth-grade general science, seventh-grade life science (introductory biology), and eighth-grade physical science (introductory physics and chemistry). Five of the nine science teachers in the school participated in the study. Two were sixth-grade science and teachers, one was a seventh-grade science teacher, and two teachers were eighth-grade science teachers.

Research Purposes:

How and at what levels do middle school science teachers use CBL probeware?

What changes in teaching strategies by the teachers are necessary to use CBL probeware?

How does technical expertise influence the use of CBL probeware?

How did interventions by the researcher influence the implementation of CBL probeware?

Was there pedagogical and curricula transformation by the teachers?

What were the strengths of the ST^{3}AIRS Model?

Conceptual Context:

Researcher's experience with CBL probeware as a middle school science teacher.

Teacher pedagogical and curricula transformation (Becker & Riel, 1999a; Ravitz, Wong, & Becker, 1999).

Common barriers to implementation of technology in schools (OTA, 1995).

Pilot studies of middle school science teachers using CBL/MBL probeware.

Researcher's experience in CBL probeware staff development training for middle school science teachers.

Research Questions:

1. How did teachers use CBL probeware with their students?
2. During implementation of CBL probeware, which factors influenced the teachers' level of use of this technology ?
3. What were the teachers' concerns regarding implementation and integration of CBL probeware?
4. What changes in teaching strategies and techniques did the teachers' make when implementing and integrating CBL probeware?
5. What were the strengths of the ST^{3}AIRS Model?

Methodology:

Empirical Multiple-Case Study
cross-case analysis
mixed dominant-less dominant qualitative/quantitative analysis

Interviews
open-ended questions

Observation
Innovation Configuration (IC) observing for correlation of LoU interview and

Science Classroom Observation Rubric (SCOR) for holistic view of teachers pedagogy

Stages of Concern Questionnaire (SoCQ) using profile comparisons

Validity and Reliability:

Triangulation through:
observation of teachers
interviews of teachers
concerns questionnaire
anecdotal records
cross-case analysis

Validation and Reliability:
Testing IC observation and LoU interview instruments using non-research teachers

SCOR/SoCQ instruments have well-researched validity and reliability

Comparison:
Relate to theory and literature
Search for discrepant evidence

Figure 3. Research Design Diagram.

Table 1

Selected Demographics of Study Participants

Teacher	Years [1] Teaching	Grade Level	Years in [2] Leadership	Level [3] of Technical Proficiency	Technology [4] College Credits	MS [5]	Ethnic Origin
1	11	8	0	II	8	No	European American
2	26	6	10	II	9	No	European American
3	21	8	2	I	9	Yes	European American
4	23	6	1	III	6	No	African American
5	33	7	0	I	6	Yes	European American

1. Years of teaching experience.
2. Leadership as a science department head, state organizations, or team leader.
3. Current level of Virginia Teacher Technology Competency Certification.
4. Instructional technology credits completed in higher education.
5. Master's degree.

Research Questions

The following questions provided the focus regarding implementation, integration, and curricula transformation of CBL probeware by the teachers involved in the study:

1. How did teachers use CBL probeware with their students?

2. During implementation of CBL probeware, which factors influenced the teachers' level of use of this technology?

3. What were the middle school science teachers' concerns regarding implementation and integration of CBL probeware?

4. What changes in teaching strategies and techniques did these middle school science teachers make when implementing and integrating CBL probeware?

5. What were the strengths of the ST^{3}AIRS Model?

Data Collection

Three interviews of each teacher were conducted to collect qualitative data in relation to CBL probeware implementation and integration. These three interviews were the Initial Teacher Interview, Levels of Use Interview, and Final Teacher Interview. Quantitative data were collected using three instruments from the CBAM Model (Hall, 1974). These three instruments were used to collect data regarding the integration of CBL probeware and included the Stages of Concern Questionnaire (SoCQ) regarding the use of an innovation, the Levels of Use (LoU) of an innovation, and Innovation Configuration (IC) regarding the actual implementation and integration of an innovation (Loucks & Hall, 1979). Figure 4 provides a timeline for data collection during the study.

