A CASE STUDY OF AN EXPERT MATHEMATICS TEACHER'S INTERACTIVE DECISION-MAKING SYSTEM USING PHYSIOLOGICAL AND BEHAVIORAL TIME SERIES DATA

A Dissertation

by

DEBORAH LARKEY JENSEN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2004

Major Subject: Curriculum and Instruction

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ABSTRACT

A Case Study of an Expert Mathematics Teacher's Interactive Decision-Making System
Using Physiological and Behavioral Time Series Data. (December 2004)
Deborah Larkey Jensen, B.A., University of California at Los Angeles;
M.A., University of Hartford
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The purpose of this exploratory case study was to describe an expert teacher's decision-making system during interactive instruction using teacher self-report information, classroom observation data, and physiological recordings. Timed recordings of instructional interaction variables using an adapted Stallings Observation System were combined with simultaneous skin voltage measurements in time series analyses to describe observable and physiological elements of an expert teacher's decision-making process. The mean and standard deviation of observable decision-action rates on teacher-identified "teaching days" were higher than the rates on "guiding" days. Bivariate time series analysis of decision-action rates and physiological response rates showed a significant positive relationship between the teacher's decision-action rate and her physiological response rate on one teaching day. The positive relationship between the teacher's decision-action rate and her physiological response rate was found to be context-dependent and related to the teaching strategy being used. High decision-action rates during direct instruction were associated with high physiological response rates compared to lower decision-action rates and physiological response rates while monitoring independent seatwork during a test. Correlation analysis of physiological response rates with time revealed slight, but statistically significant negative trends for four of the five observation days. Major features of the teacher’s decision-making system included focusing attention on academic instruction with the use of routines for managing students and materials to perform teaching tasks; both proactive and reactive improvisational decisions; and physiological events characteristic of autonomic nervous system activity during instructional sequences of high teacher-student interactivity. Damasio’s Somatic Marker Hypothesis (Damasio, 1999) is offered as an explanation for the generation of specific characteristics of the expert teacher’s instruction, such as the high frequency of decision-actions and automaticity of appropriate decisions.

DEDICATION

To my husband, Edward Jensen

ACKNOWLEDGMENTS

I owe my thanks to three people who intervened at the beginning of my selection of a dissertation problem to encourage me to select a problem which held my passionate interest, though including physiological data in the study of instructional decision-making was uncharted territory. Dr. Carolyn Clark, a professor who doesn't just teach, but transforms her students; Dr. Patrick Larkey, my brother and a professor of Public Policy at Carnegie Mellon; and my husband, Ed Jensen intervened to encourage me to follow my continuing interest in teacher decision-making rather than select a "safe" topic. All three people advised me that dissertation research is longer and harder than I could imagine, and the motivation to continue despite obstacles comes from investigating a problem that consumes your interest. I took their advice, and have thanked all three when I found myself enjoying late nights writing, long hours (days, weeks, and months) analyzing quantitative and qualitative data, and working my way through one challenge after another.

My graduate advisor and committee chair, Dr. Carol Stuessy, deserves a advisor heroism medal for guiding me through a research process that began as grand ideas of connections between the physical and mental life of teachers, emerged as a proposal to measure physiological data during instruction in conjunction with measures of teaching, and culminated in a document that represents not the end of a process, but the beginning of a research agenda. Carol has been my mentor and guide through five years of working my way through a major research process. There were times she insisted I change or add sections when I was less than willing. It was especially irritating to find that she was right

each time. It has been a privilege to work with a person of her expertise, incisive perception, and generous spirit.

My dissertation committee gave me the once-in-a-lifetime opportunity to have a group of the most intelligent and skilled individuals working in education research advise me about every phase of research and writing. During my proposal defense, my committee helped in inestimable ways. Dr. Victor Willson listened to my original research plan to record every instructional action of a teacher during authentic instruction, then made the comment that what I wanted to do was a time series analysis. Since that was the first time I had heard the term, I had a steep learning curve for the next year. Dr. Cathleen Loving and Dr. Stephanie Knight not only helped me construct a research plan, but also helped me cut the chaff and add the documentation to create a substantial product.

I also had allies at home and work. My husband, Ed, and my daughter, Patricia Chapela, have helped me edit, print, FedEx, and hand deliver various forms and pieces of this dissertation to committee members during the last five years. Ed, Patricia, and her husband, José Chapela, also helped me with software problems and creating visual basic commands to process my quantitative data. My daughter, Elizabeth Schoech, helped me master the technical challenges of collecting telemetric data from a heart rate monitor and modeled the equipment for Figure 8. My mother, Carrie Larkey, provided encouragement and loving support throughout the Ph.D. process. My colleagues, Dr. Stacia Spillane, Marty Daniel, and Dr. Nanda Kirkpatrick gave me excellent advice and encouragement as I navigated through all the paperwork and processes required to perform research with a human being teaching children in a large school district.

Finally, I want to thank the teacher in this study, as well as her school and school district for allowing me to conduct research in an authentic setting. The teacher is and has been one of the most expert teachers I have known in my career. Observing her professionalism and grace while being intensively studied during the last two weeks of the school year was a remarkable experience for me. After two years of analyzing and reanalyzing the quantitative and qualitative data I collected, it still amazes me how expert her instruction was and how fortunate I was to have the opportunity to describe one aspect of her decision-making system.

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CHAPTER I

INTRODUCTION

Consider the thoughts of a teacher in a classroom who is teaching according to an instructional plan largely from memory, while simultaneously evaluating the success of the instruction and deciding which changes to make in the future. The teacher is making real time decisions in the midst of past plans and future predictions. The teacher's knowledge, experience, values, and skills all impact the moment-to-moment decisions that occur while teaching. The reverse is also true. Moment-to-moment decisions impact the teacher's knowledge, experience, values, and skills.

Classroom environments are complex settings. Twenty-five or more children are contained in a single room with an adult who is managing their behavior and leading them through learning activities. Classroom events form a "whole dynamic ecology" of "nested conglomerates of interdependent variables, events, perception, attitudes, expectations, and behaviors, and thus their study cannot be approached in the same way that the study of single events and single variables can" (Salomon, 1991, p. 11).

It is no wonder that "Teaching tends not to be regarded in its original complexity" (Davis & Sumara, 1997, p. 121).

Contributing to the complexity of teachers' decision-making are rapid changes in the classroom occurring before, during and as a result of teachers' decisions. A high

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This dissertation follows the style and format of the *American Educational Research Journal*.

frequency of instructional decisions has been described in numerous reports of classroom instruction (Clark & Peterson, 1986; Korthagen & Lagerwerf, 1996). Furthermore, a characteristic of authentic decision contexts is the unstable nature of problems over time (Schön, 1983). Instructional problems change and require new solutions. Davis and Sumara (1997) described teaching as a “responsive choreography” and a “dynamic product” (p. 122) of changing culture and knowledge. The focus of the research in this case study is the description of an expert teacher’s decision-making in the fluid temporal context of interactive instruction in a classroom.

Statement of the Problem

Governments mandate academic standards and spend billions of dollars on education, yet classroom teachers ultimately decide what material to teach in their classrooms and how to teach their students. Some teachers choose to teach valuable academic content and skills, creatively adjusting their instruction to ensure the achievement of all students; other teachers do not. The instructional choices of teachers have been a focus of interest of educational researchers for nearly fifty years, and there is a rich knowledge base describing the differences between the decision-making processes of effective teachers compared to those who are not effective.

The kind of thinking that teachers do during interactive teaching appears to be qualitatively different from the kind of thinking they do when they are not interacting with students (Clark & Peterson, 1986). The time required to make planning decisions differs from the time needed to make interactive decisions and automatic actions.

Conscious effort also differs for different kinds of decisions. Sometimes teachers' instruction requires purposeful reflection while other times teachers' actions are automatic and involve little self-awareness of the decision action (Calderhead, 1996).

Decisions made by a teacher in the past may determine present and future decisions. "Teachers' planning, therefore, is rarely an isolated process. It may be seen more realistically as a continuous process of reexamining, refining, and adding to previous decisions" (Calderhead, 1996, p. 714). Past studies on teachers' decision-making show that their decisions involve unconscious processing of experiences preceding and allied with conscious reasoning strategies (Calderhead, 1996; Korthagen & Lagenwerf, 1996). Outside of a classroom, teachers have more time to reflect on instruction. Effective teachers simultaneously address multiple objectives, from classroom management to conceptual development in their plans; they use information about students, academic content, and available resources to create a practical plan designed to work in a real classroom; and they are creative and flexible in their plans, with alternate ways of looking at problems and construction of adaptable plans suitable for different contexts (Calderhead, 1996).

Successful teachers make many instructional decisions automatically, which enables them to do more in less time with less effort compared to the performance of inexperienced teachers (Sternberg & Horvath, 1995). Novice teachers are often overwhelmed by all the things that are going on in a classroom and the many things they have to think about to teach a lesson. In contrast, an expert teacher performs with "fluency and automaticity in which the teacher is rarely surprised and is fully adapted to and in control of the situation" (Calderhead, 1996, p. 717). Shulman wrote about the importance of understanding the how and why of teachers' planning decisions for the future course of education research in 1986, and his comments are as pertinent today as when he wrote this passage:

> Changes in both teaching and teacher education will become operational through the minds and motives of teachers. Understanding how and why teachers plan for instruction, the explicit and implicit theories they bring to bear in their work, and the conceptions of subject matter that influence their explanations, directions, feedback and correctives, will continue as a central feature of research on teaching. (p. 26)

Major methods of inquiry for studying teachers' decision-making processes in the past include thinking aloud, stimulated recall, policy capturing, lens modeling, journal keeping, repertory grid technique, personal narratives, systematic observation, and technical recordings (Clark & Peterson, 1986; Evertson & Green, 1986; Shavelson, Webb, & Burstein, 1986). None of these methods includes a measure of the somatic variables that neurologists use to study cognition. The physical basis of cognitive processes is largely ignored in education research apparently because important covert cognitive processes have been difficult or impossible to observe. Calderhead (1996) wrote, "Observation alone is of limited value, for the cognitive acts under investigation are normally covert and beyond immediate access to the researcher" (p. 711). In contrast, researchers in neurology routinely study cognitive acts through the study of brain structures and processes necessary for normal decision actions (Damasio, 1999).

Furthermore, these neurological processes have been found to cause changes in physiological parameters which are accessible and measurable, providing an information source for investigating covert cognitive acts (Damasio, 1999; Kandel, Schwartz, & Jessell, 1995). Neurobiologists have found that “in normal individuals, non conscious biases guide behavior before conscious knowledge does” and “without the help of such biases, overt knowledge may be insufficient to ensure advantageous behavior” (Bechara, Damasio, Tranel, & Damasio, 1997, p. 1293). Teachers also use non conscious biases as well as overt knowledge to guide their instruction, yet there have been no studies attempting to include physiological measures related to teacher cognition with measures of the teacher’s minute-to-minute behavioral changes in concert with the changing classroom environment. The problem with omitting physiological measures related to teacher cognition is that the brain mechanisms generating decision actions are being ignored with the loss of opportunity to understand “the minds and motives of teachers” (Shulman, 1986, p. 26).

Purpose Statement

The purpose of this exploratory case study was to describe an expert teacher’s instructional decision-making process using multiple data sources and simultaneous data recording throughout instruction. If the basic teaching skill is decision-making, as Shavelson (1973) contends, then understanding how teachers make decisions, what teachers need to know to make good decisions, and how to develop decision-making ability in teachers are critical areas of importance to anyone concerned with teaching skills. Teacher evaluation systems, preservice education, and professional development programs could all potentially benefit from an understanding of the elements, patterns, and relationships that affect instructional decisions.

A missing component in research on teachers' decision-making is a comprehensive explanation of how expert teachers use tacit, unconscious, knowledge to make their decisions. An intensive, multidimensional study of an expert teacher's instruction is needed to explore internal regulation of overt instructional behavior throughout authentic teaching episodes. Information sources included self-report data collected during teacher interviews, qualitative observation, quantitative description of classroom instruction, and quantitative measurement of physiological activity. The triangulation of information sources; the simultaneous, continuous data collection during interactive decision-making; and the authentic context for data collection were judged to be critical to this study. The view of teacher decision-making as a complex system requires this kind of data collection.

Research Questions

The questions guiding this study were:

1. How does a teacher integrate decisions made outside class into her classroom instruction?
2. How does a teacher make improvisational decisions during class?
3. Do improvisational decision-actions elicit a physiological response?

Definition of Terms

Decision making is the act of assessing and choosing among alternatives when information is uncertain or missing (Matlin, p. 379). In this study, the choices must be observed, recorded, and/or reported by the teacher in order to be included in the analysis. Teachers' decisions have been subdivided into *planning decisions* that occur before instruction and *interactive decisions* or *improvisational decisions* that occur during instruction. The *operational definition of an interactive decision-action* for this study is a teacher-initiated change in any of the elements in the who/whom, what, or how categories of an interaction sequence recorded using the Stallings' Observation System, also known as the SOS (Stallings, 1993).

Physiological changes that are associated with behavioral patterns may be measured to produce *physiological data*. The teacher may be aware or unaware of the changes in body processes such as an increase in heart rate during a stressful teaching episode. For this study, physiological data will be collected using a *Polar©* exercise heart rate monitor attached to the teacher's chest and a Vernier *LabPro©* data collection device with a signal receiver.

The *systemic approach* to the description of interactive decision-making assumes interdependent relationships between system variables requiring "the study of patterns, not of single variables" (Salomon, 1991, p. 10). It is assumed that it is not possible to manipulate one variable while controlling all the other context variables, since manipulating a system variable may affect the other non-manipulated variables in a nonlinear fashion.

Time series data is collected in order to describe "some kind of naturally occurring pattern in behavior over time" (Warner, 1998, p.14). A time series variable should be a continuous variable for which observations are recorded at equally spaced time intervals (Warner, 1998). *Bivariate time series analysis* tests the degree of correlation between two time series, interval by interval. The variables in two time series may have no relationship with each other, a simultaneous relationship, or a relationship separated by a time lag.

Reflection is a thinking process when a person "abstracts from self-awareness" and has "the ability to solve problems symbolically, in one's imagination" (Jagla, 1994, p. 28). The process may include evaluation and assimilation of experience.

Tacit knowledge is "knowledge that enters into the production of behaviors and/or the constitution of mental states but is not ordinarily accessible to consciousness" (Barbiero, 2001).

Decision-Making Attributes

The concepts of decisions and decision-making are familiar ideas which require further examination for identification of qualifying conditions. A decision is commonly defined in educational research as a deliberate choice of action completed within a discrete amount of time.

Clark and Peterson (1986) reported that despite diverse methodologies, the investigators they reviewed had "converged on a definition of an interactive decision as a deliberate choice to implement a specific action" (p.274). More recently, Freiberg and

Driscoll (2000) described decision-making as the ability to select and implement at least one alternative within a discrete time period. The characterization of a decision as a deliberate choice infers a volitional cognitive process when more than one potential for future action exists in the decision-maker's conscious mind. Therefore, educational researchers have distinguished decisions from automatic actions requiring little or no conscious thought.

Furthermore, decision-making has been distinguished from formal reasoning processes which follow rules of logic. The psychologist Matlin (1994) described the process of decision-making as choosing between alternatives when information is uncertain and there are no explicit rules to be followed, while the process of reasoning involves choosing among alternatives following rules for drawing conclusions and judging the premises to be true or false. One could conclude from this description that while decision-making may be a conscious act, it is completed without formal rules dictating the steps of the selection procedure.

Conceptual distinctions between the constructs of reasoning, decision-making, and automatic actions do not always correspond to the cognitive experiences of teachers. Empirical research on the planning, decisions, and automatic actions of teachers shows a connected, sometimes dynamic relationship between decision types. Calderhead (1996) described instructional planning as a multi-layered process in which decisions made at one level may set the conditions for decisions made at other levels. "Teachers' planning, therefore, is rarely an isolated process. It may be seen more realistically as a continuous process of reexamining, refining, and adding to previous decisions" (Calderhead, 1996, p. 714).

Education literature has revealed a key distinction between the decision-making processes of teachers in and out of the classroom. The time and conscious effort required to make a decision has been found to be different for planning or evaluative decisions made during non-instructional time, compared to interactive decision-actions made during instruction. Planning decisions outside of classroom instruction are more reflective, involving mental images of the lesson and the students. Planning decisions prepare the teacher's thought processes and the teacher's selection of instructional materials. Sternberg and Horvath (1995) wrote, "A well-developed planning structure, of the type outlined previously [scripts, propositional structures, and schemata], enables the expert teacher to teach effectively and efficiently" (p. 11).

Korthagen and Lagerwerf (1996) described interactive instructional decision-making as a process of development and accommodation of Piagetian schemas, occurring in a split second, based on the teacher's experience, and not "an exclusively cognitive process" (p. 163). They viewed interactive decision-making to be influenced by both conscious thought and the teacher's feelings (Korthagen & Lagerwerf, 1996). Decision-actions made during interactive teaching may appear to be the result of intuition rather than reason, as well as ingrained habits generated through previous experiences and previous decisions that are subsequently applied in appropriate instructional situations. For instance, a teacher may pass out papers using a particular routine that is a deliberate choice of action, though the teacher may not feel conscious volition or even awareness of the action. While the teacher may not “feel” that a decision was made, the teacher clearly has alternatives for passing out papers using a particular routine, using a different routine, or not passing out papers at all.

John Dewey (1916) described evaluation decisions during instruction in terms of the interplay between conscious and unconscious processes, and called these processes that determine our conscious thinking “habitudes” and described their importance:

> We rarely recognize the extent which our conscious estimates of what is worthwhile and what is not are due to standards of which we are not conscious at all. But in general it may be said that the things which we take for granted without inquiry or reflection are just the things which determine our conscious thinking and decide our conclusion. And these habitudes which lie below the level of reflection are just those which have been formed in the constant give and take of relationship with others. (in Ross, Cornett, & McCutcheon, 1992, p. 16)

Thus the familiar concept of decision-making involves choices of varying degrees of self-awareness and volition in uncertain situations with varying amounts of information. Though the concept of decision-making is familiar, the study of teachers’ decision-making has revealed a variety of cognitive processes underlying a common idea.

Studies of teachers in classrooms raise questions about the degree of conscious deliberation needed for an act to be classified as a decision. A teacher-generated choice between alternatives does not necessarily mean that the choice is an act requiring conscious volition, although a sense of willful action may accompany a decision. How much thinking is needed to make a decision? How much volition must a teacher feel to judge that a decision has been made? Research on teachers' decision-making does not address such questions. Rather, researchers describe the decision situation as Korthagen and Lagerwerf (1996) did with phrases such as "almost impossible to separate perception, interpretation and reaction from one other," explaining that the decision is not "an exclusively cognitive process" (p. 163).

Furthermore, a "deliberate choice" may not be observable. For instance, education literature summarized by Clark and Peterson (1986) classified unobservable teachers' thoughts during instruction (later reported to researchers) as perceptions, expectations, interpretations, and reflections. Perceptions may include decisions about the state of students in the classroom; expectations may indicate decisions about future actions; and reflections may indicate evaluative decisions. These kinds of decisions are important for instruction, but an external observer depends on a teacher's self-report to document internal thought processes.

The operational definition of a decision-action for this dissertation study included the essential attributes of a decision derived from educational research: a deliberate choice requiring time to complete and occurring in situations with incomplete information; with the addition of an attribute essential for the data collection: the decision was either a deliberate choice reported by the teacher or an observable behavior. The operational definition of a decision-action as a teacher-initiated changes in behavior was critical to the methodology and data analysis for this case study. Decision-actions are not subcortical reflex responses, such as a knee jerk or eye blink, rather they are clearly observable teacher-initiated changes in speech and coordinated movements.

While this study seeks to describe unconscious, tacit decision processes as well as conscious action, the data collection techniques are limited to decision-actions eliciting measurable physiological activity, resulting in observable behavior, or reported by the teacher. The physiological measures do not “read the teacher’s mind.” Rather, the teacher’s physiological responses were an indication of the teacher’s physiological arousal in the context of classroom instruction, whether that context was stressful or exciting, or both.

Theoretical Perspectives

This case study was based on combined perspectives of education research and neuropsychology. Both research traditions have grappled with the concept of a decision and the identification of variables, process patterns, and limiting factors affecting decision behaviors. This study does not conflict with the body of evidence gathered by education researchers on interactive decision-making, rather the findings of this dissertation study provide an additional data source, a low inference index of the teacher’s state of mind from moment-to-moment during authentic classroom instruction. Education research has thoroughly documented the complexity of teachers’ decision-making which includes both simultaneous multi-tasking processes as well as strategic sequential elements.

Shavelson and Stern (1981) proposed a model of teachers’ interactive decision-making, based on a synthesis of previous research, which found that most of teachers’ interactive teaching was “carrying out well-established routines” (p. 482). Shavelson and Stern (1981) explained interactive decision-making as the process of evaluating whether student behavior is in limits of tolerance, judging if immediate or delayed action is necessary, taking appropriate action if an action routine is available, and either remembering or forgetting the incident. The Shavelson and Stern (1981) model is summarized in Figure 1.

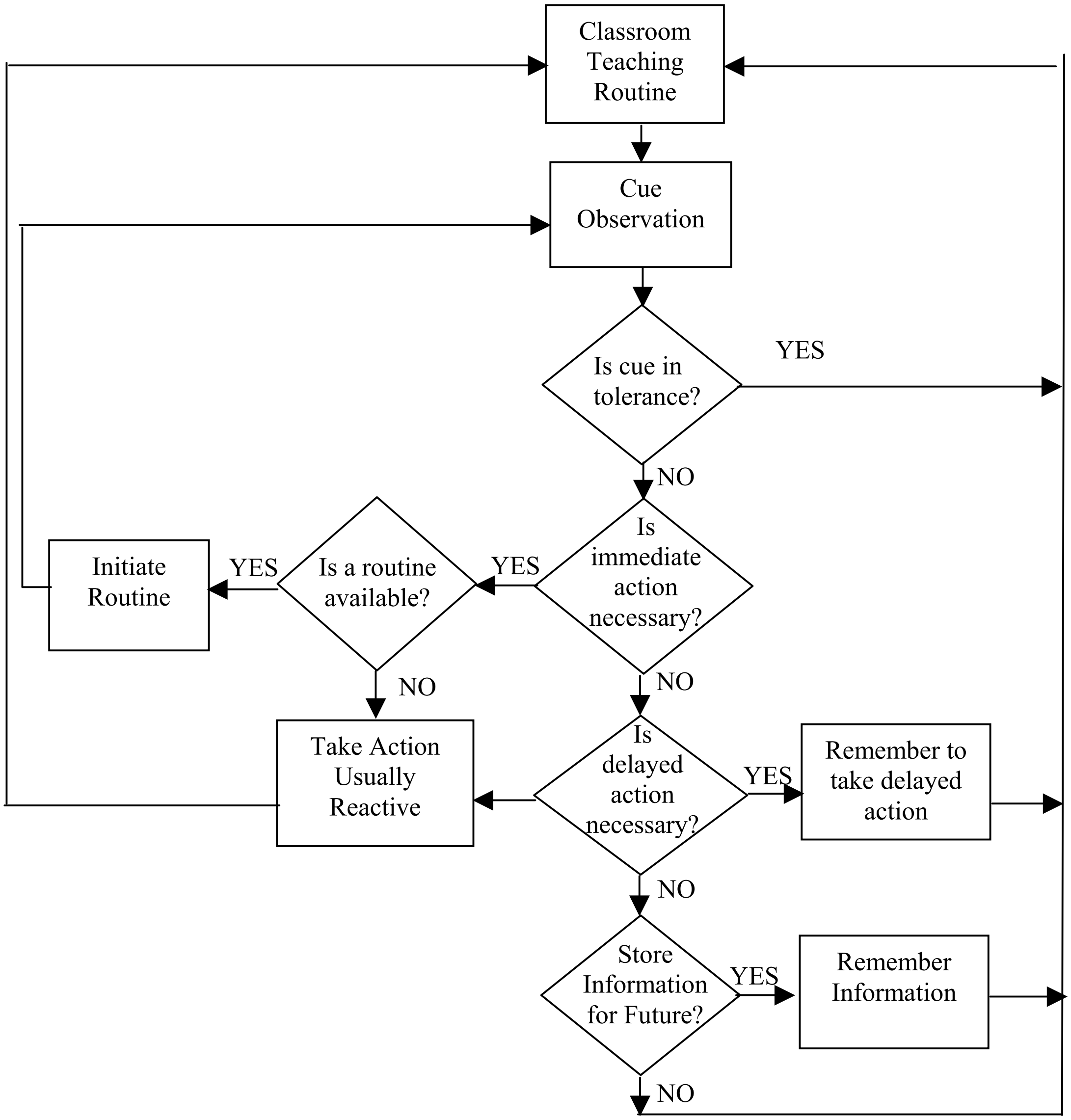


Figure 1. **Model of teachers' decision making during interactive teaching (after Shavelson and Stern, 1981).**

A basic assumption in this dissertation study was the belief that decision-making skills and processes are the outcome of neurological processes that also effect measurable physiological changes. Neurologists have an extensive research base describing the physiological bases of behavior. The relationships between specific neuroanatomic functions and emergent behaviors have been the focus of recent research, with applications to understanding human learning, memory, and the use of past experiences for real time initiation of action. Damasio (1999) proposed the somatic-marker hypothesis which described memory as evoking not only the remembered concept or skill, but also the emotional and physical state of the organism at the time of memory acquisition. Body sensations and emotional information experienced while learning a new concept or skill are connected in memory, though encoded in different parts of the brain. “Consequently, even when we merely think about an object, we tend to reconstruct memories not just of a shape or color but also of the perceptual engagement the object required and of the accompanying emotional reactions, regardless of how slight” (Damasio, 1999, p. 148).