Interviews

An Initial Teacher Interview used open-ended questions to explore teachers' prior beliefs, knowledge, use, and experience with instructional technology. The second interview, LoU Interview, consisted of recommended open-ended questions in Measuring Levels of Use of the Innovation (Loucks, Newlove, & Hall, 1975). The third interview, Final Teacher Interview, provided a sense of the teachers' actual LoU and curricula transformation involving CBL probeware at the end of the study. Loucks, Newlove, and Hall (1975) found that teacher interviews provide essential clues regarding the actual integration of an innovation.

Questionnaire

The Stages of Concern Questionnaire (SoCQ) describes seven stages of concern that individuals experience at various times in the process of change. The SoCQ had a special scoring procedure and resulted in a profile of the intensity level of teacher concern for each stage. The questionnaire consisted of 35 questions that concentrated on the feelings, thoughts, and information needs of a CBL probeware user. A pre-study SoCQ established a baseline of the teachers' intensity level of concerns regarding implementation and integration of CBL probeware at the beginning of the study. The post-study SoCQ provided a comparison of baseline data (Loucks & Hall, 1979) to develop a profile to explore any shift in teachers' concerns.

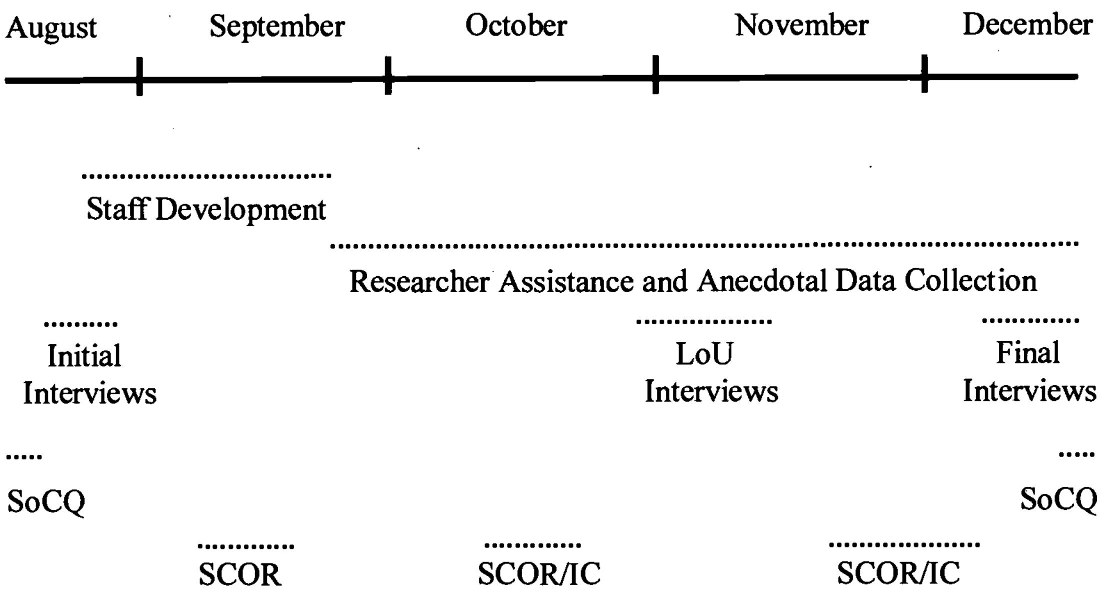


Figure 4. Data collection timeline August–December 1999.

Observations

Teacher Observations provided an opportunity to monitor the implementation and integration through observations of teachers as they used CBL probeware in classroom laboratory investigations and activities. The observations offered snapshots of the teachers integrating CBL probeware in their teaching activities. Observations concentrated on the teachers operational LoU of CBL probeware when they used the technology. These observations were used to compare the findings of the LoU interview, to determine how the teachers actually used CBL probeware with students (Loucks et al., 1975).