Emotional input has been found in clinical observations and laboratory tests to be critical to the process of successful decision-making (Damasio, 1999). Decision-making is not viewed as an entirely rational process of choosing among alternatives, but strongly dependent on previously acquired emotional cues to help humans choose actions previously associated with success rather than failure (Damasio, 1999). Furthermore, decisions based on “knowledge and logic are facilitated by a nonconscious influence prior to knowledge and logic playing their full roles” (Damasio, 1999, p. 301). Emotion is essential to giving memories a value, either rewarding experiences to be repeated or negative experiences that have been found to lead to bad outcomes and should be avoided.

The emotion evoked by a memory or experienced as a result of real time perceptions can cause measurable physiological reactions, such as a change in heart rate or in skin conductance (Damasio, 1999, Kandel, Schwartz, & Jessell, 1995). “Emotional stimuli activate sensory pathways that trigger the hypothalamus to modulate heart rate, blood pressure, respiration” (Kandel, Schwartz, & Jessell, 1995, p. 607). Furthermore, “cognition and emotion affect each other reciprocally” (Kandel, Schwartz, & Jessell, 1995, p. 607): thinking causes elicitation of emotion, and emotion affects thinking processes. The low inference data source used in this dissertation was the measure of skin voltage changes commonly used in neuropsychology to measure arousal of the sympathetic nervous system in response to internal or environmental stressors. Skin voltage changes do not tell us what someone is thinking, but skin voltage changes do give an indication of the attention, arousal, and degree of emotion that the person is experiencing.

Neurologists have been exploring the connections between cognition and emotion for sixty years, while education researchers have studied teacher cognition and decision-making for at least fifty years. There has been no previous attempt to apply biological measures to the study of teachers’ interactive instructional decision-making in order to explore transitory emotional cues that teachers use to choose instructional actions.

The decision-making process of an expert teacher may be described as a system of interacting variables, serial and parallel subroutines, feedback loops, and bottlenecks. Education research programs, based on a variety of methodologies and theoretical perspectives, have identified salient elements of instructional decision-making and organized the elements in coherent models. Neurological research has identified structures and processes in the human nervous system necessary for normal decision-making. In order to combine the two research areas of education and neurology, a systemic approach to the analysis of a teacher's interactive decision-making was used. Simultaneous data collection to describe both instruction and the state of mind of the teacher was used to search for decision-making patterns during teaching episodes. The theoretical framework for the data collection and analysis is systems theory. Salomon (1991) described the systemic approach to the study of educational phenomena:

> The systemic approach mainly assumes that elements are interdependent, inseparable, and even define each other in a transactional manner so that a change in one changes everything else and thus requires the study of patterns, not of single variables. (p. 10)

Summary

Acquisition of a deep understanding of the complex, dynamic combination of strategic planning, habits, and improvisation in a teacher's decision-making process requires more information than direct classroom observation and teacher self-report data. The dynamics of simultaneously implementing, adjusting, and revising instruction from moment to moment strongly suggests a more systemic approach to data collection that integrates physiological correlates of covert cognitive activity of the teacher with direct observation to construct a more systemic picture of what happens when a teacher directs learning in the classroom. The next chapter reviews of research literature on instructional decision-making and substantiates the need for investigation of improvisational decision-making.

CHAPTER II

LITERATURE REVIEW

Education research has a long and rich history of interest in the process and substance of teachers' instructional decisions. The research focus has changed through the years, contributing to an extensive literature base on teachers' planning, thinking, evaluating, adapting, and acting to perform the role we call teaching. This review of literature describes theory and research that has contributed to the understanding of instructional decision-making, as well as the research methodologies needed to describe decision-making phenomena. Calderhead (1996) described three distinct historical stages of research on teacher cognition, knowledge and decision-making. The first stage consisted of studies of decision-making linking teacher thought and action, depending "heavily on various forms of self-report by teachers" (Clark & Peterson, 1986, p. 259). However, much of teachers' instruction required little reflective thought on the part of teachers and did not fit the researchers' definition of decision-making as an intentional choice between alternative actions. Thus the second stage of research shifted from formal decision-making to studies of essential parts of the instructional decision-making processes such as "…teachers' perceptions, attributions, thinking, judgments, reflections, evaluations, and routines" (Calderhead, 1996, p. 710). This stage included studies of how teachers perceive and act on instructional information. Interest in the development of teachers' knowledge and beliefs led to the third stage of research with a focus on how teachers learn their subject matter and how that knowledge contributes to instruction. Overall, there has been a shift from research explicitly directed to the study of decision-making to studies of the development of teacher knowledge and beliefs that contribute to decision-making. All three stages are included in the findings cited here, as well as complementary citations from psychology and neurology. An organizational scheme is depicted in Figure 2, which displays the topics, sequence, and relationships of research literature focus areas summarized in this chapter.

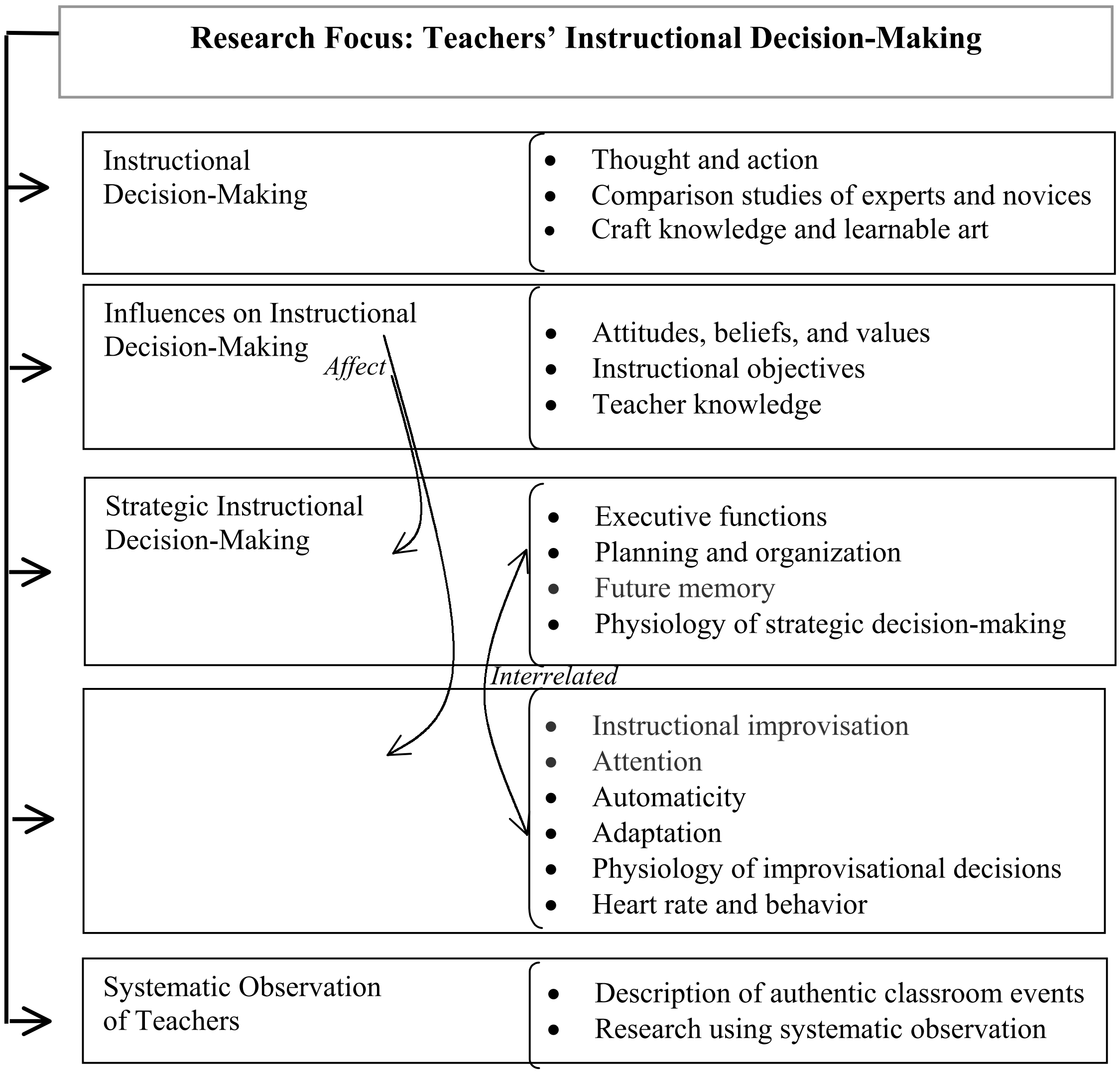


Figure 2. **Conceptual organization of literature review.**

Instructional Decision-Making

Thought and action. Philip Jackson (1968) began the current research emphasis on teacher cognition in his book *Life in Classrooms* (in Clark & Peterson, 1986). He directed interest in the planning and interactive instructional processes of teaching with an appreciation for the complexity of teachers' thought processes. The recursive relationship between teachers' thought processes, teachers' actions and observable effects of the teachers' actions was described in a model proposed by Clark and Peterson (1986). The model goes beyond the one-way cause and effect model used in process product research to include the influence of evaluative feedback on the teachers' thought processes. Not only were a teacher's instructional actions and impact studied, but also there were studies of the teacher's perception of outcomes and learning from classroom experience were examined. Shavelson and Stern (1981) presented another model of teachers' interactive judgments and decision-making in which most of instruction consisted of routines, with decisions usually being required "when the teaching routine is not going as planned" (p. 482). They sought to discover and categorize critical teaching decisions with the goal of intervening in teachers' decision-making to improve teaching. Shavelson and Stern (1981) based their research on two assumptions: (a) teachers are rational professionals carrying out "decisions in an uncertain, complex environment" (p.456), and (b) " a teacher's behavior is guided by his thoughts, judgments and decisions" (p.457). These studies of teachers' thoughts and actions relied on self-report and observational methods including policy capturing, lens modeling, process tracing, stimulated recall, ethnography, journal keeping repertory grid technique, and thinking aloud recordings.

Comparison studies. Comparison studies have been made between groups of expert teachers versus novice teachers, and effective teachers versus ineffective teachers. Education researchers using process-product analyses of effective teachers have found sometimes conflicting results. Brophy and Good (1986) concluded, “Although illustrating that instructional processes make a difference, this research [teacher behavior and student achievement] also shows that complex instructional problems cannot be solved with simple prescriptions” (p. 370). Some differences were found comparing personal characteristics of expert or effective teachers to others, but the most differences were found in how expert teachers think, create learning plans, and interact with their students (Borko & Putnam, 1996; Carter, Cushing, Sabers, Stein, & Berliner, 1988; Glaser, 1984; Good, 1996; Sternberg & Horvath, 1995).

Clark & Peterson (1986) described two problems found with the way ineffective instructors teach: (a) the teacher may try to process too much information without differentiating the information types and categories for instructional usefulness, and (b) the teacher may choose “not to change behavior when student behavior is judged to be unacceptable, even though the teacher believes that alternative behavior or strategies are available that could change the student's behavior” (p. 281). Thus, ineffective teachers were found to lack the ability to prioritize information, in order to attend to a smaller amount of more important information. There also was a problem with the volition and motivation of some ineffective teachers who chose not to enact instructional strategies that could change unacceptable student behavior.

The quality of the organization of experts' knowledge structures has been found to be "vastly superior to those of novices" (Alexander & Murphy, 1998, p. 180). Because of these extensive cognitive structures, successful teachers have been found to make better instructional decisions and make their decisions more rapidly than unsuccessful teachers.

Recently studies of expertise have identified common characteristics of experts: excellent memory for information in their subject area, acute awareness of what they do and do not know, greater ability to recognize patterns, greater ability to solve problems accurately and quickly, and extensive, organized knowledge structures (Alexander, 2003, Lajoie, 2003). In a departure from the expert-novice comparisons of past research, new studies in expertise use "cognitive methodologies, such as cognitive task analysis (CTA), to identify trajectories to competence as well as to indicate the possible transition points where instruction is needed" (Lajoie, 2003, p. 21). Cognitive task analysis has identified multiple pathways or trajectories to achieve competence, with experts using a variety of plans, actions, and mental models to solve problems (Lajoie, 2003).

Craft knowledge and learnable art. Research on the differences between the cognitive processes of experienced, successful teachers versus novices has provided some insight into the formation of instructional habits from past decisions. Experienced teachers apparently work from an internal instructional plan that they modify during improvisational interactions with their students (Borko & Livingston, 1989; Swanson, O’Connor, & Cooney, 1990). Calderhead (1996) described an instructional model based on the concept of a curriculum script “as a loosely ordered but well-defined set of skills and concepts students are expected to learn, together with the activities and strategies associated with teaching the particular topic” (p. 714). During interactive instruction, the script provides a dynamic plan for the sequence of activities and outcomes for a particular lesson. The teacher attends to student performance cues during instruction, which are used to adjust the dynamic plan. Experienced teachers have a large repertoire of curriculum scripts that they use to construct and enact their lesson plan agendas. This large repertoire of curriculum scripts provides the expert teacher with another planning tool: the ability to mentally rehearse different scripts for teaching their students, then to choose the best scripts in a workable sequence for implementation. Clark and Peterson (1986) wrote “One could hypothesize that the availability of detailed knowledge structures about a particular teaching setting provides the experienced teacher with the tools for mentally trying out learning activities and distinguishes the expert planner from the novice” (p. 265). Putnam (1987) studied “how six experienced teachers acquired information about students’ knowledge and used that information to adjust their instruction while tutoring” (p. 13). The study identified the key elements of teacher cognition to be “an *agenda*, a *knowledge base*, and a *model of the student*” (Putnam, 1987, p. 16). Putnam (1987) characterized the agenda as a “dynamic plan that changes during the course of the lesson or tutorial session as the teacher obtains new information about the students and draws upon previous knowledge” (p. 16). Thus an expert teacher during interactive teaching is actively attending to student cues and adjusting the lesson plan by selecting appropriate actions from a repertoire of possible actions.

Fenstermacher and Richardson (1993) proposed the idea of “practical rationality” of teachers, i.e., “the process of thought that ends in an action or an intention to act” (p.102), grounding education research in authentic contexts of teacher thought processes. Fenstermacher and Richardson (1993) identified a “practical argument” (p.103) as the formal elaboration of practical rationality and sought to assist “teachers in understanding the practical reasoning that ‘lies behind’ their actions” (p. 103), and to help teachers reflect on their own cognition and behavior, as well as to encourage teacher to change in accordance with educational theory. Practical arguments are not faithful descriptions of what teachers were thinking before or during instruction, rather they are the explanations teachers used to justify their actions after instruction. The researcher’s role is to elicit and reconstruct the practical arguments. A complete practical argument includes premises that provided an explanation of the value of the action, the meaning of the activity, empirical evidence supporting the use of the activity, and descriptions of the appropriate situation for using the activity (Fenstermacher & Soltis, 1993).

Batten and Marland (1993) studied expert teachers’ knowledge, judgments, and feelings in order to identify commonalities of teachers’ craft knowledge. They assembled a list of five aspects of successful teaching that “may sound like motherhood statements, the truisms of teacher education courses, but the 20 teachers in the studies were able to point to these principles in action in their classrooms and exemplify them in their lessons” (p. 65). The following are the five teaching strategies most often identified as necessary for successful teaching:

- developing good teacher-student relationships;
- creating a positive learning environment;
- exercising classroom management skills;
- catering for and responding to individual student needs;
- generating student interest and enthusiasm. (p. 65)

An expert's instructional decision-making may be viewed as the result of selection and implementation of "what works" from many past decisions, but similar classroom environments don't necessarily produce teachers with similar skills. Experienced teachers don't always become expert teachers. Some teachers learn more and become more skilled from their practice, becoming more talented teachers. Schön saw the development of professional craft knowledge similar to learning an art. He explained:

> If it is true that there is an irreducible element of art in professional practice, it is also true that gifted engineers, teachers, scientists, architects, and managers sometimes display artistry in their day-to-day practice. If the art is not invariant, known and teachable, it appears nonetheless, at least for some individuals, to be learnable. (Schön, 1983, p. 18)

Expert, effective teachers are self-made instructional artists in the sense they have developed complex performance skills for teaching while engaged in teaching.

Influences on Instructional Decision-Making

The context of classroom instruction is a complex environment in which teachers must make decisions. Teachers are faced with a variety of problems of choice which include curriculum standards, instructional goals, classroom management, classroom organization, instructional routines, and instructional sequences. Teachers' decision-making has been studied using different research designs including linking lesson planning to classroom behavior, content analysis of teachers' interactive thoughts during instruction, stimulated recall of thoughts during instruction, process-product studies of the instructional effectiveness of teachers' decisions, and the influence of teacher characteristics on decisions (Clark & Peterson, 1986).

Elements of instruction requiring teachers to make decisions are summarized below, with the assumption that it is not the choice of action itself that determines good instruction, rather it is the way teachers apply their choices that make instruction effective. Excellent teachers make effective instructional decisions according to the context of their own classrooms in order to address the needs of their own students (Borko, Livingston, & Shavelson, 1990; Calderhead, 1996).

Attitudes, beliefs, and values. Teachers' attitudes, beliefs, and values affect the instructional decisions they make. A relationship between a teacher's intentions, instructional goals, and beliefs and their instructional decision-making has been demonstrated in the research literature (Fenstermacher & Richardson, 1993; Hoy & Rees, 1977; Ross, Cornett, & McCutcheon, 1992; Shavelson & Stern, 1981; Tobin & Jakubowski, 1992). Richardson (1996) wrote, "beliefs are thought of as psychologically held understandings, premises, or propositions about the world that are felt to be true" (p.103). A strong belief system gives teachers an internal benchmark to evaluate the value of instructional actions.

Belief systems not only influence decision behavior, but also how decision outcomes are perceived and integrated into memory, thereby influencing future decisions. Richardson (1996) wrote, “Summaries of the research suggest that both attitudes and beliefs drive classroom actions and influence the teacher change process…” (p. 102). Thus teachers’ belief systems affect both how a teacher influences classroom events and how classroom events influence the teacher.

Context is important in the development of a belief system. Appropriate diagnostic and instructional interactions between a teacher and her/his students are evidence of skills which were developed during previous instructional interactions. The context for development of a teacher’s beliefs, attitudes and content knowledge influence the teacher’s subsequent classroom interactions. Calderhead (1996) wrote, “…research on the specific diagnostic and instructional interactions of teachers and students, and the thinking that accompanies these interactions, indicates the need to take account of teachers’ knowledge and beliefs and the contexts in which they are developed and used…” (p. 721).

Determination of the teacher’s attitudes, beliefs, and values requires more than teacher self-report data. Teachers’ instructional behaviors may not correspond to teachers’ expressed beliefs. Some educational researchers report discrepancies between what teachers say they believe and the way they teach, while others find consistencies in espoused beliefs and instructional practice (Calderhead, 1996). Apparently some teachers are accurately and honestly self-aware, while others are not. In either case, researchers studying teachers' attitudes, beliefs, and values should not assume that teacher self-report information is necessarily an accurate report of the teacher's behavior.

Instructional objectives. National, state, and local teaching standards are the basis of planning and testing for achievement of institutionalized instructional goals. An elementary school mathematics teacher was the subject of this case study, so appropriate teaching standards for mathematics were examined. The National Council for Teachers of Mathematics [NCTM] (1991) described the following important decisions a mathematics teacher should make:

- Setting goals and selecting or creating mathematics tasks to help students achieve these goals;
- Stimulating and managing classroom discourse so that both the students and the teacher are clearer about what is being learned;
- Creating a classroom environment to support teaching and learning mathematics;
- Analyzing student learning, the mathematics tasks, and the environment in order to make ongoing instructional decisions. (p. 5)

The NCTM list indicated the importance for teachers to choose appropriate academic learning tasks for their students, while simultaneously stimulating, supporting, and managing their students.

The Texas Essential Knowledge and Skills (TEKS) also specified standards for process skills and mathematical content knowledge for public elementary schools in Texas. The TEKS for third and fourth grade stated, "Throughout mathematics in Grades

3-5, students build a foundation of basic understandings in number, operation, and quantitative reasoning; patterns, relationships, and algebraic thinking; geometry and spatial reasoning; measurement; and probability and statistics" (Texas Education Agency [TEA], §111.15 Mathematics). The teacher in this case study taught a unit on probability to a mixed third and fourth grade class, so the specific objectives for probability and statistics were examined. Third grade objectives were to:

> (A) collect, organize, record, and display data in pictographs and bar graphs where each picture or cell might represent more than one piece of data;
>
> (B) interpret information from pictographs and bar graphs; and
>
> (C) use data to describe events as more likely, less likely, or equally likely.

The TEKS objectives for probability and statistics in fourth grade were to:

> (A) list all possible outcomes of a probability experiment such as tossing a coin;
>
> (B) use a pair of numbers to compare favorable outcomes to all possible outcomes such as four heads out of six tosses of a coin; and
>
> (C) interpret bar graphs. (TEA, §111.16 Mathematics)

In addition, the Houston Independent School District has specific mathematical instructional objectives and classroom activities described in their Project Clear documents. Objectives for mathematics are derived and directly aligned to the state standards, i.e. the TEKS.

When teachers choose their own instructional goals, institutionalized standards are just one set of objectives to be considered in addition to many other considerations. Published standards and popular curriculum reform movements do not necessarily drive instruction. Different people may interpret standards differently, and it is ultimately the teacher who chooses how standards are to be implemented in the flow of classroom events. Fenstermacher and Soltis (1992) described some of the problems with personnel and materials that might adversely affect implementing the best of curricular standards; problems which included handling intrusive school administrators and parents, managing classroom aides, coping with inappropriate instructional materials, complying with policy mandates, in addition to the day-to-day problems teaching a class of students.

Teacher knowledge. Mathematics teachers need to make decisions not only about mathematics content, but also about developmentally appropriate pedagogies and how to teach specific mathematics concepts. The research on effective versus ineffective teachers revealed differences in knowledge types and structures, with effective teachers having a deep understanding of the subject they teach. Borko and Putnam (1996) explained that it is essential to recognize “that teachers need to know more than just the facts, terms, and concepts of a discipline” (P. 676). Teachers need to know the organization of ideas and relationships among concepts in their subject area, as well as ways of communicating and developing knowledge within the discipline. This deep, connected knowledge is an important factor in how a teacher teaches a subject (Borko & Putnam, 1996).

Research on the relationship between subject matter content knowledge and effective teaching has presented surprising results. While mathematics teachers need to have a deep understanding of the mathematics concepts and skills they teach, extensive preparation in mathematics content has not been associated with more effective teaching. Bush and Kincer (1993) wrote “It is widely believed that the more a teacher knows about his subject matter, the more effective he will be as a teacher. The empirical literature suggests that this belief needs modification and in fact suggests that once a teacher reaches a certain level of understanding of the subject matter, the further understanding contributes nothing to student achievement” (p. 314). For example, rather than taking an advanced mathematics course such as calculus, an elementary school mathematics teacher’s instruction would benefit more by experiencing learning activities which deepen her/his knowledge of basic mathematics, e.g., measuring and calculating area and perimeter in a variety of authentic contexts to identify patterns of change. Furthermore, Nathan and Petrosino (2003) found evidence that subject matter expertise without strong pedagogical content knowledge may produce an “expert blind spot” in math teachers (p. 905), leading them to erroneously presume prerequisites for the development of concepts and skills in opposition to actual students’ performance.

On the basis of research on effective mathematics teachers, NCTM (1991) recommended that mathematics teachers know:

- mathematical concepts and procedures and the connections among them;
- multiple representations of mathematical concepts and procedures;
- ways to reason mathematically, solve problems, and communicate mathematics effectively at different levels of formality. (p. 132)

Educational researchers have identified the knowledge and skills of teachers who are able to choose and implement effective instruction appropriate for diverse populations of students. Pedagogical content knowledge refers to knowing how to teach subject matter content to specific types of students. Calderhead (1996) used the term craft knowledge for the array of instructional methods teachers develop to be effective, explaining “The term craft knowledge has been used to refer specifically to the knowledge that teachers acquire within their own classroom practice, the knowledge that enables them to employ the strategies, tactics, and routines that they do” (p. 717). To quote Shavelson (1973), “what characterizes the skillful teacher may not be the ability to ask higher order questions, but the ability to ask the right question of the right child at the right time” (in Calderhead, 1996. p. 710).

Tacit knowledge, or the “hidden bases for intelligent action” (Sternberg & Horvath, 1995, p. 12), has also been identified to be important for expertise in many professional fields, including teaching. Practical knowledge is often tacit and contextual, and is gained through experience teaching (Richardson, 1996). Past research on teachers' decision-making has shown that their decisions involve unconscious processing of experiences preceding and allied with conscious reasoning strategies (Alexander & Murphy, 1998; Calderhead, 1996; Fenstermacher & Richardson, 1993; Fenstermacher & Soltis, 1998; Korthagen & Lagenwerf, 1996; Lederman & Gess-Newsome, 1991; Tobin & Jakubowski, 1992). Damasio (1999) viewed emotion as a covert biasing system: “… the facts of past experience do not need to be made conscious. They do need to be connected by appropriate neural patterns with the current situation so that their preset influence can be exerted as a covert bias” (p. 302).

In summary, teachers make instructional decisions about what subject matter to teach, which routines and strategies to use, and what curricular materials to use. The teacher's subject matter knowledge influences the content decisions, the teacher's craft knowledge affects the routines and strategies the teacher decides to use, and the teacher's knowledge of available curricular resources influences the materials the teacher decides to use. Underlying all these different categories of decisions is tacit knowledge, the unconscious basis for intelligent action.