Expert science teaching educational model--science classroom observation rubric. The Expert Science Teaching Educational Model (ESTEEM) Science Classroom Observation Rubric (SCOR) is used to determine expert science teaching practices and is theoretically and empirically based (Burry-Stock & Oxford, 1994, Varrella, 1997). A constructivist, student-centered perspective underlies SCOR using a novice-to-expert theoretical framework for science teaching (Burry-Stock & Oxford, 1994). SCOR observations contributed data to develop a holistic view of each teacher, providing insight into their teaching habit(s) using a set of clear criteria. Case study and cross-case analysis used SCOR category observation data of each teacher to compare with other data collection instruments and interviews.

Validity and Reliability

The researcher was concerned with the validity and reliability of interviews and instruments to accurately represent the data to which they refer to and allow replication of this study (Peers, 1996). Additionally, the researcher was concerned with self-report bias regarding questionnaires, interviews, anecdotal records, and observations. Validity is a compliment to reliability and refers to the extent to which that what was claimed to be measured, actually was measured (Anderson, 1990). To overcome these issues, triangulation of data was part of the study design.

Interviews. The Initial Teacher Interview, LoU Interview, and Final Teacher Interview instruments were pre-tested using teachers not involved in the study. This was to control for content validity and reliability of interview questions. Each instrument was tested with teachers, rewritten as necessary, and tested again to ensure the structure of the instruments. Each instrument was validated for clarity of printing, size of type, adequacy of work space, appropriateness of language, and clarity of directions as needed. Additionally, the instruments were tested for their capability to adequately collect the significant data that reflects influences on the teachers, their LoU, collaboration efforts, and identification of concerns regarding the research questions (Anderson, 1990).

Questionnaire. The SoCQ was chosen because of the extensive research conducted by the Research and Development Center for Teacher Education, University of Texas at Austin, on teachers during their implementation of educational innovations (Hall, 1974). Research and the completeness of this instrument along with the other CBAM instruments provide the framework for this study regarding CBL probeware implementation. The SoCQ reliability coefficients for this instrument were calculated from data collected from a stratified sample of 830 teachers and professors, along with a test-retest correlation that used 132 teachers and professors (Hall, George, & Rutherford, 1979).

Observations. Complete researcher bias could not be ensured in the nonparticipant observation process due to the researcher's values, feelings, and attitude based on past experiences with CBL probeware (Peers, 1996). To reduce researcher bias, the viewing and rating of selected tapes of teachers not involved in the study established the SCOR reliability of the researcher. The researcher's SCOR ratings were compared with the ratings of an individual trained in the use of the SCOR for interrater reliability. The SCOR data, compared with LoU and IC data, helped to define each teacher's level of expertise and attitude in relation to CBL probeware in the context of this study. The reliability and validity of the IC Teacher Observation Checklist followed the same procedures as those for interviews.

Data Analysis

Data analysis was an ongoing process, beginning with the first interview. Initial data analysis was through the use of individual case studies of the five teachers using interviews, questionnaires, and observations. After analysis of each case study, a cross-case analysis was conducted on the case studies looking for common patterns. Figure 5 graphically depicts the structure of the cross-case analysis.

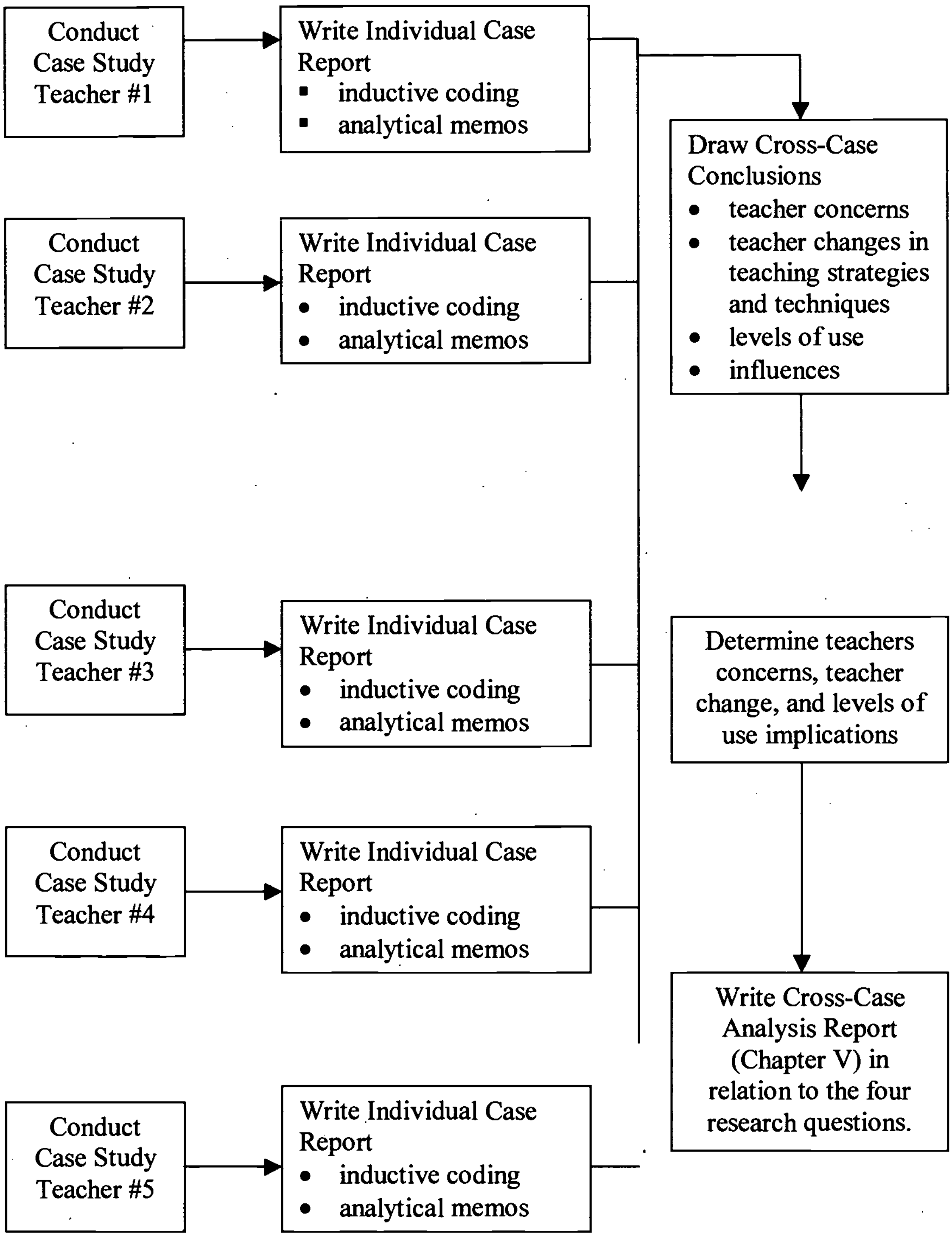


Figure 5. Multiple-case data collection and cross-case analysis diagram.

Triangulation of Data

Triangulation used multiple sources of data to reduce researcher bias and provide a better assessment generality of the findings and conclusions (Creswell, 1994). These multiple sources of data included interviews, questionnaires, and observations as part of the triangulation approach. Interviews provided insight into the teachers' personal experiences during the CBL probeware implementation and integration process. The LoU interview was conducted to operationally determine each teacher's actual use of the CBL probeware. The IC Teacher Observation Checklist was compared with data collected during LoU Interviews to establish the actual LoU of CBL probeware by the teachers. The SCOR observations were compared with IC Teacher Observation Checklists and LoU Interviews to determine each teacher's pedagogical and curricula shifts to accommodate CBL probeware.

Each individual case study consisted of convergent data collected and related to the findings and conclusions of each case. Findings of cross-case analysis considered data that were common in individual cases (Yin, 1994). Common data were analyzed for influences on teachers' concerns regarding integration, levels of use, and change in teaching strategies that developed through analysis of the data.