Strategic Instructional Decision-Making

Executive functions. The planning and instructional skills that characterize expert teachers have been identified as executive skills. According to Fenstermacher and Soltis (1998), "effective teaching might be analyzed into a discrete set of generic, or common, skills" (p. 11). Fenstermacher and Soltis (1998) believe that, regardless of the grade level, the types of students, subject matter being taught, or the school culture, specific instructional practices are regularly associated with increases in student achievement. The discrete executive skills included planning, implementing, evaluating, and revising events to achieve objectives. Fenstermacher and Soltis (1998) described the specific executive skills of teachers:

> They [executives] plan, execute the plan, appraise their effort, then revise and act again. Executives, by in large, manage people and resources. They make decisions about what people will do, when they will do it, how long it is likely to take, and what standard of performance determines whether to move on to the next task or repeat the old one. (p. 11)

Using Fenstermacher and Soltis' description, the sequence of executive skills which expert teachers demonstrated are summarized in Figure 3.

plan ⇒ execute plan ⇒ appraise effort ⇒ revise plan ⇒ act again

Figure 3. **Sequence of executive skills (Fenstermacher & Soltis, 1998).**

.An important characteristic of executive action is the proactive nature of a responsible leader. Shavelson and Stern (1981) viewed teachers as active agents who select instructional tasks consistent with the teacher's beliefs and goals. They identified the selected instructional tasks to be the basic unit of planning decisions.

Planning and organization. Teachers make many planning and organizational decisions including how to prepare for the scope and sequence of instruction, how to group students, and how to set up the classroom for instruction.

Teachers' organization of the classroom environment has a major impact on their instructional effectiveness. Thornton and Wilson (1993) summarized best practices for organization and planning of the elementary mathematics classroom, beginning with the choice of a classroom design to support effective learning. Student should be grouped to maximize student on-task behavior and minimizing distractions. Thornton and Wilson (1993) specified deliberate organizational strategies used by effective teachers, including arranging desks so that all students are visible, arranging student work areas for easy access, keeping frequently used materials accessible, and establishing traffic patterns to minimize disruptions. Thornton and Wilson (1993) also commented on the "best practices" for grouping of students. Effective teachers group students appropriately according to type of instruction, not limiting themselves to a single instructional method. "Depending on topic and need, most effective teachers combine whole class, direct instruction with cooperative learning or other models of student-centered instruction…" (Thornton & Wilson, 1993, p. 275). Thus effective elementary mathematics teachers organize their classrooms, instructional routines, and student groups to achieve academic goals, meet student needs, and minimize classroom management problems.

Time is another physical parameter of instruction requiring a teacher to make decisions. Early empirical studies of teachers highlighted the importance of time allocations for activities when planning instruction. Clark and Peterson (1986) summarized these earlier studies: "Judging from these empirically derived typologies of teacher planning we would conclude that substantial teacher energy is devoted to structuring, organizing for, and managing limited classroom instructional time" (p. 260). Thornton and Wilson (1993) wrote that teachers must make decisions about how time is to be used, taking into consideration the time needed for active learning, the shorter attention span of young children, and the amount of instructional time needed for high achievement in mathematics.

Teachers make planning decisions critical to the achievement of their students when they "convert or translate curriculum in ways that generate tasks that are educative for the students" (Fenstermacher & Soltis, 1998, p. 21). The translation of standards into a sequence of activities for a real classroom requires different types of information, including familiarity with the abilities and interests of all students, as well as knowledge of academic content standards and curricular resources.

The cognitive processes expert teachers use to plan instruction involve nonlinear, highly integrative decisions which affect present time events and future decisions while creating a mental script to guide instruction (Freiberg & Driscoll, 2000). Most of the real planning occurs in the teacher's mind, not on paper. Some planning decisions are highly reflective, while others must be made quickly in response to a rapidly changing classroom environment. Freiberg and Driscoll (2000) described four phases of instructional planning, which included preplanning, active planning, ongoing planning and postplanning. Preplanning and active planning occurred before instruction, while postplanning involved evaluation of the instruction with decisions for changes in future instruction. In contrast, ongoing planning occurred during instruction to adjust the planned lesson in response to ongoing classroom events. Ongoing planning required a teacher to think rapidly to modify a plan that the teacher perceived as needing revision. Adjustments and corrections are a part of teaching, and rigidly adhering to a plan that is not working is clearly ineffective (Freiberg & Driscoll, 2000).

Calderhead (1996) summarized research on instructional planning, identifying six main features of planning which are consistently reported despite different methodological approaches:

1. Planning occurs at different levels.
2. Planning is mostly informal.
3. Planning is creative.
4. Planning is knowledge based.

5. Planning must allow flexibility.

6. Planning occurs within a practical and ideological context. (p. 713)

In summary, teachers simultaneously address multiple objectives from classroom management to conceptual development in their plans. Teachers use information about students, academic content, and available resources to create a practical plan designed to work in a real classroom. Teachers are creative and flexible in their plans, with alternate ways of looking at problems and construction of adaptable plans suitable for different contexts (Calderhead, 1996).

Future memory. How are teachers able to envision multi-level, knowledge-based instructional scripts in their planning processes? Physiological psychologists have identified a human ability for “future memory,” which represents preplanning of potential future actions in such detail that the real acts are carried out as “a memory of already formulated plans” (Benson, 1994, p. 211). Bronowski (1973) wrote, “In man, before the brain is an instrument for action, it has to be an instrument of preparation” (p. 424). Projecting the outcome of a plan, then monitoring the plan in action demonstrates the “ability of the human mental system to monitor itself. It includes not only review of an immediate response and planned responses but the ability to consider both past and future potential” (Benson, 1994, p. 211). A teacher in a classroom simultaneously enacts a planned instructional script largely from memory, evaluates the success of the script, and decides which changes to make in future scripts. Making sense of real time experience in the midst of past and future memory helps humans choose successful strategies to follow (Damasio, 1999).

Neurophysiology of strategic decision-making. A teacher who plans tasks, sequences activities, monitors students, and has the will and the drive to carry out plans exhibits executive skills attributed to the prefrontal cortex of the brain. “With its widespread connections and vast information base, the prefrontal cortex occupies a prime position to monitor input, weigh potential response consequences, and initiate and monitor the selected response, the process called executive control” (Benson, 1994, p. 226). Common definitions of decision-making include an element of volition, the idea that a decision requires a deliberate choice of action. Effective teachers do not passively respond to the classroom environment, rather they perceive, analyze, and intervene in classroom events. Human motivation and the feeling of volition that accompanies executive decisions have also been found to be a function of the prefrontal cortex of the brain.

The frontal association area of the human brain is divided into two main subregions: the prefrontal association cortex and the orbitofrontal cortex (Kandel, Schwartz, & Jessell, 1995). The orbitofrontal cortex is connected to the limbic system, which is “devoted mainly to motivation, emotion, and memory” (Kandel, Schwartz, & Jessell, 1995, p. 83). Knowledge of human brain function is often gained by description of the deficits of impaired individuals. Deliberate impairment of this region of the brain was a result of frontal lobotomy surgery in which the connections between the limbic system and the orbitofrontral cortex were cut. This type of surgery is no longer done because of the availability of effective psychotherapeutic drugs and the deleterious side effects of the surgery, such as lack of inhibition and lack of drive (Kandel, Schwartz, &

Jessell, 1995). However, the surgery revealed how essential the connections are between emotion and cognition in order for a human to have motivation, to maintain appropriate inhibitions, and to feel volition. There is brain imaging evidence that behavior is initiated before “a feeling of volitional control over behavior emerges” thus indicating that the preconscious generation of an action is independent of the conscious feeling of intention to act (Goldberg, 1987, pp. 274-275).

In addition to volition, inhibition, and motivation, “The frontal lobes of the brain are presumed to be involved in the highest level of goal-directed acts including complex sequencing, the creation of long and short-term plans, and the internal manipulation of representational systems” (Perecman, 1987, p. 1). Executive control in psychobiology is characterized by planning, monitoring, and responding behaviors. Benson (1994), a neurologist, wrote that anticipation, planning an appropriate response, evaluating a potential response, selecting a response, and monitoring an actual response are all processes called executive functions of the brain. Furthermore, executive functions are associated with the enlarged prefrontal cortex of humans. Thus the ability of humans to extract salient information from the environment, maintain a temporal order for events, and choose to initiate present behaviors in anticipation of future outcomes is a function of the part of the human brain that uses emotional information from the limbic system to direct behavior (Benson, 1994, Damasio, 1999).

Interactive Instructional Decision-Making

Educational researchers have found qualitative differences distinguishing teacher cognition before instruction from teacher cognition during instruction. There are differences in the ways that teachers think, changes in the cues that draw their attention, and an increase in the automaticity of their actions.

Instructional improvisation. A teacher's instructional plan is stored as a mental image and is implemented as interactive teaching behaviors (Clark & Peterson, 1986). Effective teachers follow their structured plan largely from memory while simultaneously using student cues to adjust their plan to meet student needs. "Like improvisational actors, these teachers work from mental scripts that consist of general outlines of their lessons. They fill in the outlines during interactive teaching to ensure that their instruction is responsive to student performance" (Borko & Livingston, 1989, p. 483).

Teachers may simultaneously monitor, evaluate, and change their plans during instruction. Interactive teaching is an empirical mode of instruction, when abstract plans are translated into classroom actions. Fenstermacher and Soltis (1998) described the uncertainty of interactive teaching:

> After you figure out what is to be done, then you must do it. No matter how well you plan, events will occur that cause you to veer from your plan. In the course of teaching, you are constantly making decisions about the students, the material, and the overall success or failure of your efforts. You probably revise your plan many times while on your feet teaching the lesson. (p. 10)

Communication skills, instructional experience and intrinsic knowledge of teachers are sources of alternative strategies when a plan needs to be adjusted on the spot. This is the point in teaching where an expert teacher who has “an extensive network of interconnected, easily accessible schemata” (Borko & Livingston, 1989, p. 485) has an advantage over a novice teacher. According to Borko and Livingston (1989), the expert teacher also has the “ability to select particular strategies, routines, and information from these schemata during actual teaching and learning interactions, based on specific classroom occurrences” (p. 485).

Patterns in time. Frick (1990) analyzed temporal patterns of instruction in time by measuring “transactions among students, teachers, curricula, and educational settings” (p. 181). Frick(1990) characterized the analysis of patterns in time (APT) score by comparing it to someone listening to an orchestra who records the music of each instrument by writing both the musical notes and the timing of the notes. The APT score includes these kinds of records for all the instruments. In a classroom, concurrent student behaviors, teacher behaviors, and instructional outcomes might be recorded at brief intervals of time to provide a multidimensional record of events. Previously, Frick found that students are more likely to engage in off-task behavior when the teacher was not engaged in direct instruction. Frick’s APT scores have been used in expert computer systems, but not for the investigation of teachers’ interactive decision-making during instruction.

Lin and Lorenz (1999) proposed using sequential and repetitive student assessment as a measure of teacher effectiveness. The measurement instrument was a test bank of thirty-eight multiple choice items, given to a class of students of an experienced science teacher and students of a beginning science teacher. The test items were given one randomly-selected item at a time at the end of the class period, three times a week before, during, and following instruction on content applicable to the test items. The scores of the two classes were compared, and the students of the experienced teacher performed slightly better than the students of the beginning teacher during instruction and follow-up. Two observers also scored the teachers from videotapes of instruction on a Likert scale to categorize the frequency of observed teaching behaviors such as pace, encouragement, student interactions, memory activities, and down time. The time series analysis in this study was performed using student data, not teacher behaviors.

Reidbord and Redington (1995) investigated time series analysis of heart rate associated with events during psychiatric treatment in the search for "a reliable form of observational access to mental life, and an adequate means of describing and predicting what may be observed" (p. 527). They noted that "Research tends to study and describe the state [of mind], the static or cross-sectional configuration, not the "motion" from state to state, and certainly not the underlying controls that regulate this flow on a moment-to-moment basis" (p.529). They propose that the analysis of dynamic systems requires large valid data sets, and the mind can only be studied at the present time by "objectives effects, whether these consist of the subject's verbal report, autonomic outflow [sympathetic and parasympathetic nervous system effects], or actual physical behaviors such as gestures and facial expressions" (Reidbord and Redington,1995, p.531). The outcome of this research was multiple "phase portraits" (p. 539) of a patient’s heart rate during psychiatric treatment and the researchers’ plans for future studies.

Attention. Teachers who demonstrate an ongoing awareness of students and classroom activities have been described as having the quality of “withitness” (Jones, 1996, p. 512). Teachers who have withitness and “other effective management methods unquestionably have significantly fewer disruptions and less inattentive student behavior than teachers who fail to implement these methods” (Jones, p. 512, 1996). Effective teachers pick out salient cues in the classroom for their attention, which may be followed by a decision to intervene as appropriate.

How do teachers learn which classroom events require their attention and which instructional or management strategies to use when they decide that intervention is needed? Research on attention and perception indicates that the sensory environment is not the sole determinant of human response. “Descriptions restricted to the relationships between environmental stimuli and elementary responses can rarely account for the elaboration and implementation of observable behavior in humans” (Hoc, 1988, p. 3). Neither is the withitness of effective teachers a simple stimulus-response system.

Automaticity. Education researchers have found that teachers make few reflective decisions while working directly with students in a classroom. Research on the differences between the cognitive processes of experienced, successful teachers versus novice teachers has provided some insight into the formation of instructional habits from past decisions. Successful, experienced teachers tend to show an automaticity in cognitive skills that novice teachers and unsuccessful teachers lack, such as the ability to simplify, differentiate, and transform the high information load that occurs during classroom interactions (Borko & Livingston, 1989; Putnam, 1987; Swanson, O'Connor, & Cooney, 1990). Sternberg and Horvath (1995) described a basic difference between expert and novice teachers in their ability to solve problems efficiently, "That is, experts can do more in less time (or with less apparent effort) than can novices" (p. 12). Sternberg and Horvath (1995) emphasized that "the capacity to automate well-learned routines cannot be separated neatly from the schematic organization of teaching knowledge in any reasonable account of the mental processes involved in expert performance" (p. 13). Routines emerge as important processes for successful interactive decisions. Successful, expert teachers don't waste time making deliberate, reflective decisions over and over again, when they have already found workable solutions in the past.

Adaptation. Beginning teachers seem to have simple undifferentiated conceptual structures that are inadequate for making sense of classroom events (Clark & Peterson, 1986). At the other end of the experience continuum is the expert teacher whose "practice is characterized by a fluency and automaticity in which the teacher is rarely surprised and is fully adapted to and in control of the situation" (Calderhead, 1996, p. 717). The development of craft knowledge through classroom experience may be characterized as an adaptive process, since both teacher learning and selective pressures of interactive instruction contribute to the development of an expert teacher.

Many novice teachers never survive in the educational system long enough to become expert teachers. About thirty percent of teachers in Texas quit within the first five years due to "…low salaries, rampant student discipline problems, and little faculty input into school decision-making…" (Marshall & Marshall, 2003, p.6). Path analysis of empirical literature on teacher burnout indicated that "classroom climate proved to be a major variable in the nomological network of teacher burnout" (Byrne, 1999, p. 32). Negative aspects of classroom climate included "…student discipline problems, student apathy, low student achievement, and verbal and physical abuse by students…" (Byrne, 1999, p. 24). Lederman and Gess-Newsome (1991) wrote that despite the best efforts of science teacher educators, "science teachers often survive or fail as a function of the school or classroom setting into which they have been placed" (p. 455), and they suggest that "the rather sudden 'immersion' of the student teacher into such a situation may create more poor habits, in the form of survival skills, than effective instructional skills and strategies" (p. 453).

Goldberg (1987) described the mammalian nervous system as a powerful advantage in the process of adaptation:

> Living systems are continuously in a state of massively dynamic change in the adaptive struggle to surmount environmental conditions that may threaten survival. The most powerful result of the evolutionary elaboration of the mammalian central nervous system is the unequaled capacity for adaptive change and learning which its operation makes possible for the individual organism on the behavioral (microgenetic) time scale. (Goldberg, 1987, p. 276)

Instead of needing time for changes in the gene pool from generation to generation, we humans have the ability to adapt on the microgenetic time scale, which is the time (minutes to years) it takes for us to learn how to succeed in a new environment. Our brains evaluate the value of the acquisition of new skills and knowledge. Emotional input is a controlling factor in judging what is worthwhile to learn. In order to survive, humans are physically constructed to constantly engaged in evaluation "of their changing relationships with the environment with respect to the significance of these relationships for well-being" (Lazarus, 1991, p. 213). It is an ongoing challenge to understand why some teachers adapt to challenging classroom environments by developing effective instructional skills and becoming proactive instructional leaders, while others quit or burn out.

Physiology of improvisational decisions. The environment of a classroom is often stressful and fast-paced, and may bring out strong emotions in a teacher if the students misbehave. Decisions that must be made quickly in stressful conditions are likely to be more intuitive than reflective (Jones, 1996). Intuitive decisions are not necessarily bad decisions, and there is research indicating the value of intuition for making smart decisions. Neurobiologists have found that "in normal individuals, non conscious biases guide behavior before conscious knowledge does" and "without the help of such biases, overt knowledge may be insufficient to ensure advantageous behavior" (Bechara, Damasio, Tranel, & Damasio, 1997, p. 1293). Bechara et al. (1997) also found that normal people could make strategically sound decisions without being able to verbally describe the strategy that they were using. Vogel (1997) observed that: "Intuition may deserve more respect than it gets these days. Although it's often dismissed along with emotion as obscuring clear, rational thought, a new study suggests that it plays a crucial role in humans' ability to make smart decisions" (p. 1269).

Neurophysiological research has indicated the ability of the unconscious mind for complex processing of information which is in a dispositional form. These dispositions are acquired through past experience and influence our experience of the present. Damasio (1999) explained, "Dispositions hold some records for an image that was actually perceived on some previous occasion and participate in the attempt to reconstruct a similar image from memory" (p. 332). The dispositions also influence the degree of attention that is given to a current image. We are not aware of the intermediate steps needed to accomplish any of these memory or attention tasks. "We are only aware of result, for example, a state of well-being; the racing of the heart; the movement of a hand; the fragment of a recalled sound; the edited version of the ongoing perception of a landscape" (Damasio, 1999, p. 332). Allied with the dispositional, unconscious memory is the emotional content associated with the memory. Decision-making also involves unconscious processing of past emotional experiences along with conscious reasoning strategies and memory (Brown, 1990). The recognition of the importance of emotion in evaluative judgments was explained by Damasio (1999):

> In recent years both neuroscience and cognitive neuroscience have finally endorsed emotion. A new generation of scientists is now making emotion its elected topic. Moreover, the presumed opposition between emotion and reason is no longer accepted without question. For example, work from my laboratory has shown that emotion is integral to the processes of reasoning and decision making, for worse and for better. (pp. 40-41)

The findings by educational research that interactive teaching is more routine than reflective indicates the importance of unconscious processes of the mind that a teacher is not able to report or even consciously experience. The teacher may only be able to report the end product of the complex unconscious process, an end product described as feeling of well-being, increase in heart rate, hand movement, or the memory of a sound (Damasio, 1999).

Heart rate and behavior. In order to understand some of the systems that contribute to the unconscious processes involved in decisions, medical researchers have used heart rate measurements as a physiological correlate of behavior. Heart rate is influenced by both the autonomic nervous system and cortical activity, so it may change due to visceral conditions or conscious thought. Psychophysiological studies since the 1970's have found that "heart rate is related to attention and information processing" (Coles, 1983, p. 171). These "orienting reactions" are associated with heart rate changes and are "preemotional phenomena" which precede the next level of complexity, which is appraisal of stimuli as good or bad (Temoshok, 1983, p. 212). The Intake-Rejection Hypothesis predicts that heart rate increases when a person is rejecting, or blocking out stimuli, and heart rate decreases when a person attends to external stimuli (Coles, 1983). Thus psychophysiological data may indicate unconscious processes that contribute to overt, observable behaviors.

Reidbord and Redington (1995) used patients' heart rate frequencies to analyze how the rates changed during clinical interviews. They chose to measure and analyze heart rates as a "window onto mental life" (p. 527), because "…heart function may provide indirect, yet timely and precise access to autonomic nervous system dynamics, and thereby to core brain states" (p. 534). Another research group working with disabled children used heart rate changes to measure the responses of five children undergoing associative learning situations because the researchers concluded, "Autonomic components of behavioral reactions are not mere epiphenomena, but constitute an integral aspect of adaptive response. Autonomic measures have been widely employed in research on behavioral function because of their sensitivity to behavioral state and environmental change" (Ronca, Tuber, Berntson, & Boysen, 1991, p. 102). Published research on the changes in heart rate, or other physiological measures, during classroom instruction are nonexistent at this time.

Systematic Observation of Teachers

Description of authentic classroom events. The education research community uses systematic classroom observation in a variety of ways to measure and describe authentic classroom events for a wide range of studies from experimental designs to ethnographic narratives. Despite the variety of methodologies and research goals, systematic classroom observation is characterized by some commonalities, including an interest in studying instruction and learning *in situ* as opposed to laboratory environments; a concern about reliability, validity, and limits on certainty of data; and the correspondence of methodology to research questions (Evertson & Green, 1986). Furthermore, systematic classroom observation methodologies are formal, deliberate processes which need to meet criteria of methodological rigor.

Classrooms are complex environments with multiple options for a research focus—and the environmental complexity necessitates ignoring some variables in order to focus on the variables or phenomenon of interest. A research focus could be on developmental processes, micro to macro relationships between variables, intrapersonal characteristics related to classroom events, interpersonal communication related to student achievement, or a search for relationships between specific teacher behaviors and subsequent achievement test scores of students. Evertson and Green (1986) organized the variety of data collection methodologies into four classification groups: category systems, descriptive systems, narrative systems, and technological records. They further characterized each classroom observation system according to the nature of the system as open or closed, the type and method of recording data, and goals of the users (Evertson & Green, 1986).

The choice to conduct a study of the classroom as a dynamic system leads to more decisions about who and what to observe. Evertson and Green (1986) described a unit of observation as an independent variable that is not manipulated by the investigator. Units of observation may be aggregated to create to form new units of observation, such as combining measures of praise, guiding remarks, and corrective comments into a new unit of observation called teacher feedback. The unit of observation in this case study was an instructional decision, measured as directly observable, discrete teacher initiated actions and recorded using the adapted SOS.

Systematic classroom observation has been crucial to non-experimental research designs which include descriptive and correlational research studies found to be "essential in theory building and suggesting variables worthy of inclusion in experiments" (Slavin, 2002, p. 18). Early studies focused on presage variables or teacher characteristics rather than observation of instruction, and some used administrator ratings as the measure of teaching effectiveness. In contrast, Flanders created the "Flanders Interaction Analysis Categories (FIAC)" (Brophy & Good, 1986, p. 333) to document classroom processes. Another improvement was the use of multiple observers and multiple observation instruments. For instance, Good and Grouws (1977) used two trained observers with greater than 80% agreement in coding categories during training, and collected four sets of information including, a) time measurements to describe how instructional time was used, b)"low inference descriptions of teacher-student interaction patterns" (p. 50), c) high inference variables, and d) checklists describing materials and homework assignments.

Research using systematic observation. Systematic observation of classroom used in process-product research studies "tended to follow a common general paradigm" (Shavelson, Webb, & Bernstein, 1986, p. 51). The process was defined as measurements of teacher behavior, usually derived from systematic classroom observations; and the typical products or outcomes were measurements of student achievement from a large sample of classrooms (Shavelson et al., 1986). At first process-product research was correlational with a search for teaching behaviors that were associated with student gains in achievement test scores. Later the process-product research included experimental field studies to compare teaching effectiveness of teachers using a curriculum or an instructional technique versus teachers who were not using the educational innovation.

These comparisons sometimes lacked the assurance that the control teachers were not using the innovation and the assurance that the experimental teachers were using the innovation.

Dependence on norm-referenced achievement test scores, which are totaled and aggregated, has been a problem with process-product research, since aggregated scores may miss patterns of achievement or achievement in content areas not tested. It is no surprise that the curriculum program which produces superior results is the one that matches the goals of the achievement test the closest (Shavelson et al., 1986). While "opportunity-to-learn" (Shavelson et al., 1986, p. 53) and time on task were found to be the major determinants of performance on standardized achievement tests, it was not known how the effects were achieved through different teaching practices.

Process-product results have been occasionally nonlinear and sometimes even counter-intuitive. Results of correlational process-product research studies include disordinal relationships such as the correlation between emotional climate and achievement. Negative climates are associated with negative achievement, while positive climates show no significant correlation with achievement (Brophy & Good, 1986). Other results show a dependence on context, such as the process variable of teacher praise, which is associated with positive outcomes for younger students, but not with older students (Wittrock, 1986). In addition, some process-product research has neglected to verify the presence of independent variables in experimental classrooms and the absence of the independent variables in classrooms used for comparison as controls (Shaver, 1983). The complexity of the job of teaching and the self-determination of teachers makes systematic classroom observation an important part of any research on the practice of teaching (Shaver, 1983).

A coherent picture of context-dependent effective teaching emerged from the correlational process-product research, “but what products are caused by what processes cannot be determined by correlational research” (Anderson, Evertson, & Brophy, 1982, p. 15). In contrast to experimental studies conducted in controlled laboratory settings, Anderson et al. (1982) examined teacher behaviors “in a more natural way, because the study used the materials, the schedules, the lessons, and the settings that already existed in the schools” (p. 15). Anderson et al. (1982) used extended observation periods to measure the process of both control and experimental teachers, since “not all treatment teachers adopt a treatment, and some control teachers may already be using some of the techniques that a treatment is designed to encourage” (pp. 15-16). The treatment used in their study was based on an extensive research base of process-product studies, from which Anderson et al. (1982) derived twenty-two principles of good instruction including recommended use of non-verbal signals, optimal placement of the teacher relative to the class, a recommended instructional sequence for concept development, and suggested feedback techniques.