As part of the triangulation scheme, data codes were based on inductively generated issues that emerged from each case study. Using multiple sources of data provided evidence for cataloging and analysis of data, these multiple sources of evidence included: transcripts of interviews with the teachers; observation notes of teachers as they used CBL probeware in their classroom; summaries of informal conversations between the researcher and research teachers during visits to the research site; anecdotal field notes concerning the teacher's behavior, classroom, and school environment; and the operational definitions for LoU Interview data to determine actual levels of use of CBL probeware of the teachers.

Using multiple sources of evidence and chain of evidence established construct validity and reliability. Data pattern matching strengthened internal validity. While the following case study procedures contributed to data reliability (Yin, 1994): established field procedures while visiting the research site; study questions were the basis for collecting data when investigating potential sources of information; and use of a descriptive analytical structure for each case study and cross-case report.

Findings

General conclusions can be drawn from the evidence of this study through case study findings and cross-case analysis of the data. The following general conclusions are presented through the framework of the research questions.

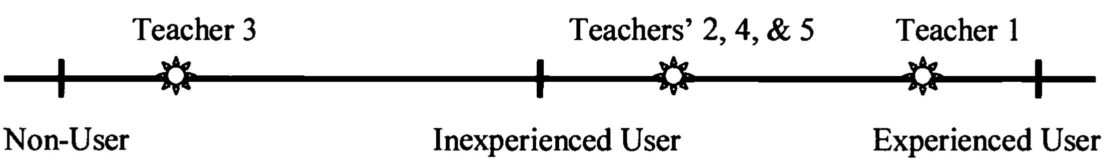
Research Question 1: How did the teachers use CBL probeware with their students?

- Four of the five teachers used a constructivist student-centered approach when using CBL probeware with students. Which was a shift in pedagogy for three of these four teachers.

- Four of the five teachers shifted their teaching strategies and techniques to include higher-order thinking and process skills when using CBL probeware with their students.

<u>Research Questions 2: During implementation of CBL probeware, which factors influenced the teachers' level of use of this technology?</u>

- Collaboration among the five teachers was an instrumental influence in the successful short-term transformation of pedagogy and curricula by four of the five teachers.
- The mean of 22.8 years of teaching experience for the teachers in the study had no influence on their technical ability to use CBL probeware.
- Pre-service and inservice preparation in computer-based instructional technology did not influence the teachers' implementation and integration of CBL probeware.
- Four of the five teachers successfully integrated CBL probeware in their curriculum on a continuum that ranged from inexperienced through experienced users, see Figure 6.
- There was no evidence of a pedagogical or curricula transformation in the school's climate or culture to support the long-term use of CBL probeware by the teachers.



<u>Figure 6</u>. Final positions of teachers on the nonuser to experienced user of CBL probeware LoU continuum.

<u>Research Question 3: What were the teachers' concerns regarding the implementation and integration of CBL probeware?</u>

- Four of the five teachers had a meaningful decrease in their concerns in relation to their awareness and information regarding their integration of CBL probeware (see Figure 7).
- All five teachers were concerned with the Virginia Standards of Learning (SOL) and this concern was a key factor for nonintegration of CBL probeware by one of the five teachers.
- All five teachers were concerned with limited CBL probeware resources that restricted the collaborative efforts of the teachers to integrate CBL probeware in their curriculum.

- Four of the five teacher's concerns with the implementation and integration of CBL probeware were substantially reduced by giving them ownership of the process (see Figure 7).

Figure 7 compares the profile of the five teachers' pre- and post-study Stages of Concern Questionnaire (SoCQ). Their combined pre- and post-study SoCQ profile indicated a shift of their concerns during the study, which ranged from very intense concerns in their awareness and information stages to decreased concern regarding these two stages. The decrease in concern in these two stages indicated that the impact of the ST^3AIRS Model and their experiences increased their technical knowledge regarding CBL probeware through staff development, along with support from colleagues. Their personal, management, and consequence stages decreased to a point of less concern, which suggested that they were developing skill in the use of CBL probeware. The findings of this research were that time for teachers to learn was a key factor for integration of this technology into their pedagogy and curriculum.

Research Question 4: What changes in teaching strategies and techniques did these middle school science teachers make when implementing and integrating CBL probeware?