However, the introduction of an experimental research design in educational settings sometimes presents problems. Stallings, Bossung, and Martin (1990) conducted an experimental study of the Houston Teaching Academy to prepare student teachers to teach inner city students. They compared a group of 44 experimental student teachers to 25 control student teachers. Stallings et al. (1990) acknowledged difficulties conducting experimental research in educational environments which include confounding variables beyond their control. Recruiting and matching student teachers for each group was particularly difficult (Stallings et al., 1990).

A persistent problem with process-product research in the past was the possible loss of information about differential effects due to aggregation of data. Generalizability theory has provided a way to analyze variance of facets of a study by partitioning sources of variance in behavioral measurements (Shavelson et al., 1986). Shavelson et al. (1986) concluded that “as research progresses into new areas at an explosive rate, measurement issues abound” (p. 86).

Summary

An instructional decision has been defined as a deliberate choice when more than one potential alternative exists in the teacher’s conscious mind. Other qualifying conditions include a discrete time interval for the decision and a feeling of volition accompanying the choice. Empirical studies of teacher cognition during interactive instruction have blurred the distinction between conscious decisions and automatic actions, since the automatic behaviors have often developed from conscious decisions in the past. Attitudes, beliefs, values, teacher knowledge, and external conditions influence the instructional decisions that teachers make. The expert teacher who plans tasks, sequences activities, monitors students, and has the motivation to carry out plans is demonstrating executive skills attributed to the prefrontal cortex of the brain (Benson, 1994). The prefrontal cortex is the part of the human brain that uses emotional information from the limbic system to direct behavior (Kandel, Schwartz, & Jessell, 1995). Both pleasant and unpleasant events are associated with sympathetic nervous system arousal and increase in heart rate, so assumptions about the emotional context for an increase in heart rate cannot be made (Kalat, 1995). The contribution of teachers' unconscious physiological processes to their observable decisions has yet to be described.

CHAPTER III

METHODOLOGY

This is an empirical study of a complex system in which there is an “interdependence among variables, actions, events, and constructs…” (Salomon, 1991, p. 13). Both qualitative and quantitative data collection and analysis methods were used, and found to be necessary for description of instructional decision-making. The quantitative data were used for nonexperimental quantitative description (Johnson, 1998) and the qualitative data were used for constant comparative analysis using predetermined categories (Meriam, 1988). Dewey wrote, “Behavior is serial, not a mere succession. It can be resolved—it must be—into discrete acts, but no act can be understood apart from the series to which it belongs” (in Salomon, 1991, p. 16). The teacher’s decision-making system was analyzed as serial elements in a whole system.

In this case study, a teacher’s instructional decision-making was viewed as a part of the dynamic ecology of her classroom. No variables were manipulated in this research, and data collection was designed for minimal disruption to the activities of the teacher and students. In order to describe multiple facets of the teacher’s decision-making process, a combination of physical recordings, coded observations, and teacher self-report data were used as information sources.

This case study included high frequency, continuous data collection to document the rapidly changing teacher behavior during instruction. Identification and analysis of rapid decision-making during classroom instruction requires research methods that are appropriate for both the decision-action context and frequency. Time series analysis was chosen for the collection and processing of quantitative data in this case study because it is an analytic method for the identification of trends and patterns in complex behaviors over time (Goldberger, 1999). Qualitative data sources were collected and processed to identify planning decisions which were integrated into the classroom instruction. The two data types were found to be necessary for the interpretation and description of the teacher's decision-making.

The physiological recordings were part of the data collection in this case study because medical research has demonstrated the value of heart rate recordings to measure a subject's autonomic nervous system responses, which are allied with emotional responses. "Autonomic measures have been widely employed in research on behavioral function because of their sensitivity to behavioral state and environmental change" (Ronca, Tuber, Berntson, & Boysen, 1991, p. 102). "In recent years emotional behavior has increasingly been viewed as an outcome of the interaction of peripheral and central [cortical] factors" (Kandel, Schwartz, & Jessell, 1995, p. 596). A list of comparisons of measures used to index fear in animals and DSM-III criteria for generalized anxiety was headed by "increased heart rate" for the animals and "heart pounding" for the humans (Kandel, Schwartz, & Jessell, 1995, p. 597).

The teacher's heart rate was recorded simultaneously with the coded teacher behaviors and classroom observations in order to identify events associated with changes in her autonomic nervous system activity. Published research on changes in the teacher's physiological measures related to classroom instruction are nonexistent.

Research questions. The following research questions were used to guide the data gathering and analysis methodology in this descriptive case study of the salient elements of an expert teacher's decision-making process:

(1) How does a teacher integrate decisions made outside class into her classroom instruction?

(2) How does a teacher make improvisational decisions during class?

(3) Do improvisational decisions elicit a physiological response?

Description of Research Methods

Quantitative and qualitative methodologies were combined in this exploratory case study of an expert teacher's decision-making process while planning and teaching mathematics to a combined third/fourth grade class. The quantitative methodologies included analyses of time series and calculation of correlation coefficients to investigate possible relationships between physiological responses and decision-actions, variables measured as skin voltage changes and observed instructional behaviors, respectively. Quantitative data on these two variables were collected continuously and simultaneously during classroom instruction, then partitioned into time intervals for use in univariate and bivariate time series analysis. The time series were analyzed for trend, stationarity, relationships between data points within the same time series (autocorrelation), and relationships with other time series (cross correlation).

In addition to the quantitative data, qualitative data from multiple sources were collected, arranged, organized, and analyzed. Stallings Observation System (SOS)

(Stallings, 1993) categories and decision types identified by educational research findings were used to identify, organize and analyze qualitative data. Once the qualitative data were selected and categorized according to decision type and context, the information was then categorized into codes representing salient decision-making elements following the constant comparative method as described by Merriam (1988) and Bogdan and Biklen (1992). Emergent themes were discussed with the teacher participant throughout the data collection period. Categories and codes were analyzed for hierarchical relationships, temporal sequences, and other patterns.

Research design. This exploratory case study used mixed methods appropriate to descriptive research, including categorical analysis, constant comparative qualitative analysis, time series analysis, and calculation of correlation coefficients between quantitative data sources. The time series analyses were used for nonexperimental quantitative description (Johnson, 2001); while qualitative information was used to provide context for the quantitative description and meaningful information about patterns of decisions in classroom instruction (Creswell, 1994).

Johnson (2001) identified time series research as a strong quasi-experimental research design. He proposed that nonexperimental quantitative research may be classified according to three research objectives: descriptive, predictive, or explanatory; cross-classified by three time dimensions: retrospective, cross-sectional, or longitudinal. Johnson (2001) described research as longitudinal when “the data are collected at more than one time point or data collection period and the research makes comparisons across time.” In this study, though the observation period is not long term according to a human life span, high frequency data collection throughout entire class periods every day the class met for two weeks made it possible to make both qualitative and quantitative comparisons across time. Johnson (2001) further classifieD research as descriptive when there is a positive response to these two questions:

- "Were the researchers primarily describing the phenomenon?"
- "Were the researchers documenting the characteristics of the phenomenon?"

This study sought to describe a teacher's instructional decisions through the collection of large amounts of data during instruction. Thus, the time series analysis in this study was classified as a longitudinal, descriptive (type 3) study using Johnson's proposed categories for nonexperimental quantitative research, based on the time dimension for data collection and research objectives.

Research design issues. A primary concern in the design of research on teachers' instructional decisions has been what Schön (1983) called the dilemma of "rigor or relevance" (p. 42). Decision-making research may be conducted in controlled laboratory environments or it may be conducted in fast-paced, complex classroom environments. This chapter includes descriptions of data collection methods selected to gather data using unobtrusive procedures in an authentic classroom environment.

The case study research design was chosen because of the exploratory nature of this project. There are no previous studies of the physiological responses of teaching while teaching and no time series analysis studies of teachers using simultaneous, rapid data collection. A case study is well matched to the objective of studying a phenomenon in order to discover salient variables, processes, and interactions that show promise for future study.

Another important issue was the selection of data sources for the description of decision-making that would sample the multiple layers of decision-making processes, from unconscious automaticity to conscious reflection. Education literature and methodology are rich sources of information about the study of reflective instructional decision-making. However, measurement of tacit knowledge-in-action required a new approach, derived from research in psychology and medicine.

Finally, there was a necessity to gather data on interactive decision-making simultaneously and rapidly to match the rapidity of the phenomenon being studied. The teacher was able to produce instructional interactions at a higher rate than a human could document or interpret. Recording technologies were essential for subsequent examination of what was happening in real time and to check for the validity of the data collected.

The fourth issue guiding data collection was the need to describe connections between the unconscious automatic processes and the processes of conscious reflection, which necessitated the collection of both quantitative and qualitative data. The mixed methodology of nonexperimental quantitative description combined with qualitative description proved to be essential for the interpretation of the data.

Qualifications of the Researcher

Deborah Jensen is the Associate Director of Precollege Science Education Programs, Wiess School of Natural Sciences at Rice University. She has co-directed the Eisenhower/Teacher Quality-funded *Science and Mathematics Institute* and the *Micro to Macro Institute* for the past three years, as well as serving as the lead instructor for the *Science and Mathematics Institute* since its inception in 1999 as part of an NSF award. She also co-leads a high school level professional development program focused on space biology funded by the National Space Biomedical Research Institute, a collaborative effort with the University of Texas Medical Branch in Galveston, Texas. Ms. Jensen has over 14 years of experience teaching science and mathematics and was awarded the Region VI (Texas) Secondary Teacher of the Year in 1991.

Ms. Jensen has a bachelor's degree in experimental psychology, a master's degree in the biological sciences and laboratory research experience in mammalian physiology. She has been a contract curriculum writer (*Modern Biology* ©1996) for Holt, Rinehart, and Winston. Ms. Jensen trained in the Stallings Observation System (SOS) Active Teaching and Learning Program during a workshop August 20-24, 1996, and trained in the Learning to Teach Inner-City & Diverse Populations Program during a workshop September16-20, 1996. She then was hired to be an SOS Observer in K-8 classrooms for two research projects at Texas A & M University during the following year. While at Texas A & M University, Ms. Jensen conducted two pilot studies of expert science teaching using qualitative research methodology. Her interest in science and mathematics education is an outgrowth of her experiences in the discipline and has caused her to pursue research that focuses on in-service teachers' decision-making processes.

Context and Data Collection

Figure 4 shows the sources for qualitative and quantitative data collected either during instruction, or at times outside classroom instruction, i.e., before or after instruction. Multiple data sources were selected for the different types of information that could be analyzed, with the assumption that rich description of a teacher's instructional decision-making required exploration and measurement of multiple levels of cognition and neural processing.

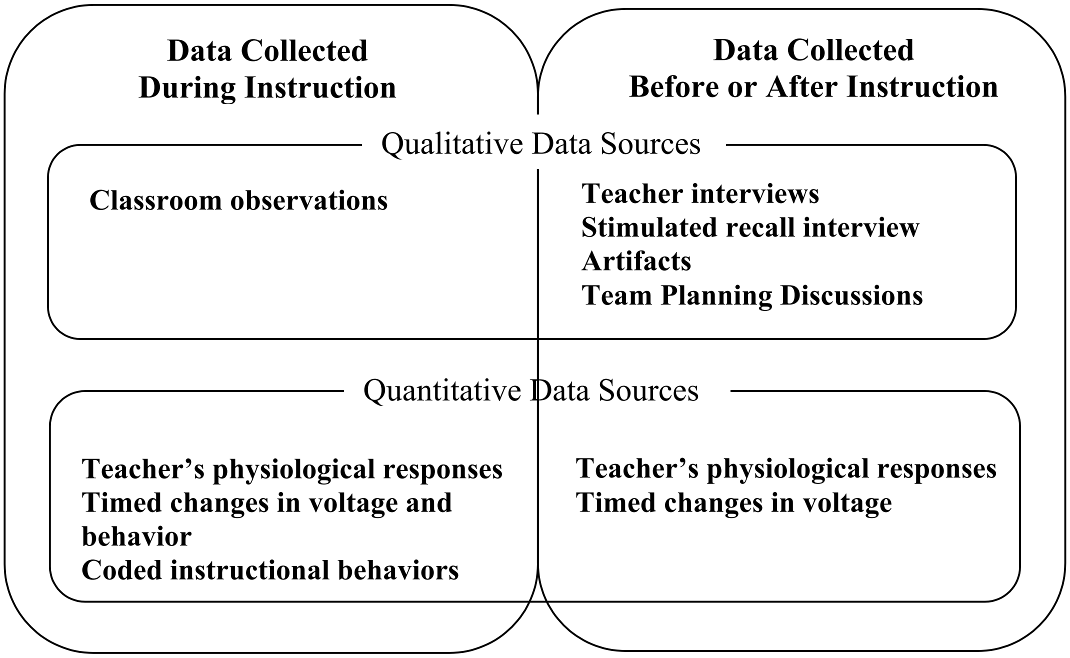


Figure 4. **Data sources.**

Collection schedule. The data collection schedule was planned to intensively sample the teacher's instructional decisions throughout a lesson cycle by measuring elements in her decision-making process in the context of different stages of teaching. The data collection occurred during six days at the end of the 2001-2002 academic year and during a stimulated recall interview one month after the last day of instruction (see Tables 1 and 2). The longitudinal dimension of this study ranged from measurement of variables that changed in a fraction of a second to measurement of variables that changed from day to day.

Table 1
Collection and Use of Qualitative Data Sources

Qualitative Data Source	Documentation	Information	Collection Dates (2002)
Teacher interviews	Audio tapes and notes	Instructional and planning data	May 13, 14, 15, 17, 20
Stimulated recall interview	Video tape	Instructional and planning data	June 21
Instructional Artifacts	Photographs and sample documents	Instructional and planning data	May 20
Team discussion	Audio tapes	Planning data	May 13,15, 17
Classroom observations	SOS field notes	Instructional data	May 14,15,17, 20, 21

Table 2
Collection and Use of Quantitative Data Sources

Quantitative Data Source	Documentation	Information	Collection Dates (2002)
Codes of teacher behavior, event times	Excel© files and videotape	Interactive decision-action data	May 14, 15, 17, 20, 21
Skin voltage changes, event times	LabPro files	Evidence ANS activity	May 14, 15, 17, 20, 21 June 21

The qualitative data sources provided context information for the quantitative data. The physiological and behavioral measures yielded distinctive patterns that would have been incomprehensible without information derived from verbal reports.

The subject. The teacher was an elementary mathematics specialist in a large urban school district in Texas. She has led district professional development institutes, taught mathematics lessons on district television programs, and led Marilyn Burns professional development workshops in mathematics education. She has also continued her own professional development through formal courses, workshops, conferences, and independent study. She has taught elementary school for over thirty years; and administrators, peers, and students have recognized her expertise in mathematics instruction. The teacher was a white female, 52 years old, in good physical health who did not smoke, consume alcohol or caffeine drinks.

The teacher taught a class of twenty-five third and fourth grade students. The class included some students receiving special education services, while others participated in gifted/talented programs. The majority of the students performed at grade level. The class was representative of the school population, which was 48% Hispanic, 37% African-American, 9% white, and 7% Asian. Fifty-two percent of students in the school qualified for free or reduced cost lunches. One small group of students in the class had won an *Odyssey of the Mind* © competition at the state level and were absent on the last observation day, May 21, 2002, to travel to a world competition in Colorado.

Instructional conditions. The teacher planned her final standards-based mathematics unit for the school year to be taught May 13, 14, and 15, 2002. Probability was the instructional focus for the three days. The teacher alternated direct instruction with group work by gathering the students at the front of the room for direct instruction and group analysis of probability data, and by arranging the students for small group work at tables around the perimeter of the classroom. Group work usually consisted of inquiry activities requiring the use of manipulatives such as dice and spinners with collection of data. May 15 also included an assessment activity to write an essay answering the question, “What is probability?”

The first two time series described in this paper were based on data collected on May 14 and 15. May 13 was used as an acclimation day in which the students and teacher became accustomed to a classroom visitor with a computer and video camera, and the teacher became accustomed to wearing a heart rate monitor and apron containing a data collection device. During the last few days of instruction of the 2001-2002 school year, the teacher planned mathematical games based on probability, number operations, and strategy (e.g., *Shut the Box*); and taught the students how to draw a straight line with a ruler, use the ruler to make evenly spaced hatch marks, and create symmetrical patterns by connecting the marks at different intervals. The last three time series were based on data collected during these last scheduled instructional days of the school year, May 17, 20, and 21, 2002.

Skin voltage was also recorded during the stimulated recall interview on June 21, 2002. The teacher was sitting down and either talking about her instruction or watching a videotape of her instruction during the recording.

Quantitative Data Sources

Quantitative data consisted of measurements of the teacher's decision-action rates calculated from continuous and simultaneous timed recordings of Stallings Observation System (SOS) codes and changes in skin voltage. The data collection design included controls to minimize extraneous variables that might influence the behavior being observed. Threats to internal validity included adaptation, practice effects, fatigue, maturation, and naturally occurring response variation over time (Warner, 1998). Furthermore, attaching electrodes to study participants may cause physiological arousal, so an adaptation period of one classroom observation was included at the beginning of the study on May 13, 2002 to allow the teacher's possible initial reactions to subside. Data collection occurred at the same time of day, in the same classroom, with the same class of students, for about the same amount of time, and with the same teacher. Classroom data collection for analysis occurred over five days beginning on May 14, 2002 and concluding on May 21, 2002; maturation of the teacher was therefore minimal.

Adaptation and practice effects were not applicable to the study of an individual who has been teaching for thirty-two years.

SOS (adapted) data. Instructional behaviors were recorded by an observer using an adapted Stallings' Observation System, also known as the SOS (Stallings, 1993). The adapted Stallings' Observation System (SOS) used in this dissertation is a category system, which is characterized as closed because of the predetermined code choices. Although open-ended comments may be recorded as part of the SOS data collection, in this dissertation, the comments were by no means rich description of classroom events. Rather, the adapted SOS codes and comments were used to document moment-to-moment changes in teacher behavior. The SOS was the preferred observation system for this study, because it is a system using low inference coding of teacher behaviors throughout intervals of time and it is easily adapted for continuous recording of changes in the teacher's actions during instruction, thereby providing information needed to answer the research questions.

The reliability and validity of the original Stallings Observation System has been well documented in previous studies (Stallings, Bossung, & Martin, 1990), but this is the first use of the adapted SOS instrument for time series analysis. SOS codes, brief notes, and times were recorded continuously throughout the instructional period on a preformatted Excel© spreadsheet (Appendix C). The SOS *who/whom, what* and *how* codes for quantitative variables were then edited and verified using a videotape of the classroom instruction, necessary because the pace of instruction was too rapid for accurate coding in real time.

The Stallings Observation System (SOS) is based on two types of classroom observation: the five minute interaction (FMI) and the classroom snapshot. An observer using the FMI records classroom events for five five-minute intervals evenly distributed during the class period. The focus of attention is the teacher, though student actions are also recorded when the student(s) interact with the teacher. If the teacher behavior occurs too rapidly to encode every interaction, then the observer must be sure to encode a representative sample of complete action sequences in preference to larger numbers of incomplete sequence codes.

The FMI codes were judged to be appropriate for a study using time series analysis, with some adaptations which included the following:

- Codes were recorded continuously for the entire instructional period.
- Every change in interaction frame was recorded.
- Interaction frame sequences were divided into 30 second intervals for calculation of decision-action rates and data processing.

Thus the original FMI is a representative sample of instruction, while the adapted procedure produces a continuous and comprehensive coded record of every observable teacher action and associated student interaction behavior.

Table 3 shows two interaction frames using the SOS coding system. In the first frame, the teacher (*who; T*) asked a small group of students (*whom; S*) a low cognitive level direct question (*what; 1Q*) about academic content (*how; A*). In the second frame, the small group of students (*who; S*) responded (*what; 3*) to the teacher (*whom; T*), giving an academic-content answer (*how; A*).

Table 3
Example of SOS Coding Frames

Frame Number	SOS Code Categories			
	Who	*Whom*	*What*	*How*
1	T teacher	S student	1Q direct question	A academic
2	S student	T teacher	3 response	A academic

Table 4 shows all the SOS codes used to record the observed instructional behaviors of the teacher in the four-code frames.

Table 4
SOS Five-Minute-Interaction Frame Codes

Stallings Observation System FMI Frame Codes					
Who or Whom		What		How	
T	teacher	1	command	A	academic
F	student-first interaction	1Q	direct question	B	behavior
M	student-continuing interaction	2	higher order question	O	organizing
E	whole class	2Q	open ended question	G	guide
L	large group	3	response	P	positive
S	small group	4	instruct/inform/lecture	N	negative
V	visitor	5	social comment	L	reading aloud
O	loudspeaker	6	task related comment	I	intrusion
A	aide	7	praise/support		
		8	for future use	S	brainstorming
		9	correction	X	movement
		10	don't know	W	written
		11	refuse/reject		
		12	observe/monitor	V	non-verbal

The SOS codes are not high inference observations. During instruction, *who* is speaking to *whom* is usually obvious, and what kind of communication is occurring is usually obvious. Exceptions include when the observer cannot hear a private comment between teacher and student, when the teacher was out of sight of the observer, and when the assignment of a question level code requires some familiarity with the experiences of the students in order to judge whether they are being asked a higher level question or simply being asked to recall an outcome from a previous class.

The operational definition of a decision-action for the time series analysis in this study was a teacher-initiated change in any of the elements in the *who/whom*, *what*, or *how* categories of an interaction sequence recorded in a four-code frame. SOS codes are categorical data and not suitable for harmonic analysis. Therefore, the number of teacher-initiated changes in SOS codes in each time interval were used as the decision-action rate in this study. The code change rates are continuous data appropriate for time series data analysis (Warner, 1998).

SOS observer consistency. A number of measurements were performed to determine the consistency of the single observer's SOS coding data. Twenty-two samples of five consecutive video-taped teaching intervals per sample were coded eighteen months after the initial SOS codes were recorded and edited. The intervals were thirty seconds in duration, so a sample of five intervals was two and a half minutes long and twenty-two samples represented 55 minutes of videotaped instruction. The initial sample was selected randomly, then samples were selected every twenty intervals starting from the first random sample the first day through the last sample possible on the last day. Two samples consisting of intervals from two different days were excluded since one of the objectives of sampling was to examine representative 2.5 minute sequences of uninterrupted instruction. Figure 5 shows the distribution of the samples by video recording day.

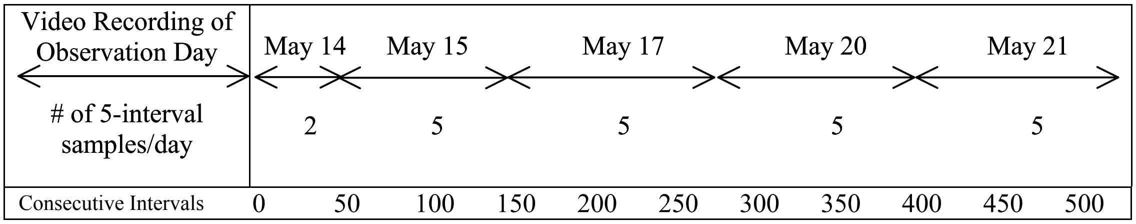


Figure 5. **Distribution and number of 5-interval samples used to calculate single observer consistency.**

Shavelson, Webb, and Burstein (1986) said that the "most common method used to assess consistency over observers, often called interrater agreement or consistency, is percent agreement" (p. 60). In this study, percent agreement was calculated for the same observer at two different times eighteen months apart and under two different coding conditions. The first codes were recorded in a real classroom, then edited using videotape recordings of the instruction. The comparison codes were recorded with only the video recordings. Despite the confounding variables, the percent agreement for the total number of decision-actions coded during the data collection compared to the eighteen month post observation samples was 96.6%. For comparison, interrater agreement in research reported by Stage, Cheney, Walker, and LaRoque (2002) was an average of 98% with a range of 95-100%. However, a simple percent agreement was judged to be an inadequate measure for a study using time series analysis, so a Pearson *r* correlation was computed for the 22 sample intervals. The correlation coefficient was 0.857, which is significant at the 0.01 level (2-tailed). Thus the decision-actions coded for each sample eighteen months apart and under different conditions yielded very similar number of decision-actions per sample.

The SOS codes were used in this study to calculate relative percent occurrence of specific teaching behaviors in addition to the calculations of decision-action rates, so the post-study verification samples were compared to the original codes recorded. Table 5 provides a summary of the comparison of relative occurrence of the three most commonly coded teaching behaviors. All the post-observation percentages fall within the range of the original observations, except for the 9B correction code which is 1% over the original range.

Table 5

Observer Consistency for Recording SOS "What" Codes for Teacher-Initiated Actions

	Code 1 command	**Code 1Q** direct question	**Code 2** higher order question	**Code 2Q** open ended question	**Code 4** instruct/ inform/ lecture	**Code 5** social comment	**Code 7** praise/ support	**Code 9B** correction	**Code 12** observe/ monitor
classroom coding with video editing (5-day range)	9-19%	11-25%	0-7%	0-5%	6-16%	0-4%	5-23%	2-8%	28-38%
post observation video coding (22 samples)	11%	20%	1%	4%	14%	1%	11%	9%	30%

The observer consistency measurements described here do not measure the reliability of the SOS instrument itself, rather they are an indication of the repeatability of the observer's coding technique. The observer's training in using the SOS, the past experience of the observer using the SOS, the observer's extensive use of video verification, and the low inference nature of the SOS codes provide further evidence of observer accuracy. As stated above, the rapidity of the events being coded was also considered and required extensive use of video recordings. The teacher in this study was an unusual subject in regard to her expert skills and the observation context at the end of a school year was unusual, so generalizations to other teachers and other times of the year were not made. Rather, the high frequency, continuous records were used to answer exploratory questions for identification of micro patterns of teacher behavior and physiology during instructional decision-making, and to identify variables for future investigation.

Voltage data. The voltage recordings used to calculate heart rates were continuous ratio data that could be used for time series analysis, including spectral analysis. The skin voltage recordings were technological records used for classroom observation in this dissertation, limited to voltage and time data.