- Four of the five teachers had a shift in their teaching strategies and techniques in relation to CBL probeware integration, which provided evidence of short-term transformation in their pedagogical practices and curricula.
- Four of the five teachers' views and beliefs regarding their concern with CBL probeware as being an appropriate instructional technology in middle school science shifted from nonsupport to support.

Research Question 5: What were the strengths of the ST^3AIRS Model ?

- Collaboration among the teachers in the study and a sense of partnership with the researcher were instrumental in the successful short-term transformation of pedagogy and curricula by four of the five teachers.
- Staff development sessions that allowed the teachers to explore the technical aspects of CBL probeware and how it fit within their curriculum, before implementation.
- Support before, during, and after classroom implementation of CBL probeware by the teachers.
- Teachers were allowed to select the time and curriculum integration point without a sense of pressure to integrate CBL probeware before they were ready.
- Involvement of the teachers in all phases of the implementation and integration process.

Several key factors related to the research questions led to drawing these general conclusions. The first factor was the influence of the Virginia SOL tests on the teachers in the

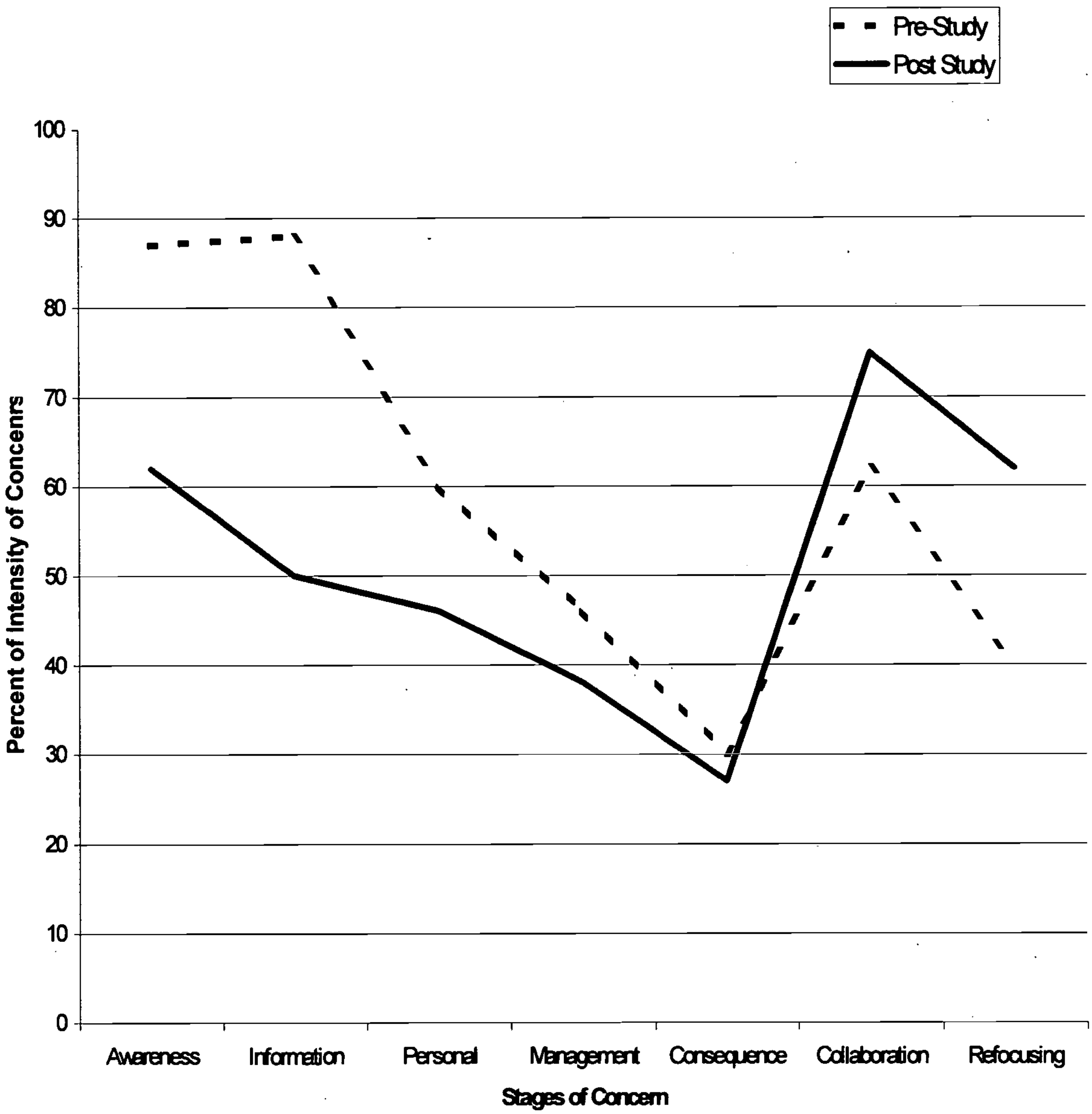


Figure 7. Combined SoCQ profile for all five teachers.

study. One teacher had such strong concerns regarding the Virginia SOL tests and her students' achievement on these tests, she remained at the nonuser level of CBL probeware at the end of the study. The other four teachers in the study were concerned with the Virginia SOL tests, although not at the intensity of the teacher who was unable to overcome her concerns. These four teachers were able to overcome their own concerns and integrated CBL probeware into their pedagogy and curriculum, at least in the short-term. Also, these four teachers were in agreement that CBL probeware improved their students' understanding of science concepts as their students used real-time data collection techniques to manipulate variables and draw better conclusions from their data. Additionally, these four teachers were convinced that this technology would improve their students' Virginia SOL test scores, due to their students' increased understanding of science concepts.

A second key factor was the collaboration among the teachers. All five teachers worked together to integrate CBL probeware into their curriculum. They accomplished this through formal and informal sharing sessions in which they discussed strategies for improving their teaching and student learning related to use of CBL probeware technology. Their collaborative efforts resulted in four of the five teachers successfully transforming their pedagogy and curriculum to include CBL probeware. Further evidence of collaboration was through their grant applications and modification of their science departmental budget for the next five years to increase their CBL probeware resources. These successful results occurred even though their collaborative efforts were limited by having only one class set of CBL probeware for the entire science department.