It is obvious that measurement of changes in skin voltage cannot be performed without technological assistance. Changes in skin voltage were recorded using a *Polar*© exercise heart rate monitor attached to the teacher's chest and a Vernier *LabPro*© data collection device with a signal receiver. The *Polar*© heart rate monitor has also been demonstrated to be a reliable and valid recording instrument (Polar Electro Oy, 2004). Positive control and negative control recordings were made with the skin voltage recording system each day before use to document the continued accuracy of the heart rate monitor. In order to collect the physiological data in a noninvasive manner with minimal classroom impact, the *LabPro*© data collection device and an exercise heart rate monitor were set up for remote data collection so the teacher had complete freedom of movement during data collection. The teacher secured the heart rate monitor dampened with sterile saline solution around her chest before class began, put on an apron with the *LabPro©* data collection device in a pocket (see Figure 6), triggered data collection at the beginning of instruction, then removed the data collection equipment after class. Voltage recordings were then downloaded from the *LabPro©* using a USB connection to a laptop computer (see Figure 7).

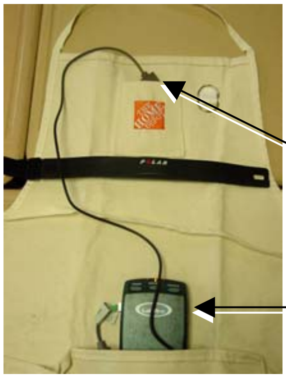
Monitor	Data Collection Device
This is the wireless transmitter belt of the *Polar©* exercise heart rate monitor that detects skin voltage levels. 	 The teacher's endogenous voltage signal was transmitted to the receiver module plugged into a Vernier LabPro data collection device in the pocket of an apron the teacher wore during instruction.

Figure 6. **Voltage data collection equipment.**

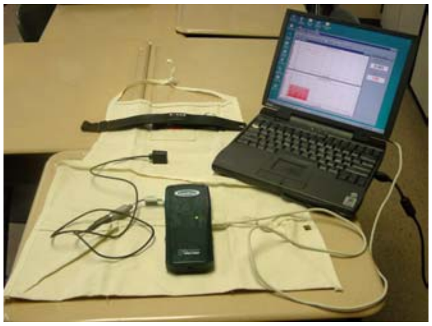
Before Instruction The *LabPro©* data collection device was connected to the computer with a USB port, checked for recording accuracy, and set up for remote data collection with *Logger Pro©* software. The *LabPro©* was disconnected from the computer and placed in the pocket of the teacher's apron.		After Instruction The *LabPro©* was again connected to the computer with a USB port, then voltage data was downloaded to a data file using *Logger Pro©* software.

Figure 7. **Voltage data computer interface.**

The *Logger Pro©* data collection and analysis software that was developed to accompany the *LabPro©* data collection device allowed the researcher to set a sampling rate and calibrate some of the data collection probes. The exercise heart rate monitor (http://www.vernier.com/probes/ehr.html) was a probe that is permanently calibrated at the factory. Vernier provided the disclaimer with the exercise heart rate monitor that it was not intended for research with a reference to the manufacturer *Polar©* for more information. In contrast, *Polar©* recommended using their devices for research (http://www.polar.fi/research/index.html) and cited previous research publications. The heart rate monitor was checked for validity by comparing the real time heart rates of three adults, each recorded simultaneously by the *Polar©* heart rate monitor and a commercial blood pressure-heart rate device before the study. The commercial device recorded an average heart rate for the time needed to take a blood pressure reading, while the exercise heart rate monitor was set to 200 samples/minute. Upon averaging the monitor readings and comparing the mean to the blood pressure/heart rate device for the same time period, the two recordings were found to vary from zero to three beats/minute. Before data was collected for this study, tests with the exercise heart rate monitor showed that it performed with reliability and sensitivity to changing activity levels. The exercise heart rate monitor was briefly checked before data collection each day by the researcher by first recording heart rate when placed on the investigator's chest, then checking for a heart rate of zero when the monitor was removed from the skin.

The sampling rate was set at 200 samples/minute because this was the maximum rate that the *LabPro©* could record and store data for an hour using the exercise heart rate monitor analog sensor in remote data collection mode. For the lessons that were 60 minutes long, 200 x 60 = 12,000 samples were recorded and downloaded to the computer. The rate and total number of voltage data samples were far greater than any other data collected in this study.

An important data collection issue was the source of the voltage that was recorded. The monitor did not induce a current or affect endogenous voltage levels, rather it was a passive receptor of changes in the potential difference of skin that is in electrical contact with the monitor. Cardiac electrical activity may not have been the only endogenous electricity affecting skin voltage levels. Other electrical influences included Galvanic skin responses and muscle activity. Since the purpose of this study was to explore physiological correlates of unconscious neural activity associated with observed behaviors, the changes in skin conductance of a Galvanic skin response were not viewed here as a threat to validity. There were high amplitude, low frequency peaks in the voltage recordings at periodic intervals that did not correspond to heart function, apparently indicating muscular activity related to respiration. Since activity of the autonomic nervous system affects respiration as well as heart rate, these peaks also were not viewed as a threat to validity. In contrast, voluntary muscle activity that leads to changes in skin voltage directly or through increased heart rate was a threat to validity. However, one day's observation dramatically showed that, for this teacher, heart rate increase due to physical activity is apparently negligible. On May 15, 2002, her heart rate actually decreased during a period when she increased her physical activity by walking around the classroom monitoring students writing an essay.

Temporal data. Time was the third quantitative variable in this study. Time was the standard by which the other variables were sequenced, partitioned, and compared. The primary data source used for the standard time reference was the videotape of the teacher's instruction, which recorded time in hours, minutes, and seconds. The teacher triggered the *LabPro©* in view of the camera and the trigger time, according to the videotape, was recorded on the Excel© spreadsheet of SOS codes. The time was then partitioned into 30-second intervals for both the SOS codes and the voltage data. Time zero for each time series was set at the first "00" or "30" second time recorded on the videotape after the *LabPro©* was triggered, to facilitate partitioning the SOS data.

The time interval length selected for this study was 30 seconds. Thirty seconds was short enough to partition the data collected during each class period into at least 50 intervals, which was the minimum needed to perform spectral analyses of time series data according to Warner (1998). The voltage data could be partitioned into shorter intervals, but the SOS observation sequences required enough time for teacher-student interactions to occur. Thirty seconds was judged by the investigator to be adequate to record the number of teacher-initiated changes in instruction accurately. Because of the high rate of data acquisition during each class observation, it was possible to perform a time series analysis on each of the five class periods (see Table 6).

Table 6
Temporal Partition of Quantitative Data

	Instructional Behavior		Physiological Response	
	Amount of Data			
Observation Date	SOS Code Frames	30-Second Intervals	Voltage Recordings	30-Second Intervals
5-14	454	50*	11,982	119
5-15	764	105	10,998	110
5-17	555	104	11,100	111
5-20	585	120	11,899	119
5-21	518	116	11,699	117
TOTALS	2,876	495	57,678	576

*After 25 minutes, the teacher took the students out of the classroom for an activity in the grade level cluster area. The SOS recordings were interrupted in the move and videotaping was not possible.

Quantitative Data Processing

The SOS codes were recorded by the observer during the entire class period, then later they were edited using a videotape of instruction. On the day of the example below, there was a single 30-second interval when the videotape showed 44 frame changes with 30 teacher-initiated changes within a 30-second interval. The teacher was polling all the students for the results of their probability activity; then students answered individually; and individual results were recorded on the board. Table 7 shows an example of SOS frames recorded during the fifth 30-second interval after the *LabPro* © was triggered on May 15, 2002, and Table 8 shows the SOS frames during the 53rd 30-second interval on May 15, 2002.

Table 7
SOS Data for Interval 5 on May 15, 2002

Interval	Video time	WHO	WHOM	WHAT	HOW	Change 1=yes, 0=no	Decision-action: teacher initiated change 1=yes, 0=no	Cumulative # of decision-actions for the interval	# of Decision-actions per interval	Comments
5	10:03:30	T	S	1Q	A	1	1	1		
5		S	T	3	A	1	0	1		
5		T	S	7	A	1	1	2		
5	10:03:40	T	E	1	O	1	1	3		So, look at these results
5		L	T	3	O	1	0	3		
5		T	E	1Q	A	1	1	4		
5		S	T	3	A	1	0	4		
5		T	E	2	A	1	1	5		Why all evens?
5		S	T	3	A	1	0	5		
5		T	S	7	A	1	1	6		
5		T	L	9	B	1	1	7		Raise your hands
5		L	T	3	B	1	0	7		
5		T	E	2Q	A	1	1	8		
5		S	T	3	A	1	0	8	8	

Table 8
SOS Data for Interval 53 on May 15, 2002

Interval	Video time	WHO	WHOM	WHAT	HOW	Change 1=yes, 0=no	Decision-action: teacher initiated change 1=yes, 0=no	Cumulative # of decision-actions for the interval	# of Decision-actions per interval	Comments
53	10:27:30	T	E	12	AX	0	0	0		
53		T	E	12	AX	0	0	0		
53		T	E	12	AX	0	0	0	0	

Notice that fourteen frames were encoded for the fifth interval, while only three frames were encoded for the 53rd interval. This difference was because there were fourteen changes in teacher-initiated interactions and the frame codes in interval five, while there were no changes in interactions or frame codes in interval 53. Fourteen frames could have been recorded for interval 53, but they would all be “T E 12 AX” and there would still be zero changes and zero decision-actions as operationally defined in this study. The following Figure 8 shows the number of teacher decision-actions per 30-second interval for the entire class period on May 15, 2002:

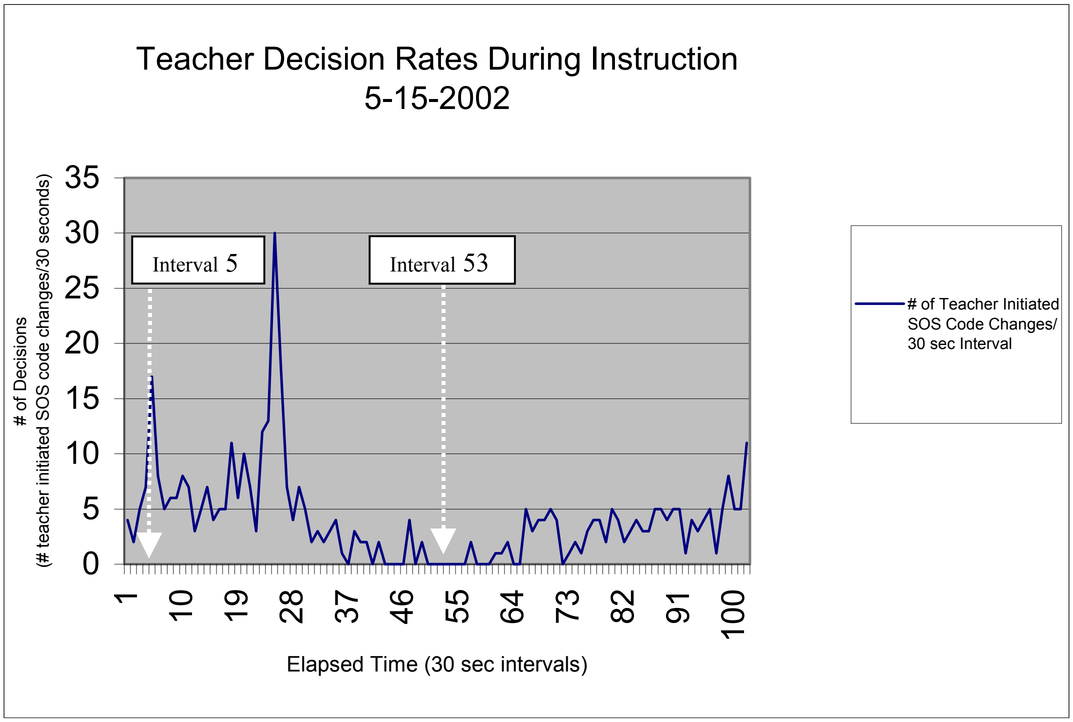


Figure 8. **Time series graph for teacher-initiated SOS code changes on May 15, 2002.**

Processing voltage data. The *Logger Pro©* data collection and analysis software used the recorded voltage levels in algorithms to calculate instantaneous heart rate as a function of relative amount of time elapsed between voltage peaks, i.e. interbeat intervals. When the *Logger Pro©* software program operated at the default setting of 2000 samples/minutes, the software calculated heart rate data that were reasonable for a normal human. However, when using a remote collection rate of 200 samples/minutes, the software program yielded numerous “0” and “100” heart rates that were not reasonably representative of the raw voltage data recordings. Therefore, the raw voltage and time recording data were exported into Excel© spreadsheets for data processing rather than using the *Logger Pro*©-calculated heart rate output of the software algorithm for data analysis. *Logger Pro*© was also found to be inadequate for data management tasks, so the initial data processing tasks were performed using Excel© spreadsheet functions.

Bivariate time series analysis requires that time intervals in the two series be identical. Therefore, heart rates were calculated for 30-second time intervals from this data to make it possible to perform bivariate analyses with the SOS time series data, that were recorded at lower sample rates than the heart rates. Because of the large size of the Excel© files, the raw data files are available on a CDROM while filtered versions are attached to these notes. The following Table 9 shows 30 seconds of *LabPro*© data on a spreadsheet with columns that set the voltage threshold for a heart beat at 0.025 volts and counted heart beats for different intervals of time. Columns F, H, and I were removed because they were used to calculate the heart rate for 1-minute intervals, which were judged to be too long a period of time. Columns J. K, and L were removed because they were used to calculate the heart rate for 12-second intervals, which were judged to be too short for sampling interactive teacher behaviors with the SOS codes.

Table 9
Thirty Seconds of *LabPro©* Data Recorded May 15, 2002

SAMPLE # (1-12,000)	ELAPSED TIME LABPRO DATA (MINUTES)	POTENTIAL DIFFERENCE LABPRO DATA (VOLTAGE)	ELAPSED TIME (TRUNCATED COLUMN B MINUTES)	ELAPSED TIME (COLUMN B ROUNDED DOWN)	PRESENCE OF HEART BEAT (THRESHOLD 0.025 V) 1=yes, 0=no	SAMPLE COUNT (1-100 EACH 30 SECONDS)	CUMMULATIVE HEART BEATS DURING 100 SAMPLE COUNT (# OF BEATS)	SAMPLE TO SAMPLE HEART RATE DURING 30 SECOND INTERVAL (BEATS/MIN)
81	0.400000036	0.277166992	0	0.400	1	1	1	
82	0.405000001	0.00488401	0	0.405	0	2	1	
83	0.410000026	1.593410015	0	0.410	1	3	2	
84	0.415000021	0.00976801	0	0.415	0	4	2	
85	0.420000046	0.003663	0	0.420	0	5	2	
86	0.425000012	0.043956	0	0.425	1	6	3	
87	0.430000007	0.003663	0	0.430	0	7	3	
88	0.435000032	0.247862995	0	0.435	1	8	4	
89	0.440000027	0.00488401	0	0.440	0	9	4	
90	0.445000023	2.056169987	0	0.445	1	10	5	
91	0.450000018	0.013431	0	0.450	0	11	5	
92	0.455000013	0.002442	0	0.455	0	12	5	
93	0.460000038	0.117215998	0	0.460	1	13	6	
94	0.465000004	0.003663	0	0.465	0	14	6	
95	0.470000029	1.46886003	0	0.470	1	15	7	
96	0.475000024	0.00976801	0	0.475	0	16	7	
97	0.480000019	0.003663	0	0.480	0	17	7	
98	0.485000044	0.078144103	0	0.485	1	18	8	
99	0.49000001	0.003663	0	0.490	0	19	8	
100	0.495000035	0.610500991	0	0.495	1	20	9	
101	0.5	0.00610501	0	0.500	0	21	9	
102	0.504999995	0.003663	0	0.504	0	22	9	
103	0.51000005	0.034187999	0	0.510	1	23	10	
104	0.515000045	0.003663	0	0.515	0	24	10	
105	0.520000041	0.290598005	0	0.520	1	25	11	
106	0.525000036	0.003663	0	0.525	0	26	11	
107	0.530000031	0.003663	0	0.530	0	27	11	
108	0.535000026	0.039071999	0	0.535	1	28	12	
109	0.540000081	0.003663	0	0.540	0	29	12	
110	0.545000017	0.377288997	0	0.545	1	30	13	
111	0.550000012	0.00488401	0	0.550	0	31	13	
112	0.555000007	0.003663	0	0.555	0	32	13	
113	0.560000002	0.068376102	0	0.560	1	33	14	
114	0.565000057	0.003663	0	0.565	0	34	14	
115	0.570000052	1.247859955	0	0.570	1	35	15	
116	0.575000048	0.00854701	0	0.575	0	36	15	
117	0.580000043	0.003663	0	0.580	0	37	15	
118	0.584999979	0.109889999	0	0.584	1	38	16	
119	0.590000033	0.00488401	0	0.590	0	39	16	
120	0.595000029	1.51038003	0	0.595	1	40	17	
121	0.600000024	0.00976801	0	0.600	0	41	17	
122	0.605000019	0.002442	0	0.605	0	42	17	
123	0.610000014	0.100121997	0	0.610	1	43	18	
124	0.615000069	0.003663	0	0.615	0	44	18	
125	0.620000064	1.306470037	0	0.620	1	45	19	
126	0.62500006	0.00976801	0	0.625	0	46	19	
127	0.629999995	0.003663	0	0.629	0	47	19	
128	0.63499999	0.063492097	0	0.634	1	48	20	

Table 9 (continued)

SAMPLE # (1-12,000)	ELAPSED TIME LABPRO DATA (MINUTES)	POTENTIAL DIFFERENCE LABPRO DATA (VOLTAGE)	ELAPSED TIME (TRUNCATED COLUMN B MINUTES)	ELAPSED TIME (COLUMN B ROUNDED DOWN)	PRESENCE OF HEART BEAT (THRESHOLD 0.025 V) 1=yes, 0=no	SAMPLE COUNT (1-100 EACH 30 SECONDS)	CUMMULATIVE HEART BEATS DURING 100 SAMPLE COUNT (# OF BEATS)	SAMPLE TO SAMPLE HEART RATE DURING 30 SECOND INTERVAL (BEATS/MIN)
129	0.640000045	0.003663	0	0.640	0	49	20	
130	0.645000041	0.299145013	0	0.645	1	50	21	
131	0.650000036	0.00488401	0	0.650	0	51	21	
132	0.654998362	2.156290054	0	0.654	1	52	22	
133	0.659998357	0.013431	0	0.659	0	53	22	
134	0.664998353	0.003663	0	0.664	0	54	22	
135	0.669998407	0.035409	0	0.669	1	55	23	
136	0.674998403	0.002442	0	0.674	0	56	23	
137	0.679998398	0.089133099	0	0.679	1	57	24	
138	0.684998333	0.003663	0	0.684	0	58	24	
139	0.689998329	0.219779998	0	0.689	1	59	25	
140	0.694998384	0.003663	0	0.694	0	60	25	
141	0.699998379	0.50305301	0	0.699	1	61	26	
142	0.704998374	0.00610501	0	0.704	0	62	26	
143	0.709998369	1.716729999	0	0.709	1	63	27	
144	0.714998364	0.010989	0	0.714	0	64	27	
145	0.719998419	0.003663	0	0.719	0	65	27	
146	0.724998415	0.219779998	0	0.724	1	66	28	
147	0.72999835	0.00488401	0	0.729	0	67	28	
148	0.734998345	0.0622711	0	0.734	1	68	29	
149	0.739998341	0.003663	0	0.739	0	69	29	
150	0.744998395	0.135530993	0	0.744	1	70	30	
151	0.749998391	0.00488401	0	0.749	0	71	30	
152	0.754998386	0.279608995	0	0.754	1	72	31	
153	0.759998381	0.00488401	0	0.759	0	73	31	
154	0.764998376	1.282050014	0	0.764	1	74	32	
155	0.769998372	0.00976801	0	0.769	0	75	32	
156	0.774998367	2.661780119	0	0.774	1	76	33	
157	0.779998362	0.024420001	0	0.779	0	77	33	
158	0.784998357	0.003663	0	0.784	0	78	33	
159	0.789998353	0.129426003	0	0.789	1	79	34	
160	0.794998407	0.00488401	0	0.794	0	80	34	
161	0.799998403	1.100119948	0	0.799	1	81	35	
162	0.804998398	0.00854701	0	0.804	0	82	35	
163	0.809998393	0.003663	0	0.809	0	83	35	
164	0.814998329	0.087912098	0	0.814	1	84	36	
165	0.819998384	0.003663	0	0.819	0	85	36	
166	0.824998379	1.909649968	0	0.824	1	86	37	
167	0.829998374	0.01221	0	0.829	0	87	37	
168	0.834998369	0.002442	0	0.834	0	88	37	
169	0.839998364	0.167276993	0	0.839	1	89	38	
170	0.844998419	0.003663	0	0.844	0	90	38	
171	0.849998415	2.156290054	0	0.849	1	91	39	
172	0.85499835	0.013431	0	0.854	0	92	39	
173	0.859998345	0.002442	0	0.859	0	93	39	
174	0.864998341	0.168497995	0	0.864	1	94	40	
175	0.869998395	0.003663	0	0.869	0	95	40	
176	0.874998391	2.664220095	0	0.874	1	96	41	
177	0.879998386	0.019536	0	0.879	0	97	41	
178	0.884998381	0.003663	0	0.884	0	98	41	
179	0.889998376	0.269840986	0	0.889	1	99	42	
180	0.894998431	0.00488401	0	0.894	0	100	42	84

A voltage threshold of 0.025 volts was set as the criterion value for the presence of a physiological response peak, i.e., a heart beat, a respiratory movement, or a skeletal muscle movement. The voltage threshold was empirically determined by relating the amplitude and number of voltage peaks recorded with the exercise heart rate monitor and *LabPro©* data collection device to the number of heart beats recorded by an Omron Digital Blood Pressure Monitor, model HEM-711, for three adults. High amplitude low frequency peaks such as the 2.056 volt reading at sample # 90, are commonly reported in single lead voltage recordings of cardiac function and may be the result of respiratory movements (Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996).

The major data processing objectives and explanations of the algorithms used in the Excel© spreadsheet are in Table 10.

Table 10

Excel© Logic Commands for Voltage Data Processing

Data Processing Objective	Column Heading	Visual Basic Command Structure
Decide if the voltage exceeds the empirically-determined threshold value	**G** Presence of peak (threshold 0.025 V) 1=yes, 0=no	If ("voltage recording" >0.025, then 1, else 0)
Separate the voltage data into 30-second time intervals, i.e. 100 rows of data.	**M** Sample count (1-100 each 30 seconds)	If (("the sample number" <100), then ("the sample number"+1), else 1)
Add the heart beats (data value peaks) throughout a 30-second interval, then begin again for the next interval.	**N** Cumulative heart beats (during 100 sample count)	If (("the sample number for the 30-second interval" >1), then ("add 0 or 1 to the previous cumulative heart beats, depending on the value of column G"), else "cumulative heart beats for the previous sample")
1. Calculate the heart rate (beats/minute) for the entire 30-second (0.5 minute) interval. 2. Select the heart rates at the end of each 30-second time interval.	**O** Sample to sample heart rate during 30-second interval (beats/minute)	1. If (("the sample number"=100), then "cumulative heart beats"/0.5, else "[blank space]") 2. Data filter Excel© command selects for non-blanks cells of column "O"

The heart rates for each 30-second interval and the elapsed time for each interval were imported into a Statistical Package for the Social Sciences (SPSS) file for further data analysis.

An important consideration in choosing time partitions was how intervals of different lengths of time affect how the data is sampled and reported. The two following graphs, Figures 9 and 10, show the teacher's heart rate data for a single class period to illustrate the effect on reported data when the time interval is changed from twelve seconds to 30 seconds.

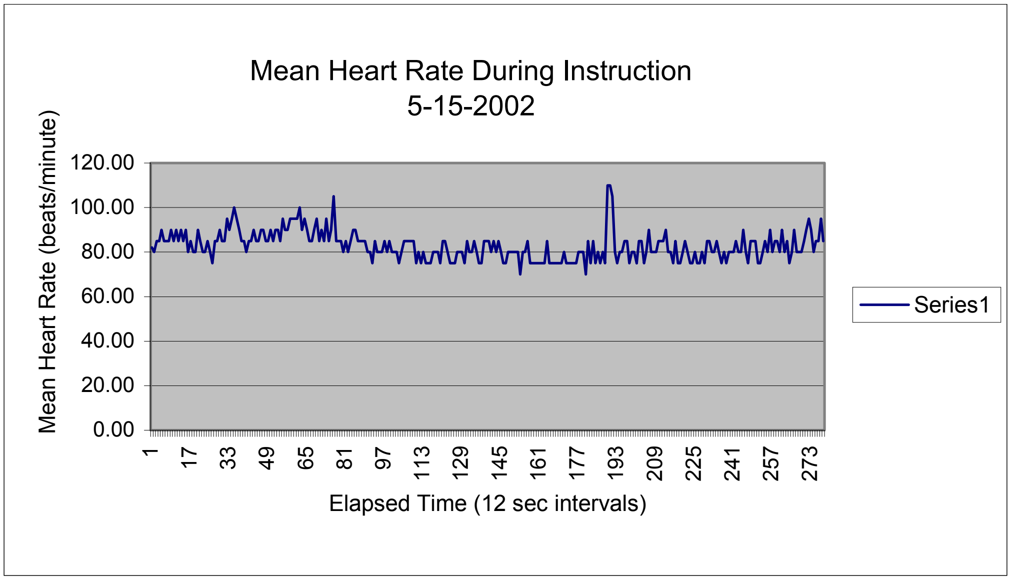


Figure 9. **Time series data partitioned at 12 second intervals**.

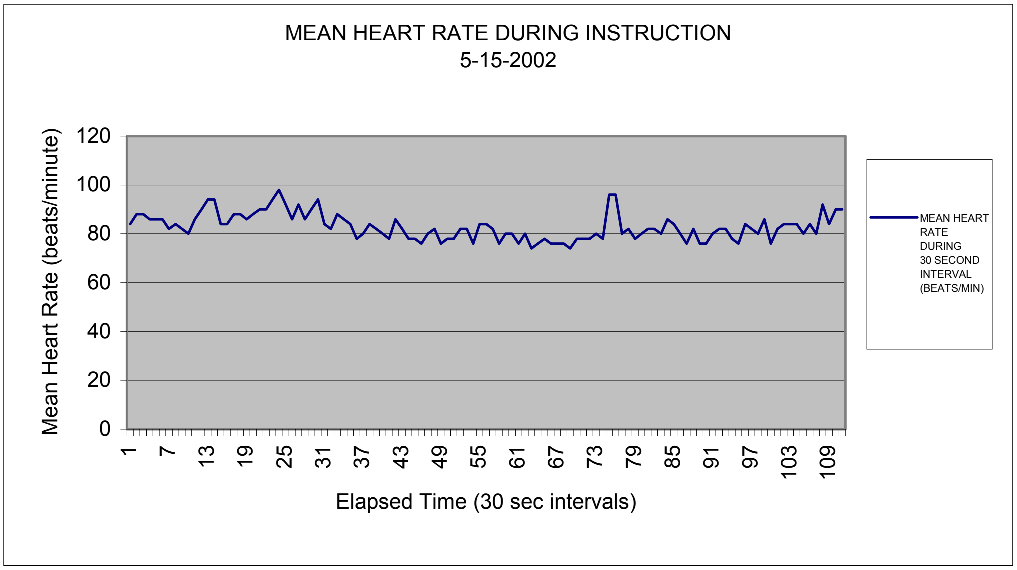


Figure 10. **Time series data partitioned at 30 second intervals.**

Table 11 shows a comparison of the descriptive statistics for the same data partitioned at different time intervals corresponding to the graphs in Figures 9 and 10.

Table 11
Descriptive Statistics of Data Partitioned at Different Time Intervals

Descriptive Statistics for May 15, 2002 Heart Rate Data		
	12-second intervals	30-second intervals
Mean	82.81313411	82.88288288
Standard Error	0.386514499	0.51045398
Median	80	82
Mode	85	82
Standard Deviation	6.444484565	5.377966393
Sample Variance	41.53138131	28.92252252
Kurtosis	2.094674156	-0.028326553
Skewness	1.022090323	0.665710378
Range	40	24
Minimum	70	74
Maximum	110	98
Sum	23022.05128	9200
Count	278	111
Confidence Level(95.0%)	0.760878877	1.011600454

The graphs and the table show that the choice of a time interval can affect the data analysis. Not only are the frequency and amplitude of peaks on the graphs different, but also the descriptive statistics are different for the central tendency, range, and variance of the data sets.

Qualitative Data Sources

The qualitative information sources included audio recordings of interviews, a video recording of the teacher’s stimulated recall interview, field notes, and digital photographs of instructional artifacts. Think-aloud recordings during lesson planning were replaced by audio and written records during informal third grade team planning at lunch after each day's observation, because the teacher was more verbal in a group than talking to a tape recorder. The field notes included comments the teacher made to her class during instruction, as well comments made in interviews.

The first interview was conducted on May 13, 2002, after the "acclimation day" and before the first data collection day on May 14. A prepared list of questions was used as a guide for the interview, though two of the questions, "How do you decide what to teach?" and "How do you decide what kind of attention a student needs?" prompted the teacher to give extended explanations that answered most of the other prepared questions before they were asked.

A "think aloud" audio recording was originally planned, but did not suit the planning style of the teacher. In place of think aloud recordings, the teacher gave informal interviews about planning decisions immediately after each class on May 13, 14, 15, 17, and 20 while the teacher joined three other third grade team teachers to eat lunch. Though unsolicited, the other teachers freely contributed their own ideas about instructional issues raised during these informal interviews.

A stimulated recall interview was planned to occur within three days following the last day of instruction. There was an unavoidable time lag of one month between the last day of instruction and the stimulated recall interview, due to the teacher taking early summer leave after the May 21 class. The long delay between the classroom instruction and the stimulated recall interview is a limitation of this study. Approximately 30 minutes of extended classroom episodes in the 52-minute tape of instruction on May 17 were shown to the teacher on June 21, while the teacher explained her instructional rationale and reacted to watching herself teach. Her comments were transcribed and used for qualitative analysis. The May 17 videotape was chosen for this interview because it was the midpoint of the classroom observations.

The artifacts that provided information about instructional decisions included notebooks, file crates prepared by the third grade team, school district curricular materials, storage containers of math manipulatives, and commercial and teacher-prepared manipulative materials. Digital photographs were taken of the artifacts, and the teacher explained the use of each of the artifacts for instruction.

The field notes consisted of handwritten descriptions of conversations with the participant teacher and brief notes entered on the Excel© spreadsheet used to record SOS codes. The handwritten notes were used when the audio tape was not available or was not appropriate due to the presence of other teachers not participating in this study. The brief notes recorded on the Excel© spreadsheet were necessary to track the classroom events and to identify repetitive or emphasized dialog of the teacher. See Table 12 for a summary of the qualitative data collection sources used for data analysis

Table 12
Summary of Qualitative Data Sources for Analysis

	Summary of Qualitative Data Sources for Analysis	
Decision Categories	**Planning Decisions Before Instruction**	**Interactive Decisions During Instruction**
Academic	Interviews Artifacts Stimulated recall interview	Classroom observations Stimulated recall interview
Organizing	Interviews Artifacts Stimulated recall interview	Classroom observations Stimulated recall interview
Behavior	Interviews Artifacts Stimulated recall interview	Classroom observations Stimulated recall interview

Qualitative Data Processing

The qualitative description in this study included a two-stage process. In the first stage, information was classified using predetermined categories (Creswell, 1998); in the second stage, the categorized information was grouped for salient features using constant comparative analysis. The information available for analysis was limited by the selection of predetermined categories for classifying information before performing constant comparative analysis of the data. Bogdan and Biklen (1992) recommended narrowing a study to concentrate data collection on a more specific problem. The qualitative information initially was placed in a two-dimensional matrix of three predetermined categories derived from the Stallings Observation System *how* code categories (i.e., Academic, Organizing, Behavior) and two decision categories based on when the decisions were made (i.e., Before or After, During). Qualitative evidence of the teacher's decisions was first divided into three categories based on SOS *how* codes: (1) academic decisions about the content to be taught, (2) organizational decisions about people and materials, and (3) behavioral management decisions. The three categories were then divided further into subcategories based on educational research literature: (1) the decisions that were made before or after instruction and (2) the decisions that were made during instruction. The three by two classification scheme yielded six cells for coding evidence of the teacher's decisions according to the salient features of the information. Within the six "*how*" and "when" combination categories, the qualitative data cells were then analyzed using the constant comparative method (Merriam, 1988; Bogdan & Biklen, 1992).

Integration of Qualitative and Quantitative Data

The qualitative and quantitative data were then combined to describe the teacher's decision-making process during classroom instruction. The qualitative and quantitative data analyses were combined to describe how this expert teacher made decisions during instruction: how she integrated decisions made before class into classroom instruction, how she made improvisational decisions during class, and which decisions elicited changes in her physiological responses.

The three research questions guided the selection of variables for study and subsequent data collection, results of which are described in Chapter IV. Table 13 summarizes the information sources used to answer the research questions, the variables that were measured, and the salient elements of decision-making that were identified.

Table 13
Research Questions and Information Sources

Research Questions	Quantitative Information	Qualitative Information
	Measured Variables	Salient Decision-Making Elements
1. How does the teacher integrate decisions she made outside class into classroom instruction?		prior planning decisions integrated into interactive decisions
2. How does the teacher make improvisational decisions during class?	1. physiological response rates 2. decision-action rates	improvisational decision contexts
3. Do improvisational decisions elicit a physiological response?	1. physiological response rates 2. decision-action rates	evidence of emotion or stress during improvisational decisions

The first research question, how the teacher integrated decisions she made outside class into classroom instruction, was answered by relating the qualitative codes in the “planning before instruction” category to qualitative codes in the “decisions during instruction” category and quantitative analysis of time series data. The second research question, how she made improvisational decisions during class, was answered by analysis of qualitative information and time series analysis of quantitative data. The third research question, do improvisational decisions elicit a physiological response, was answered by relating the time series of physiological responses during instruction to the time series of instructional decisions.

Limitations of the Study

A single case study is limited by its lack of generalizability. The properties and mechanisms found in this study might apply to other teachers and classrooms, or they may be specific to a single situation. This single case study included a set of five days of instruction and a stimulated recall interview. Hundreds of decision-actions were recorded within each analysis of a day of instruction. While a generalization to other teachers may be unwarranted, the decision-making behavior of this one teacher was intensively examined.

This case study is also limited by the types and methods of data collection. Decisions had to be observed, recorded, or reported for inclusion in the data. The long delay between the classroom instruction and the stimulated recall interview is also limitation of this study. Transcribing and transforming teacher communications involved recording accuracy and editing judgments influenced by the skills and biases of the researcher. Though the recording instruments were calibrated and checked for reliability, they were limited in range, accuracy, and sensitivity. This study was also limited by the effect of the researcher-observer and recording equipment on natural classroom behavior.

Assumptions

The researcher made the following assumptions about decision making processes, thereby affecting both the data to be collected and the analyses of the data:

1. Decision making is an outcome of complex cognitive processes which cannot be reduced to discrete elements without regard to the interrelationships of the elements over time.
2. Good teachers monitor themselves and alter their own classroom behavior in response to a perceived need. This monitoring process is not always conscious and a teacher’s reactions do not always require reflective conscious thought.
3. The data collected in this study represented phenomena that were the result of neurological processes. For example, the teacher’s speech was the result of internal neurological processes including motor-speech areas of her brain and her motor association cortex in the left frontal lobe of her brain (Kandel, Schwartz, & Jessell, 1995).
4. Humans exhibit intentionality and may be arbitrary in their actions. Therefore teaching behavior cannot be accurately described or predicted solely on the basis of environmental stimuli.
5. Teachers encounter and resolve many common instructional problems for which they were not prepared nor trained. Successful teachers generate or seek out solutions to instructional problems.

CHAPTER IV

RESEARCH FINDINGS

This chapter describes the data collected, criteria for data selection, and data analysis procedures used to describe a teacher's instructional decision-making. The procedures for data collection, selection, and analysis varied for each of the three types of data collected. The first two types of data, coded instructional behaviors and physiological recordings of the teacher, were used for time series analyses. Time series analysis is a type of nonexperimental quantitative description, according to Johnson (2001). The third type of data, qualitative information from interviews and observations, was used in constant comparative analysis within a preassigned coding system (Bogdan & Biklen, 1992) to identify elements of the teacher's decision-making process.

The mixed methodologies made it possible to study a teacher's instructional decision-making system at three distinct levels of information processing (see Figure 11). Past research on teachers' decision-making has shown that their decisions involve unconscious processing of experiences preceding and allied with conscious reasoning strategies (Alexander & Murphy, 1998; Calderhead, 1996; Fenstermacher & Richardson, 1993; Korthagen & Lagenwerf, 1996). This chapter is organized according to the three data types intended to measure three levels of awareness: (a) physiological response rates, (b) instructional decision-action types and frequencies, and (c) prominent elements of planning decisions. Interactions between the physiological response rates and the decision-action types and frequencies are explored using bivariate time series analysis.

Possible connections between decision-action types and frequencies and elements of planning decisions are also discussed.

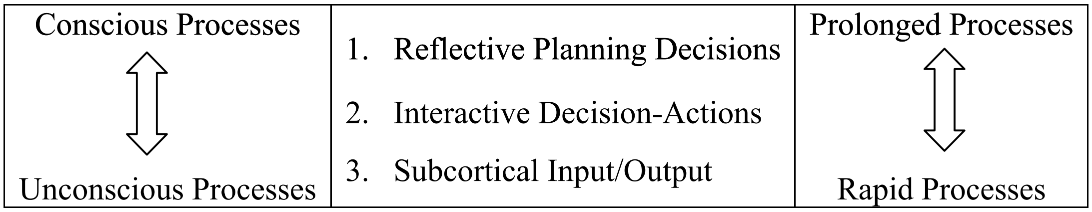


Figure 11. **Description of three layers of decision-making processes.**

Research questions. The following research questions were used to guide the data gathering and analysis methodology in this descriptive case study of the elements of an expert teacher's decision-making process:

(1) How does a teacher integrate decisions made outside class into her classroom instruction?

(2) How does a teacher make improvisational decisions during class?

(3) Do improvisational decisions elicit a physiological response?

In order to answer the research questions, three classes of variables were measured or categorized: (a) information about the teacher's planning decisions was gathered and analyzed for integrative processes; (b) field notes and the SOS coding system were used to describe interactive decision-action types and frequencies; and (c) the physiological response rates of the teacher were measured during interactive instruction. Table 14 summarizes the variables, instrumentation and documentation used to gather information, and the dates and locations for data collection for this case study of instructional decision-making.

Table 14
Decision-Making Variables and Data Collection.

Variables - Instruments and Documentation	Data Types - Information Collected	Collection Dates	Collection Locations
Physiological Response Rates During Interactive Instruction - LabPro, Polar Heart Rate Monitor	Quantitative - time - skin voltage changes	5 times-during instruction - 5/14/02 - 5/15/02 - 5/17/02 - 5/20/02 - 5/21/02 (1 stimulated recall interview - 6/21/02)	Classroom (and private room at school 6/21/02)
Interactive Decision-Action Types and Frequencies - SOS Computer Coding, Videotapes, Field notes	Quantitative - time - teacher behavior	5 times-during instruction - 5/14/02 - 5/15/02 - 5/17/02 - 5/20/02 - 5/21/02	Classroom
Elements of Planning Decisions - Audio recordings of interviews, field notes of informal communication, artifacts, photographs, videotapes	Qualitative - teacher self-reports - description of materials and physical environment	Pre and post instruction - 5/13/02 - 5/14/02 - 5/15/02 - 5/17/02 - 5/20/02 1 stimulated recall interview - 6/21/02	Classroom and private rooms at school

Physiological Response Rates During Interactive Instruction

The physiological response rates of the teacher were measured as an indicator of her emotional state. The physiological response rate peaks are made up largely of low amplitude, high frequency voltage peaks due to heartbeats and high amplitude, low frequency voltage peaks purportedly due to respiratory movements (Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996). This physiological response variable was chosen because "…an important feature of all theories of emotion is the involvement of the autonomic nervous system and endocrine systems…" (Kandel, Schwartz, & Jessell, 1995, p. 597). "Emotional stimuli activate sensory pathways that trigger the hypothalamus to modulate heart rate, blood pressure, and respiration" (Kandel, Schwartz, & Jessell, 1995, p. 607). The voltage recordings used to calculate physiological response rates were continuous ratio data that could be used for time series analysis. Changes in skin voltage were recorded using a *Polar©* exercise heart rate monitor attached to the teacher's chest and a Vernier *LabPro©* data collection device with a signal receiver. In order to collect the physiological data in a noninvasive manner with minimal classroom impact, the *LabPro©* data collection device and an exercise heart rate monitor were set up for remote data collection so the teacher had complete freedom of movement during data collection.

Descriptive statistics. Table 15 shows a summary of statistics describing the teacher's physiological response rates for the five instructional days and one interview. The descriptive statistics of the physiological response rate data on the five instructional days appear to be similar in value, variation, and distribution. May 14 and 15 were labeled "teaching" days while May 17, 20, and 21 were labeled "guiding" days according to comments volunteered by the teacher in an interview on June 21, 2002. The value of the physiological response rates do not appear to be related to "teaching" or "guiding" days when they are compiled in the basic descriptive statistics graphically displayed in Figure 12.

Table 15

Descriptive Statistics of Physiological Response Rates

		Physiological Response Rates (skin voltage peaks per minute)				
		5-14 Teaching Day	5-15 Teaching Day	5-17 Guiding Day	5-20 Guiding Day	5-21 Guiding Day
N	Valid	119	110	111	119	117
	Missing	1	10	9	1	3
Mean		91.41	82.82	89.21	92.86	84.39
Std. Error of Mean		.590	.511	.359	.464	.365
Median		92.00	82.00	90.00	92.00	84.00
Mode		94	82	90(a)	90	86
Std. Deviation		6.433	5.359	3.778	5.066	3.950
Minimum		80	74	82	84	76
Maximum		106	98	98	110	98
Percentiles	10	82.00	76.00	84.00	86.00	80.00
	25	86.00	78.00	86.00	88.00	82.00
	50	92.00	82.00	90.00	92.00	84.00
	75	96.00	86.00	92.00	96.00	86.00

a Multiple modes exist. The smallest value is shown

The teacher's physiological responses were also measured during a stimulated recall interview while watching a video recording of her instruction on May 17. Figure 12 shows her physiological response rates while viewing her instruction were distinctively different from her physiological response rates on May 17.

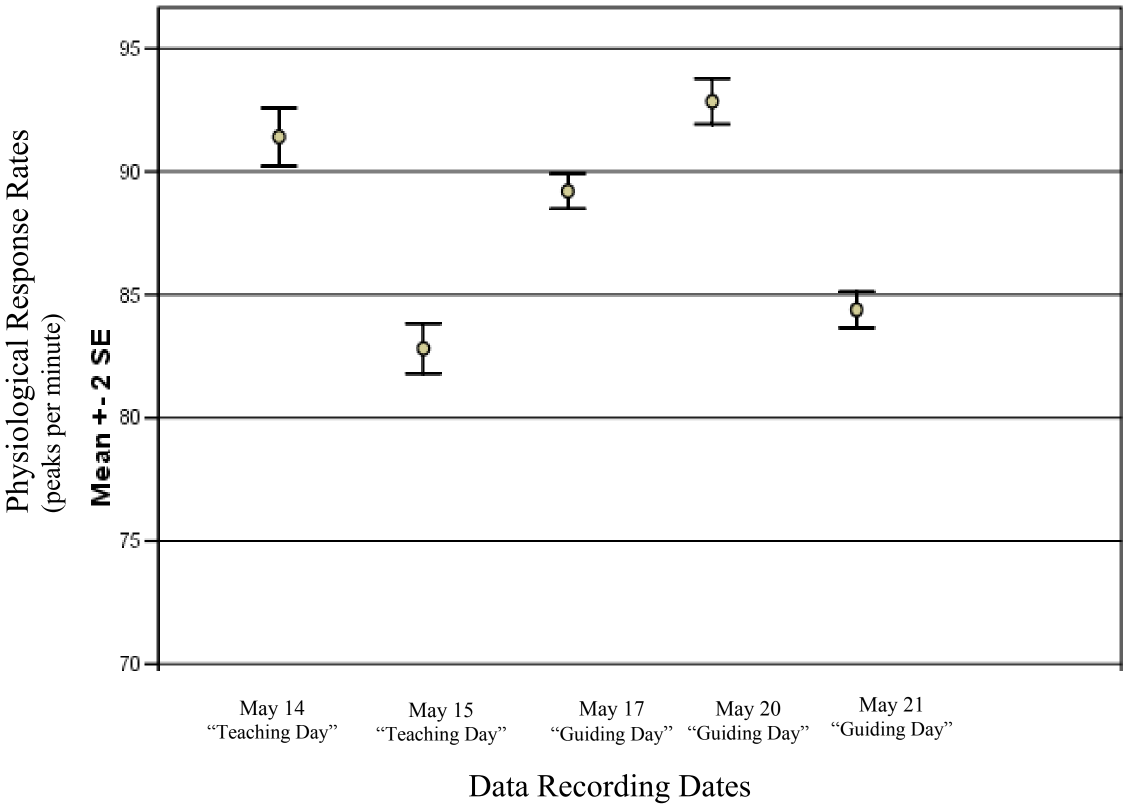


Figure 12. **Physiological response rate mean ± 2 standard errors**

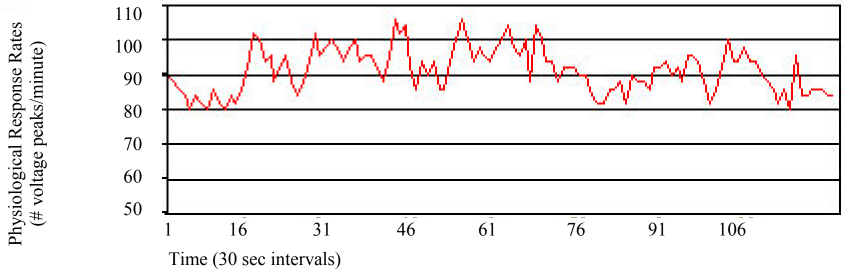
Time series data. The physiological response rate data were graphed as time series for the five observation days of instruction (see Table 16). As described in Chapter III, thirty seconds was the chosen interval length to partition the data. There were over 100 intervals for this data collected each class period which were greater than 50 minutes long.

Table 16
Summary of Physiological Response Rate Data Used in Time Series Graphs

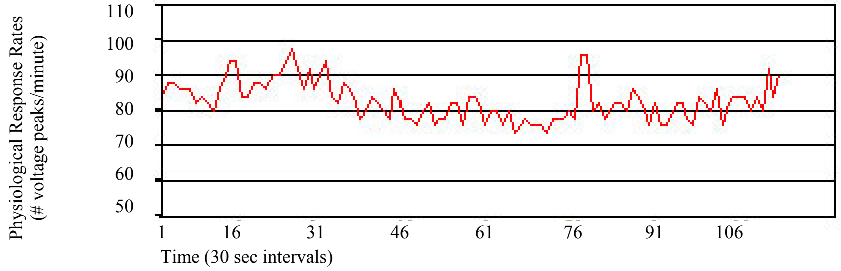
Summary of Quantity of Physiological Response Rate Data		
Data Collection Date	Number of Voltage Data Points	Number of 30-Second Intervals
5/14/02	11,982	119
5/15/02	10,998	110
5/17/02	11,100	111
5/20/02	11,899	119
5/21/02	11,699	117
Total five days:	**57,678**	**576**

The highest physiological response rate, i.e. the greatest number of peaks per 30-second interval, occurred on Monday, May 20. After the class was over, the teacher mentioned that she had had only three hours of sleep the night before because she had stayed up caring for a sick pet, which may have affected her heart rate. Another peak in physiological response rate occurred around time interval 76 on May 15 while the teacher was outwardly calm, not exercising, and initiating relatively few changes in her actions. There is no corresponding peak in the decision-action rate data on Figure 13, May 15, near interval 76. Obviously, not all physiological responses that occurred were related to overt instructional behavior.

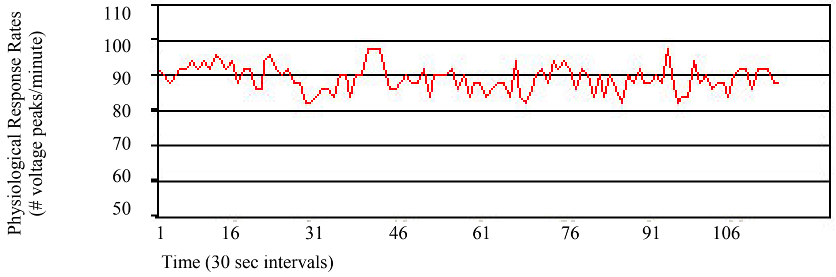
Recording
Date
5-14



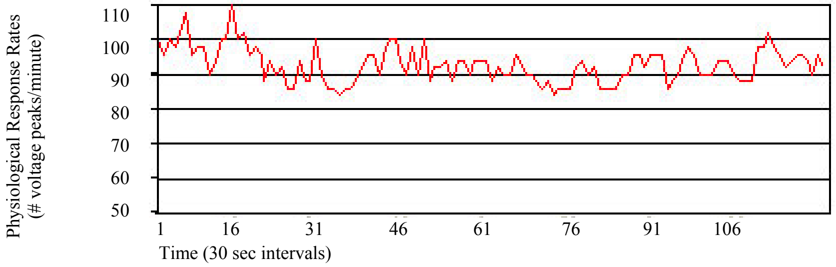
Recording
Date
5-15



Recording
Date
5-17



Recording
Date
5-20



Recording
Date
5-21

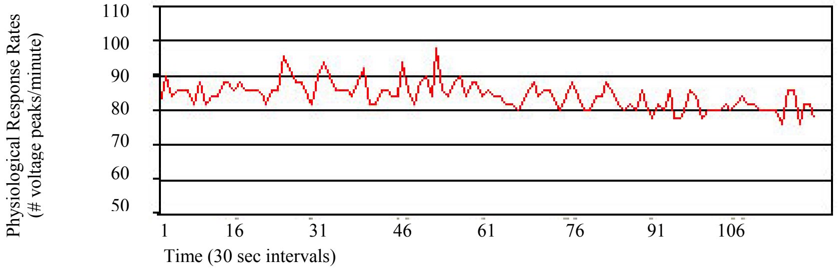


Figure 13. **Time series line graphs of physiological response rates.**

Investigation of possible trends in the decision-action rates and physiological response rates was done using linear and curvilinear regression models for the data. The slopes of all the lines generated by both linear and curvilinear models for all five days were close to zero. Table 17 shows the results of linear and curvilinear regression analysis of the physiological response rates (`H_RATE`) versus time.