A third key factor was their pre-service and inservice instructional technology staff development preparation that was computer-based. Even though CBL probeware does rely on downloading new and updated programs through the Internet and loading these new programs to graphing calculator using a computer, CBL probeware technology operates independently of computer-based technology. Their mean of 7.6 graduate credits of instructional technology preparation did not provide these teachers with adequate background knowledge and experiences that were transferable to CBL probeware. This technology uses a graphing calculator, and these five teachers did not have any prior knowledge or experience with graphing calculators.

A final key factor was that the teachers had incorporated instructional technology in their curricula and there was pedagogical and curricula transformation, at least in the short-term. The potential for long-term pedagogical and curricula transformation was evidenced in the change in the teachers' beliefs regarding the technology focus of this study. The ST^3AIRS Model provided a foundation for long-term pedagogical and curricula transformation, given their positive attitude and motivation to improve their teaching and student learning.

Limitations and Considerations

As with all studies, there are limitations in the research design. One limitation of this study was the small number of teachers, which was five teachers. Even though there were only five teachers, their number provided in-depth findings and conclusions of the data. This limitation of five teachers does not allow the findings of this research to be generalized and are confined to the conclusions within the context of this study. However, with consideration of the limited body of literature related to CBL probeware in middle school science and this research, the findings of this study can be generalized within a similar context.

While caution must be used in generalizing the experiences of these teachers to all middle school science teachers, the study indicates that within this context there was an 80 % success (i.e., four of five teachers) for short-term pedagogical and curricula transformation. This 80 % success rate exceeds the findings of research completed by Becker (1991), who found that only 36 % of teachers were willing to transform their pedagogy and curriculum to include instructional technology. Research findings by Ravitz, Wong, and Becker (1999) corroborate this research. Even with this caution, the study's findings expand the knowledge of instructional technology implementation and integration processes regarding CBL probeware with middle school science teachers.

The study identified a number of factors that influenced the implementation of CBL probeware by the five teachers in this study. Many of these factors are common to previous research regarding instructional technology as found in research completed by the U.S. Congress, Office of Technology Assessment (1995). These barriers included time to learn, adequate assessment practices, access to hardware, vision and rationale, teacher apathy, and support. Further research by Becker and Riel (1999a), along with prior research by the U.S. Congress, Office of Technology Assessment (1995), found that support factors include using adequate staff development using master teachers, providing expert resource assistance, and getting support from school administrators. This study found several factors that were unique to CBL probeware in this study:

Support Factors

- The CBL probeware system's simple design and ease of operation.
- The students' ability to quickly grasp the basic operational functions and applications in inquiry-based investigations.
- The adaptability and design to meet middle school science curriculum objectives and goals.
- The teachers' beliefs that CBL probeware was appropriate for their curriculum.
- The teachers' support using the ST^3AIRS Model structure as a framework for staff development and assistance throughout the study.

Barriers

- The teachers having insufficient time for staff development in integration techniques and strategies related to CBL probeware.
- Insufficient CBL probeware resources, the teachers only had one class set.
- The Virginia's SOL tests that were content specific and fact-based, encouraging teacher-centered transmission of facts and limiting student-centered teaching and learning.
- The lack of support by the school system by not allowing CBL probeware to be accepted as an instructional technology tool for technology certification.

Rogers (1997), Settlage (1995), and Krajcik and Layman (1989) found similar support factors and barriers to the implementation and integration of CBL probeware with high school science and mathematics teachers. Additional research by Wetzel (1998, 1997), along with Bowman and Davis (1997), found similar support factors and barriers to the implementation and integration of CBL probeware by middle school science teachers. These researchers' findings were that CBL probeware is designed for ease of use by teachers and students, portability for collecting data in diverse learning environments; that there is never enough time for adequate staff development because of the education profession norm that the majority of staff development be conducted outside normal school and teacher contract hours; and funding for adequate resources is always an issue due to the nonprofit nature of education. All though there was change with in the science department in the middle school, there was not profound change (Buck and Horton, 1996) in the organizational culture of the school and school system.

Recommendations for Further Research

Based on the findings, conclusions, support factors, and barriers on the implementation and integration of CBL probeware found in this study, a number of additional questions were raised that offer areas for further research. The following is recommended areas for future research involving CBL probeware and the ST^3AIRS Model: the replication of this research with a larger number of middle school science teachers and the research of the ST^3AIRS Model in other instructional technology applications and other school settings.

These recommendations for further research are based on the need to generalize this study's findings to middle school science teachers and middle school science in other school settings. Along with the ST^3AIRS Model (Wetzel, 1999), the use of this model as a framework for staff development and continuing support throughout the study period proved to be very successful with the four of the five teachers transforming their pedagogy and curricula in the short-term. Additional research involving this model will provide further evidence to determine the potential for its success in instructional technology applications.

Implications for Practice

The findings of this research have implications for the integration of CBL probeware technology to transform middle school science teacher pedagogy and curricula. First are the implications that this technology can transform teaching and learning to a student-centered constructivist approach as middle school science teachers integrate CBL probeware in their curriculum. Similar to research by Ravitz, Wong, and Becker (1999), the teachers in this study transformed their teaching practices as they changed their goals and learning objectives for their students, changed their teaching practices because they had a new understanding of how their students learned, and because of the staff development experiences they had in relation to CBL probeware.

Second are the implications for staff development. The ST^3AIRS Model met the needs of the teachers in this study. The model gave these teachers ownership in the implementation and integration process and contributed to the 80 % success rate of short-term pedagogical and curricula transformation. The use of this model for instructional technology staff development, can help close the gap between the 80 % success rate in this study and the typical 36 % rate for instructional technology integration as found in research by Becker (1991) and Ravitz, Wong, and Becker (1999). This model gives teachers the continuous support they need to fully implement and integrate any instructional technology tool, which then shifts the focus from frustration to satisfaction.

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