Table 17
Regression Tests for Physiological Response Rates Versus Time

Date	**Dependent**	**Mth**	**Rsq**	**d.f.**	**F**	**Sigf**	**b0**	**b1**	**b2**
5-14	H_RATE14	LIN	.009	117	1.11	.293	92.4988	-.0006	
	H_RATE14	QUA	.248	116	19.13	.000	85.3233	.0113	-3.E-06
5-15	H_RATE15	LIN	.137	108	17.12	.000	86.2676	-.0021	
	H_RATE15	QUA	.266	107	19.41	.000	90.6761	-.0099	2.4E-06
5-17	H_RATE17	LIN	.036	109	4.12	.045	90.4622	-.0007	
	H_RATE17	QUA	.079	108	4.62	.012	92.2418	-.0039	9.4E-07
5-20	H_RATE20	LIN	.049	117	5.96	.016	94.7979	-.0011	
	H_RATE20	QUA	.240	116	18.32	.000	99.8605	-.0094	2.3E-06
5-21	H_RATE21	LIN	.282	115	45.27	.000	88.0448	-.0021	
	H_RATE21	QUA	.331	114	28.15	.000	86.0650	.0013	-9.E-07

Thus the physiological response rate data showed a slight negative trend as indicated by the small values of slope (b1) in Table 17 using a linear model. The large difference between the physiological response rates of the teacher when she was teaching versus when she was watching a video of herself teaching in the stimulated recall interview was not definitive, but worth future investigation.

Interactive Decision-Action Types and Frequencies

Instructional behaviors were recorded by using an adapted Stallings' Observation System, also known as the SOS (Stallings, 1993). The teacher was always the focus of observation. SOS codes, brief notes, and times were recorded continuously throughout the instructional period on a preformatted Excel© spreadsheet (Appendix C). The SOS *who/whom, what* and *how* codes for quantitative variables were then edited and verified using a videotape of the classroom instruction, necessary because the pace of instruction was too rapid for accurate coding in real time. The videotape images were blurred to prevent identification of students during recording with a piece of clear plastic. The privacy of the students and confidentiality of the teacher were required by the school district. The number of teacher-initiated changes in SOS codes per 30-second time interval was used as the decision-action rate data appropriate for time series data analysis.

Descriptive statistics. Table 18 and Figure 14 show descriptive statistics of compiled decision-action rates for the five days of observations. The descriptive statistics confirm differences between the decision-action rates on the "teaching" versus "guiding" days. May 14 and 15 had both higher mean decision-action rates and higher standard deviations: 5.76 ± 4.15 for May 14 and 4.07 ± 4.27 for May 15. In contrast, the "guiding" days showed decision-action rates of 3.36 ± 1.82, 3.27 ± 1.40, and 2.96 ± 1.43

teacher-initiated changes per 30 seconds. These decision-action rates are twelve to twenty times greater than rates reported in past research, apparently due to major differences in the degree of self-awareness required to meet the definition of an interactive decision in the research studies summarized by Clark and Peterson (1986).

Table 18
Descriptive Statistics of Instructional Decision-Action Rates

		Instructional Decision-Action Rates (# of teacher-initiated changes in SOS code frames per 30-second interval)				
		5-14 “Teaching” Day	5-15 “Teaching” Day	5-17 “Guiding” Day	5-20 “Guiding” Day	5-21 “Guiding” Day
N	Valid	50	105	104	120	116
	Missing	70	15	16	0	4
Mean		5.76	4.07	3.36	3.27	2.96
Std. Error of Mean		.587	.417	.178	.128	.133
Median		5.00	4.00	3.00	3.00	3.00
Mode		4	0	3	4	3
Std. Deviation		4.148	4.268	1.816	1.401	1.429
Minimum		0	0	0	0	0
Maximum		24	30	10	7	7
Percentiles	10	3.00	.00	1.00	1.00	1.00
	25	4.00	1.00	2.25	2.00	2.00
	50	5.00	4.00	3.00	3.00	3.00
	75	6.00	5.00	4.00	4.00	4.00

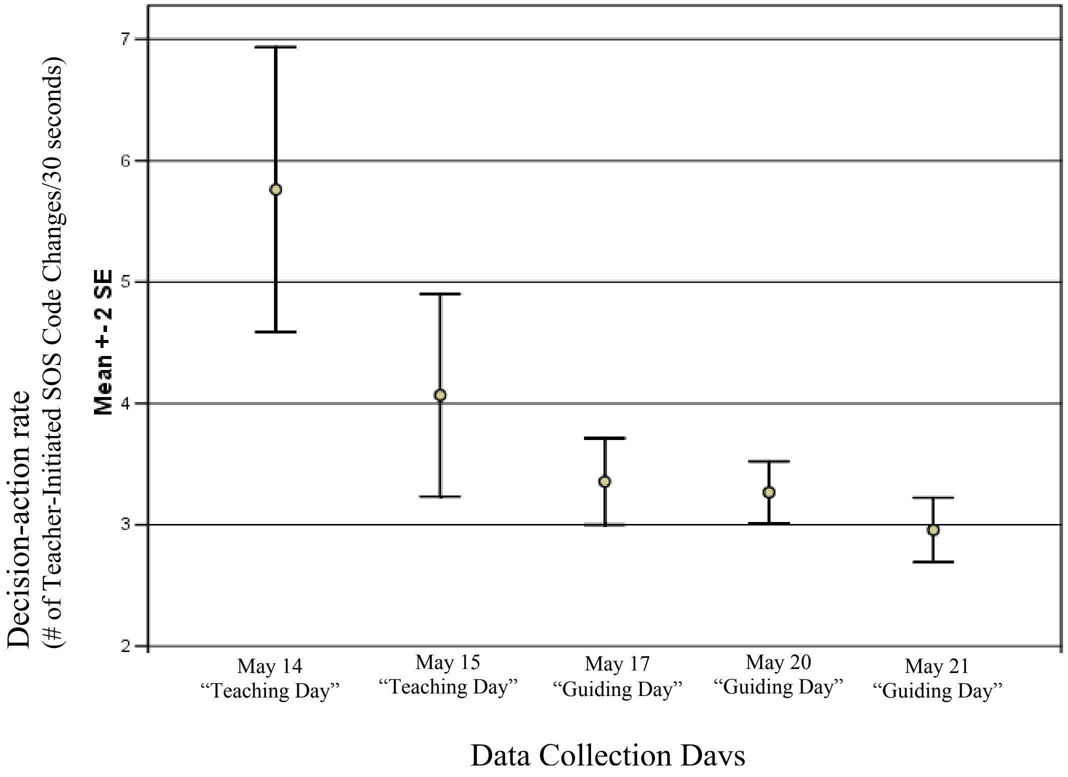


Figure 14. **Decision-action rate means ± 2 standard errors**.

Table 19 provides a summary of the number of code frames recorded each class period and the number of 30-second intervals used to create each time series. As explained in Chapter III, the number of code frames varies in each 30-second interval according to the number of instructional interactions recorded.

Table 19
Summary of Decision-Action Rate Data Used in Time Series Graphs

Summary of Quantity of Decision-Action Rate Data

Data Collection Date	Number of SOS Code Frames	Number of 30-second Intervals
5/14/02	454	50*
5/15/02	764	105
5/17/02	555	104
5/20/02	585	120
5/21/02	518	116
Total five days:	**2,876**	**495**

*After 25 minutes, the teacher took the students out of the classroom for an activity and the SOS recordings were interrupted.

Time series data. Figure 15 shows time series data on five line graphs of decision-action rates during instruction for the classroom observation days. After the data collection period, the teacher participated in a stimulated recall interview in which she said she was not really teaching the last three days of data collection, which occurred on May 17, 20, and 21. The teacher explained that the formal objectives-based instruction she did on May 14 and 15 was “real” teaching, while the math games and drawing activities she taught on May 17, 20, and 21 were “guiding days” when she used math-based enrichment activities to keep the students engaged during the last week of school. Visual inspection of the time series graphs reveals obvious differences in the variability of the decision-action rates on the teacher-identified “teaching” days versus the “guiding days.”

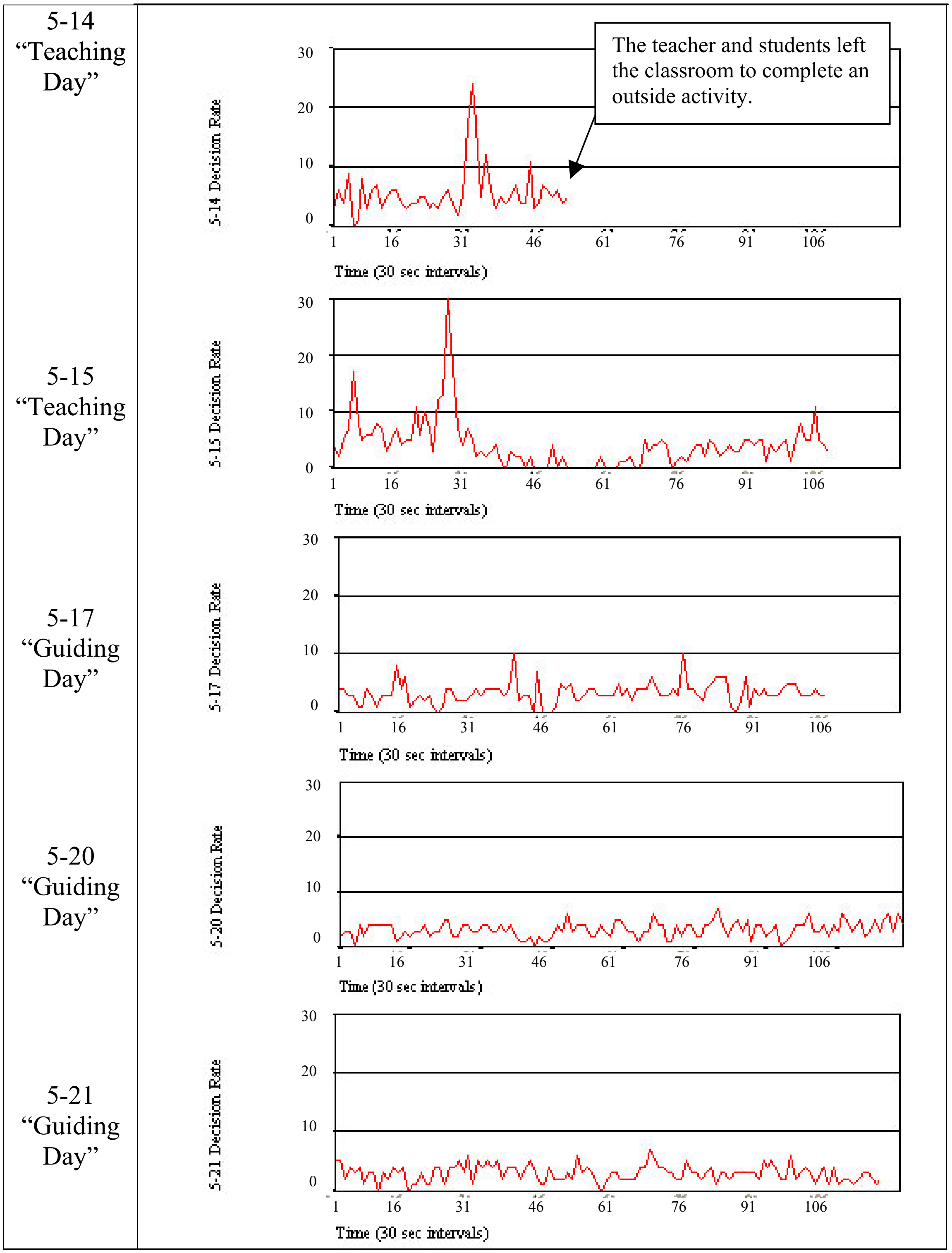


Figure 15. **Time series line graphs of instructional decision-action rates (SOS Data).**

Investigation of possible trends in the decision-action rates was done using linear and curvilinear regression models for the data. The slopes of all the lines generated by both linear and curvilinear models for all five days were close to zero, indicating that there is no apparent trend in this data. Table 20 shows the results of linear and curvilinear regression analysis of the decision-action rates (`D_RATE`) versus time.

Table 20
Linear and Curvilinear Regression of Decision-Action Rates Versus Time

Date	Dependent	Mth	Rsq	d.f.	F	Sigf	b0	b1	b2
5-14	D_RATE14	LIN	.024	48	1.20	.280	4.6286	.0015	
	D_RATE14	QUA	.063	47	1.58	.216	2.7097	.0089	-5.E-06
5-15	D_RATE15	LIN	.069	103	7.59	.007	6.0128	-.0012	
	D_RATE15	QUA	.219	102	14.31	.000	9.8035	-.0083	2.2E-06
5-17	D_RATE17	LIN	.028	102	2.97	.088	2.8239	.0003	
	D_RATE17	QUA	.029	101	1.52	.223	2.6965	.0006	-8.E-08
5-20	D_RATE20	LIN	.053	117	6.56	.012	2.6973	.0003	
	D_RATE20	QUA	.066	116	4.10	.019	3.0623	-.0003	1.7E-07
5-21	D_RATE21	LIN	.006	114	0.71	.403	3.1519	-.0001	
	D_RATE21	QUA	.026	113	1.53	.222	2.6883	.0007	-2.E-07

Thus the decision-action rate data showed no consistent trends in linear slope, though there were consistent differences in the amplitude of decision-action rates of different days corresponding to the instructional modes identified by the teacher. After analysis of these initial results, the decision-action types on the “teaching” and “guiding” days were compared for relative frequency. There were differences between the two days of “teaching” versus three days of “guiding” in the relative number of “7” praise/support and “1Q” direct question codes (see Table 21). In addition, on May 15, the teacher also asked 33 higher order “2” code questions, compared to 0-9 “2” codes on the other days. Interestingly, the “teaching” days showed relatively fewer “1” commands and “4” instruction/inform/ lecture codes than the “guiding” days. In teacher interviews, the teacher reported that she was unaware of the high frequency of decision-actions in some teaching intervals. Inspection of the SOS codes during high frequency intervals revealed intense, rapid question-answer-data recording sequences were occurring. The polling of all students repeatedly during direct instruction to collect data for subsequent group analysis was apparently a technique that this teacher used as a routine. As previously noted, an expert teacher is characterized by the “ability to select particular strategies, routines, and information”…”during actual teaching and learning interactions, based on specific classroom occurrences” (Borko and Livingston, 1989, p. 485). The teacher’s high frequency decision-actions apparently were part of a routine the teacher used at appropriate times during direct instruction to regularly involve all students in a small amount of time.

Table 21
Percent Relative Occurrence of SOS "What" Codes for Teacher-initiated Actions

	Code 1 command	Code 1Q direct question	Code 2 higher order question	Code 2Q open ended question	Code 4 instruct/ inform/ lecture	Code 5 social comment	Code 7 praise/ support	Code 9B correction	Code 12 observe/ monitor
5/14/2002 Teaching Day	14%	17%	3%	2%	12%	0%	18%	5%	**29%**
5/15/2002 Teaching Day	9%	**25%**	7%	0%	6%	0%	**23%**	2%	**28%**
5/17/2002 Guiding Day	17%	11%	1%	5%	16%	2%	5%	8%	**36%**
5/20/2002 Guiding Day	19%	13%	1%	2%	9%	4%	7%	8%	**38%**
5/21/2002 Guiding Day	13%	19%	0%	2%	15%	0%	10%	8%	**32%**

Note: Percentages ≥ 20% are bold type.

Bivariate Analysis

The third research question guiding this study was: Do improvisational decisions elicit a physiological response? To answer this question, the relationship between physiological response rates and decision-action rates was explored with the calculation of Pearson’s correlation coefficients and bivariate time series analysis.

Pearson’s correlation coefficients were calculated to test for a possible relationship between each day’s simultaneously occurring decision-action rates and physiological response rates, which correspond to zero lag in time series analysis. Table 22 shows a summary of the calculations. On May 15, a weak positive correlation was found between the decision-action rate and the physiological response rate. On May 20, a weak negative correlation was found between the two variables. A 2-tailed test for correlation was chosen, since it had not been determined whether heart rate rises or falls with an increase in the number of instructional decision-actions. Both correlation coefficients are significant at the 0.01 level, indicating possible interactions between decision-action rates and physiological responses that occur at zero lag, i.e., within 30 seconds of each other As stated before, 30 seconds is a relatively long time interval compared to other research using heart rates in conjunction with behavior.

Interestingly, no relationship could be found between “B” codes (the teacher’s behavioral correction actions) and changes in the physiological response rates. The weak negative correlation on May 20 between decision-action rates and physiological response rates is intriguing. Research literature cites an “Intake-Rejection” hypothesis (Coles, 1983) for a relationship between heart rate and sensory perception, with an increase in heart rate with blocking or rejecting sensory stimuli, and a decrease in heart

Table 22
Pearson *r* Correlation Coefficients of Decision-Action Rate Versus Physiological Response

Correlation Coefficients of Decision-Action Rate Versus Physiological Response Rate

		5-14 Physiological Response
5-14 Decision-Action Rate	Pearson Correlation	.245
	Sig. (2-tailed)	.086
	N	50
		5-15 Physiological Response
5-15 Decision-Action Rate	Pearson Correlation	**.456 (**)**
	Sig. (2-tailed)	.000
	N	105
		5-17 Physiological Response
5-17 Decision-Action Rate	Pearson Correlation	.018
	Sig. (2-tailed)	.852
	N	104
		5-20 Physiological Response
5-20 Decision-Action Rate	Pearson Correlation	**-.239 (**)**
	Sig. (2-tailed)	.009
	N	119
		5-21 Physiological Response
5-21 Decision-Action Rate	Pearson Correlation	.044
	Sig. (2-tailed)	.640
	N	116

** Correlation is significant at the 0.01 level (2-tailed).

rate when actively attending to sensory stimuli. There is no basis in the decision-action rate data or field notes to support or reject this hypothesis as an explanation of the observed tendency for a decrease in heart rate with an increase in decision-action rate on May 20. However, future data collection strategies could focus data collection on instructional situations in which teachers pay attention to or ignore external classroom stimuli.

Bivariate time series analysis. Bivariate time series analysis is a technique to test for a possible lead/lag relationships between each day's decision-action rates and physiological response rates. The variable named "physiological response rate" does not infer response to the "decision-action rate" variable, rather it is meant to represent the measurable outcome of multiple processes located in the brain and expressed though the autonomic nervous system. Bivariate time series analysis allows for identification of significant relationships between variables which change over time. For example, the rise in one variable could be associated with the rise in another variable one minute later.

One of the checks that should be performed on time series data is the autocorrelation function to test for the independence of the data within each univariate time series. An autocorrelation function (ACF) "measures the linear predictability of the series at time t, say x_t, using only the value of x_s [the adjacent value of x]" (Shumway & Stoffer, 2000, p. 19). That is, the ACF measures how independent each data point is compared to data points proceeding and following the data point. Figure 16 shows lagged autocorrelation function (ACF) graphs for physiological response rates on each day, while Figure 17 shows lagged autocorrelation function (ACF) graphs for decision-action rates on each day of observation. There was a significant autocorrelation at lag six for the May 21 physiological response rates. Each time interval was 30 seconds, so a lag of six is three minutes. Thus on May 21 the heart rate/physiological response rates for each 30-second time interval was significantly related to the heart rate/physiological response rates three minutes before or after the time interval. Decision-action rates had a weak positive autocorrelation at one lag, i.e., 30 seconds later in the time series, but were not strongly correlated at longer times. Thus the number of decision-actions the teacher was making in one 30-second interval was not significantly related to the number of decision-actions being made a minute later or earlier. The heart rate/physiological response rates showed longer dependence times. Apparently the teacher’s heart rate/physiological response rates tended to stay at the same level for a few minutes.

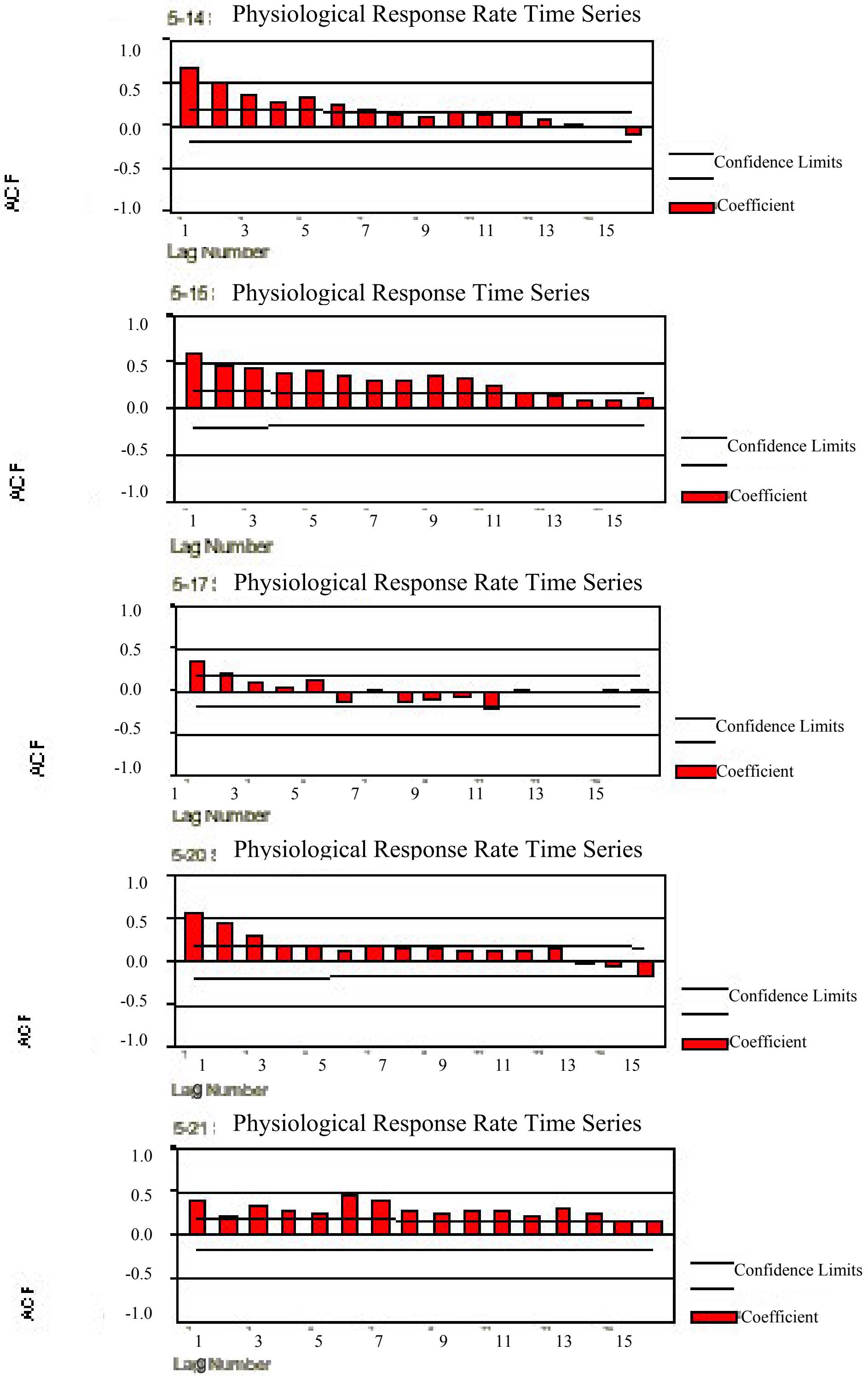


Figure 16. **Autocorrelation function graphs of physiological response time series.**

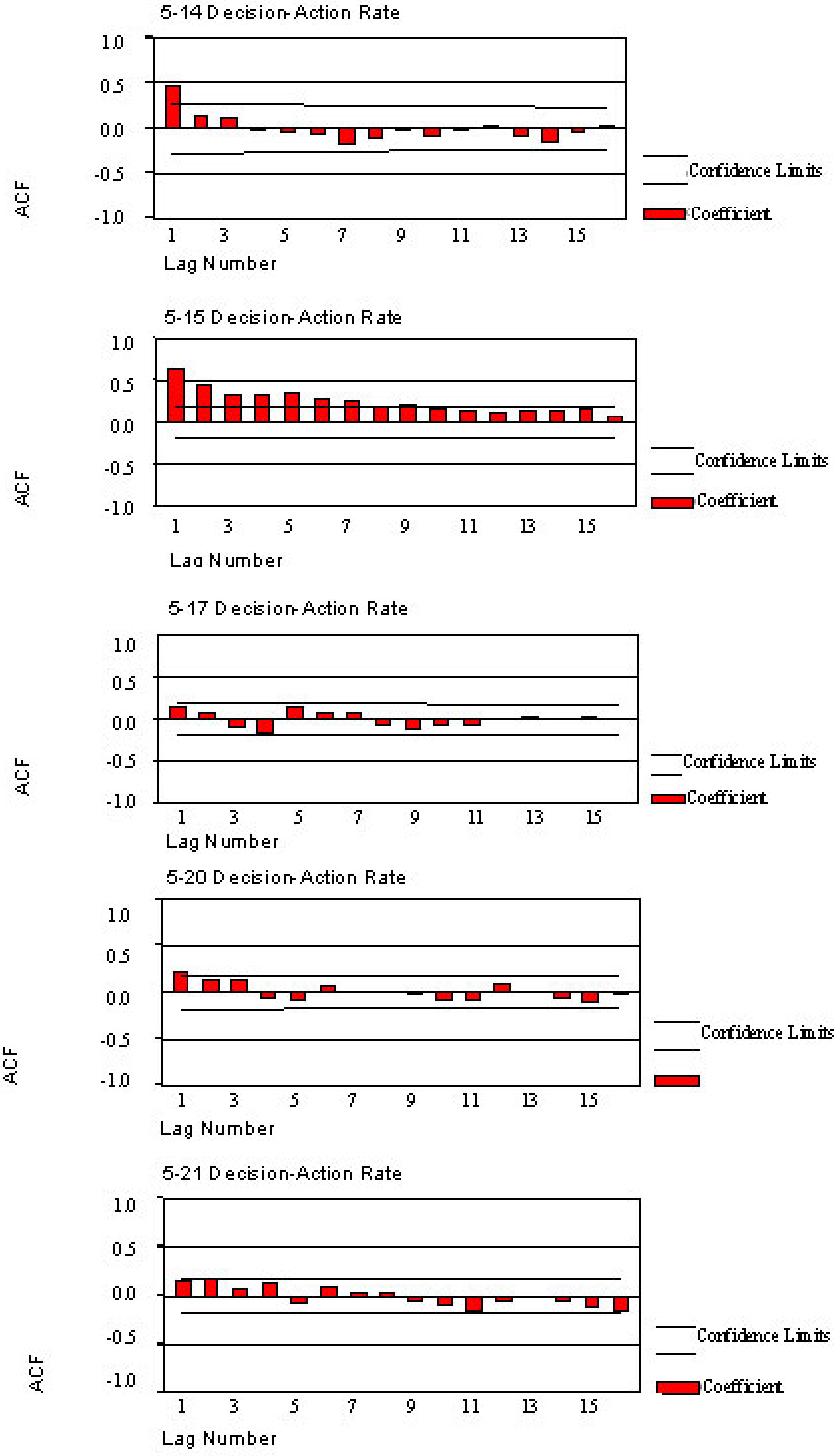


Figure 17. **Autocorrelation function graphs of decision-action rate time series.**

The cross correlation function (CCF) of the two time series for the decision-action rates and physiological response rates each day of instruction were graphed without prewhitening. Prewhitening must be performed on time series that required the removal of trends, cycles, or autoregressive components removed from the series before testing for relationships between two time series. In the time series in this study, there were minimal trends and no cycles detected for extended periods of time in the series. There were indications of one lag dependence of data points in the autocorrelation functions of both the decision-action rate and longer periods of the physiological response rate data, which are typical of “real world” data. At zero lag, only the May 15 and May 20 data show significant covariance, in agreement with the Pearson’s correlation coefficient calculations. The CCF graph for May 15 data shows that decision-action rate data and physiological response rate data were significantly coordinated in both lead and lag relationships for that “teaching” day. The physiological response rate increased about 3.5 minutes before a teacher-initiated change, then tended to remain at an elevated rate up to 5 minutes after a rise in decision-action rate. The autocorrelation of the heart rate/physiological response rates did not appear to impact the cross correlation functions in a consistent pattern from day to day.

The following cross correlation function (CCF) graphs (Figures 18, 19, 20, 21, and 22) are the results of serial comparisons of the relationships between decision-action rates and physiological response rates for each day of instruction. One day, the May 15 “teaching” day, showed significant and extended relationships between the two variables. There is evidence of extended, greater than five-minute lags of increased physiological response rates after a rise in decision-action rate. There is also evidence of a three-minute lead of an increase in the physiological response rate before a rise in decision-action rate on May 15. Thus there is evidence that the teacher's physiological response rates rose before and after she initiated changes in her instruction.

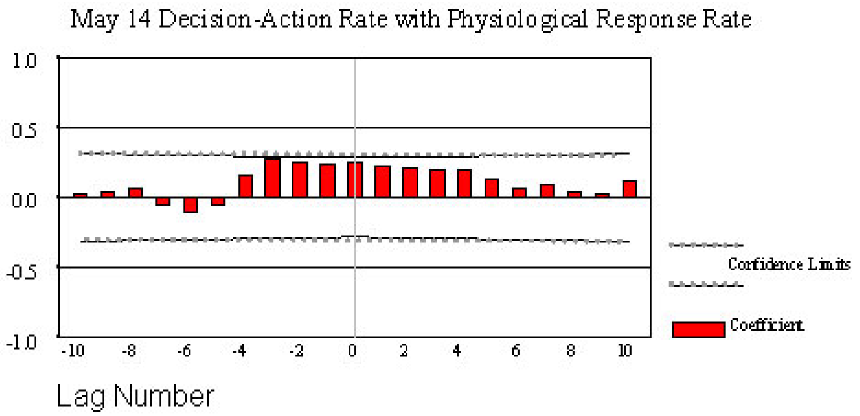


Figure 18. **Cross correlation function graph of May 14 decision-action rate versus physiological response rate.**

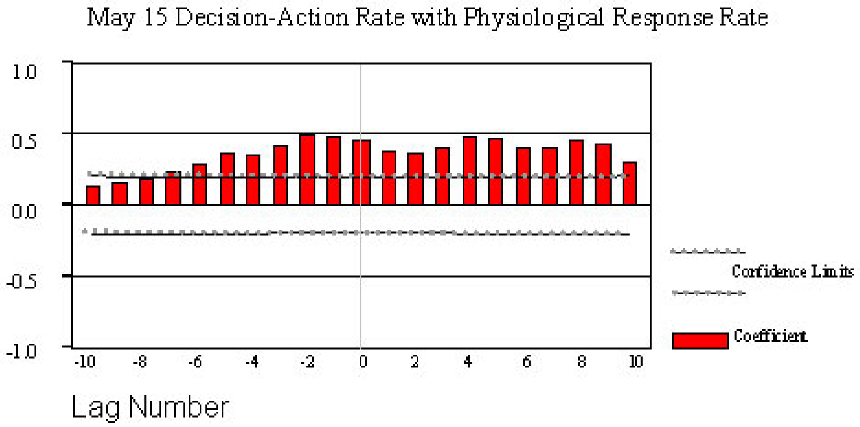


Figure 19. **Cross correlation function graph of May 15 decision-action rate versus physiological response rate.**

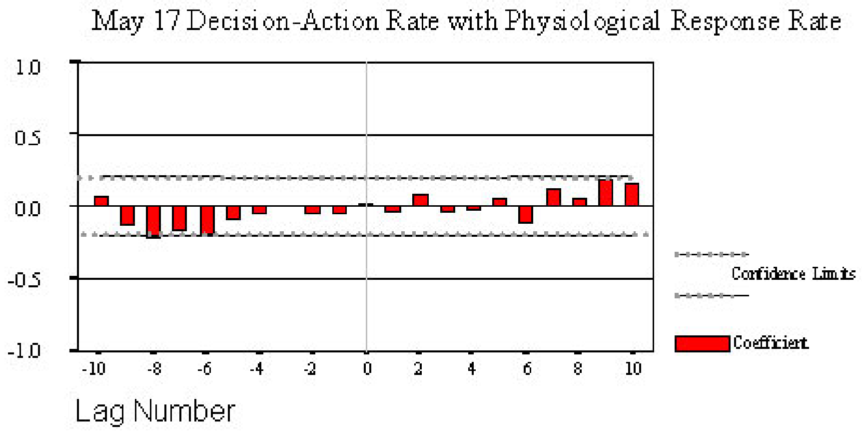


Figure 20. **Cross correlation function graph of May 17 decision-action rate versus Physiological response rate.**

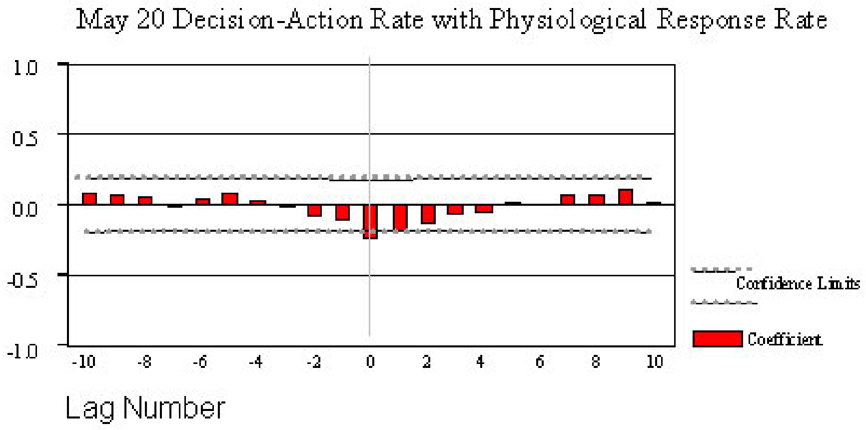


Figure 21. **Cross correlation function graph of May 20 decision-action rate versus physiological response rate.**

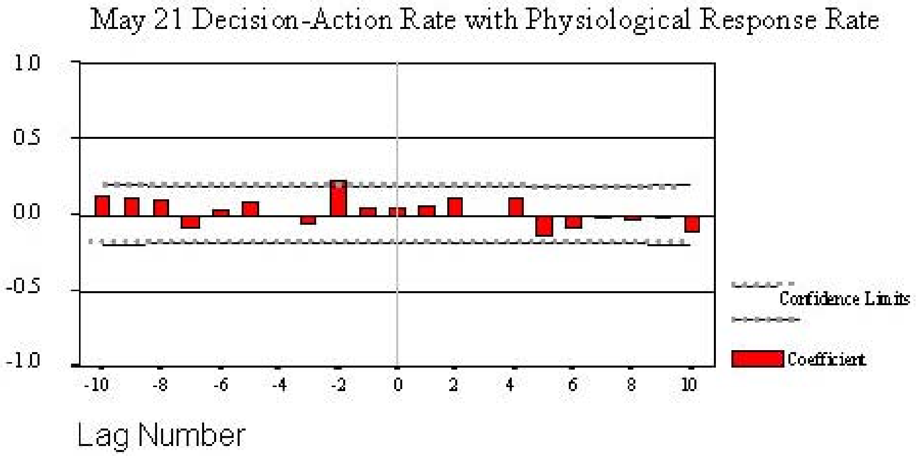


Figure 22. **Cross correlation function graph of May 21 decision-action rate versus physiological response rate.**

Exploratory Quantitative Data Analysis

The skewed distributions of the decision-action rate data, presence of outliers found in the data distributions, and variation in the day-to-day data collection contexts presented challenges in the exploration of significant relationships and patterns in the data. The following sections include a description of methods used for minimizing the impact of outlier data values in the analysis of data collected in this study, exploration of the relationship between data collected and elapsed time, and exploration of the relationship of teaching strategy variables to physiological and behavioral variables.

Minimizing the impact of outliers. Warner (1998) suggested that outliers should first be checked for measurement validity, then may be rounded to the next valid data value. The SOS codes contributing to these outliers were checked and rechecked a minimum of two times for each 30 second interval during the initial data collection procedure, then later tested for observer consistency, so the extreme data values were accepted as valid information. However, outliers in time series data sets may have a disproportionate impact on trend analysis and regression analysis results (Warner, 1998). Outliers in the time series data sets recorded in this study were identified using stem and leaf data descriptions with SPSS 12.0 software (see Table 23). The outliers in each data set were converted to the closest non extreme value. For instance, outliers in the May 14 decision-action rate data were converted to 8.0 for high extremes and converted to 2.0 for low extremes.

Table 23
Identification of Outliers

	Number of Extreme Values				
Data Type	May 14	May 15	May 17	May 20	May 21
Decision-action rate	6 values ≥ 9.0 2 values ≤ 1.0	3 values ≥ 17.0	3 values ≥ 7.0	none	none
Physiological response rate	none	1 value ≥ 98	none	2 values ≥ 108	6 values ≥ 92

Analysis of the relationship between decision-action rates modified for outliers and physiological response rates did not substantially alter the levels of significance in the calculation of correlation coefficients or the outcome of bivariate time series analysis for each day's data. For example, May 14 data which required the correction of eight values yielded no significant results for linear regression, curvilinear regression, Pearson's r correlation, or cross correlation of the time series after controlling for extreme values in the data.

The next modification performed on the decision-action rate data was to convert the data to log 10 values. Warner (1998) recommended logarithmic conversion of an entire time series data set to minimize the impact of extreme outliers. Analysis of the relationship between log 10 decision-action rate and physiological rate data yielded no new significant results for linear regression, curvilinear regression, and Pearson's r correlation for May 15, 17, 20, or 21. However, a weak positive relationship at –2 lag (one minute prior to a decision-action) and +3 lag (one and a half minutes subsequent to a decision-action) was found in the cross correlation calculation of the time series for May 14 (see Figure 23).

```
     Cross Stand.
Lag  Corr.   Err. -1  -.75  -.5 -.25   0   .25  .5   .75   1
                   +----+----+----+----+----+----+----+----+
 -7   .146   .152                .     |***  .
 -6   .102   .151                .     |**   .
 -5   .190   .149                .     |**** .
 -4   .211   .147                .     |**** .
 -3   .222   .146                .     |**** .
 -2   .292   .144                .     |******
 -1   .216   .143                .     |**** .
  0   .206   .141                .     |**** .
  1   .234   .143                .     |*****.
  2   .243   .144                .     |*****.
  3   .285   .146                .     |******
  4   .178   .147                .     |**** .
  5  -.010   .149                .     *     .
  6  -.056   .151                .    *|     .
  7  -.020   .152                .     *     .

Plot Symbols: Autocorrelations *  Two Standard Error Limits .
Computable 0-order correlations:  50      Valid cases:  50
```

Figure 23. **Cross correlation of the log of physiological response rates and log of decision-action rates for May 14.**

In general, controlling for outliers in the data sets did not yield new information about relationships within the data sets.

Exploration of the relationship of elapsed time to data values. There were three sets of quantitative data collected each observation day to be used for time series analysis: decision-action rates, physiological response rates, and elapsed time. Linear and quadratic regression analysis, Pearson's r correlation analysis, and bivariate time series analysis were performed on the decision-action data and physiological response data in the search for relationships between these two data types. As previously described, a significant, positive relationship was found between the decision-action rate and physiological response rate data on May 15 as shown in Table 24.

Table 24

Correlation of May 15 Decision-action Rates with Physiological Response Rates

	5-15 Systemic Response (peaks/min)
5-15 Decision Rate (# of T initiated changes/30 sec)	
Pearson Correlation	.456**
Sig. (2-tailed)	.000
N	105

** Correlation is significant at the 0.01 level (2-tailed).

A correlation analysis was also performed to explore the relationship between decision-action rates, physiological response rates, and elapsed time for May 15 data. Both the decision-action rate and physiological response rates were found to have a significant negative relationship with elapsed time, i.e., the decision-action rates and physiological response rates tended to decline from the beginning to the end of the class period (see Table 25).

Table 25

Correlation of May 15 Decision-action Rates and Physiological Response Rates with Elapsed Time

	5-15 Elapsed Time (seconds)
5-15 Decision Rate (# of T initiated changes/30 sec)	
Pearson Correlation	-.370**
Sig. (2-tailed)	.000
N	110
5-15 Systemic Response (peaks/minute)	
Pearson Correlation	-.262**
Sig. (2-tailed)	.007
N	105

** Correlation is significant at the 0.01 level (2-tailed).

Correlation analysis was subsequently used to search for possible relationships between decision-action rates or physiological response rates and elapsed time on the other observation days. The only significant relationship between decision-action rate and time was found in the May 20 data: decision-action rate was positively correlated to elapsed time significant at the 0.05 level. Since the May 15 decision-action data was negatively correlated to time at the 0.01 level, no consistent pattern between decision-action rates and time was found for all five observation days. Thus, it was not possible to predict whether the teacher would increase or decrease the number of her self-initiated actions as a function of elapsed time during the class period.

In contrast, a decrease in the physiological response rates was found for all five observations, with a significant decrease for four out of five observation days (see Table 26). Correlational analysis revealed a negative trend in the physiological response rate data from the beginning to the end of a class period, i.e., the teacher's state of arousal tended to be higher at the beginning of class compared to the end of class.

Table 26

Correlation of Systemic Response Rates (peaks/minute) vs. Elapsed Time (seconds) for Each Observation Date

Observation Date	Pearson Correlation Coefficient	Sig. (2-tailed)	N
5-14	-.097	.293	119
5-15	-.370**	.000	110
5-17	-.191*	.045	111
5-20	-.220*	.016	119
5-21	-.531**	.000	117

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Exploration of instructional strategy variables. Classroom observation, examination of the videotapes, and inspection of the SOS records revealed a variety of instructional strategies used by the teacher during the five observation days. The majority of instructional time was spent with the students either sitting on the floor around an overhead projector during direct instruction or with students seated at tables in small groups working on cooperative activities while the teacher managed and monitored student progress.

On May 15, a different instructional situation was observed as the students worked independently on an essay for approximately one third of the instructional time, while the teacher walked around the classroom monitoring students' performance. During the last part of the May 15 class, the teacher provided activities for students who finished their essays while continuing to monitor and encourage students who were still writing their essays.

The decision-action rate data and physiological response data recorded each 30 second interval were examined for differences related to instructional activity. The instructional activities selected for comparison were teaching strategies readily distinguishable by student location and task type. They were:

- direct instruction—the teacher leading instruction at the overhead projector with students sitting on the floor listening and responding to the teacher,
- group work—the teacher managing, instructing, and guiding small groups of students working cooperatively,
- monitoring—the teacher watching students work independently on an assignment while walking around the classroom, and
- multi-tasking—monitoring, managing, and guiding students working on different assignments.

Relationships between physiological response rates and instructional strategies were explored by comparing the physiological response rates during different instructional strategies using t-tests (two tailed). Comparisons were confined to data within single classroom periods to control for day-to-day fluctuations in the teacher's physiological state. Restricting comparisons to instructional strategies observed during a single class period resulted in the removal of the May 20 and 21 class periods from analysis; because the instructional strategy used by the teacher on both guiding days was predominately group work, i.e., managing and guiding small groups of students, so a meaningful comparison with other instructional strategies on the same day was not possible. The instruction on May 14 and 17 consisted of both managing student group work and direct instruction teaching, while May 15 consisted of direct instruction teaching, monitoring independent seat work (the essay test), and simultaneously monitoring the essay test and managing post-test activities for students who finished their tests (multi-tasking). Table 27 shows the number of intervals the teacher used each specific strategy on each observation day according to the SOS data and videotape recordings. Intervals in which students were changing location were not included in the interval categories.

Table 27

Total Number of 30 Second Intervals Associated with Specific Teaching Strategies for Each Observation

Observation Date	Instructional Activity	# of Intervals
May 14	Direct instruction (students seated on floor)	18
	Group work (students seated at tables)	14
May 15	Direct Instruction (students seated on floor)	26
	Monitoring during test (students seated at tables)	31
	Multi-tasking/monitoring/managing group work	24
May 17	Direct instruction (students seated on floor)	25
	Group work (students seated at tables)	58
May 20	Modified direct instruction (students seated at tables)	16
	Group work (students seated at tables)	97
May 21	Group work (students seated at tables)	105

T-tests of equality of means were performed using decision-action rate data and physiological response rate data associated with different teaching strategies for May 14, 15, and 17. The SOS teacher-initiated code change rates and physiological recordings were judged to be independent samples during the calculation of t-values for 2-tailed tests. Equal variances were assumed for the physiological response data, but not for the decision-action rate data.

The results of t-tests comparing the mean of decision-action rates during direct instruction teaching to the mean of decision-action rates during group work on May 14 and May 17 revealed no significant differences between the sample means. Furthermore, t-tests for equality of means of physiological response rate data associated with time intervals when the teacher was using direct instruction teaching compared to intervals the teacher managed small group work revealed no significant differences. T-test information summarized in Tables 28 and 29 show the teacher's self-initiated actions and her physiological arousal were indistinguishable during direct instruction teaching compared to managing students working in small groups on May 14 and 17.

In contrast to May 14 and May 17, the teacher showed distinctly different decision-action rates and physiological response rates on May 15 when she included a different teaching strategy during class, i.e., monitoring students while they worked independently on an essay to be used for assessment. A t-test (Table 28) for equality of the decision-action rate data mean during direct instruction and the decision-action rate data mean during monitoring independent seatwork revealed a significant difference at the 0.01 level, two-tailed and with no assumption of equal variances. The decision-action rates were higher during direct instruction. It is no surprise that an expert teacher initiates more actions during direct teaching than during test monitoring, and the SOS decision-action data collected on May 15 confirmed this difference.

A t-test (Table 29) was also used to compare the equality of the mean physiological response rate data during direct instruction teaching to the mean physiological response rate data while monitoring independent seatwork on May 15. A significant difference was found, with the physiological response rates higher during direct instruction. Thus, this expert teacher showed a state of higher physiological arousal during direct teaching than during test monitoring, as indicated by the skin voltage data collected on May 15. Figure 24 shows a graph of the physiological response rates versus decision-action rates for two different teaching strategies on May 15.

Table 28
T-Test of Equality of Decision-action Rate Means for Different Instructional Strategies

Date	Instructional Variable	# of Cases	Mean	Standard Deviation	Standard Error	F Value	Significance (2-tailed)
May 14	Direct Instruction	20	7.20	6.031	1.349	8.288	.150
	Group Work	16	5.06	1.982	.496		
May 15	Direct Instruction	27	8.37	5.752	1.107	13.140	.000*
	Monitoring Test	32	.97	1.425	.252		
May 17	Direct Instruction	28	2.89	2.299	.434	11.905	.263
	Group Work	61	3.43	1.384	.177		

*Difference is significant at the 0.01 level (2-tailed), equal variances not assumed.

Table 29
T-Test of Equality of Physiological Response Rate Means for Different Instructional Strategies

Date	Instructional Variable	# of Cases	Mean	Standard Deviation	Standard Error	F Value	Significance (2-tailed)
May 14	Direct Instruction	20	89.20	7.324	1.638	4.075	.197
	Group Work	16	92.13	5.632	1.408		
May 15	Direct Instruction	27	88.15	6.113	4.400	3.488	.000*
	Test Monitoring	32	79.56	1.982	3.079		
May 17	Direct Instruction	28	89.71	3.473	.656	.914	.154
	Group Work	61	88.46	3.973	.509		

*Difference is significant at the 0.01 level (2-tailed), equal variances assumed.

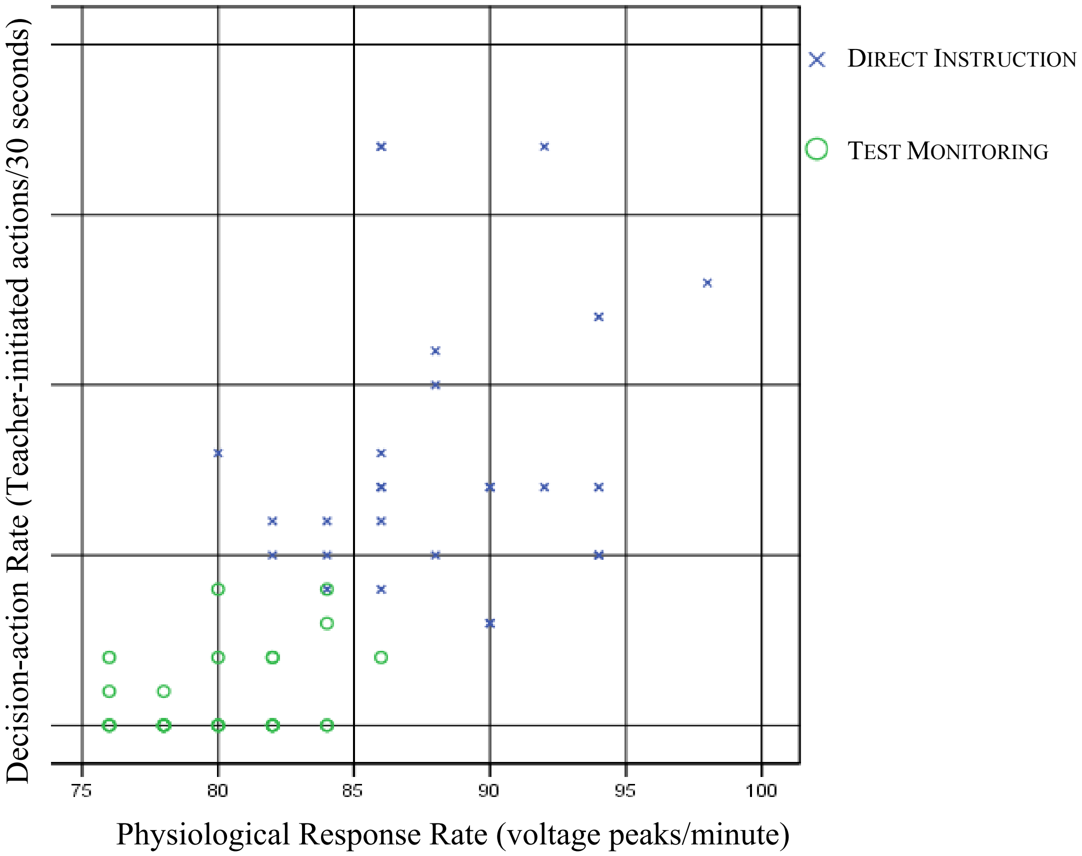


Figure 24. **Graph of May 15 physiological response rates versus decision-action rates for direct instruction and test monitoring.**

The May15 data indicate the teacher used instructional strategies which were associated with different rates of teacher-initiated actions and levels of arousal. In retrospect, it is obvious that May 15 was the only day observed during which the teacher was not intensively interacting with the students throughout the period. Specifically, the teacher exhibited less interactivity during monitoring of independent seatwork on May 15, thus providing a contrast to the high interactivity and physiological arousal the teacher showed during direct instruction that day.

Summary of Quantitative Analysis

The quantitative results provided a description of the moment-to-moment instructional behaviors of the teacher and her physiological responses during instruction. The means and standard deviations of decision-action rates on days the teacher identified as “teaching days” were higher than the rates on “guiding” days, showing both higher and more variable decision-action rates for instruction the teacher identified as “real teaching.” The decision-action rate patterns on time series graphs were also visibly different for the “teaching” versus “guiding” days. On the May 15 “teaching” day, the teacher made 30 teacher-initiated changes in behavior in a single 30-second interval. There was at least one sequence of zero teacher-initiated changes in behavior on both “teaching” and “guiding” days. A zero decision-action rate does not mean that the teacher was not actively teaching. Rather, it meant that she was making no discernible changes in her teaching behavior.

No overall consistent trends were found in the decision-action rate data during the observed instructional periods, while a minimal negative trend was found in the physiological response rate data. Calculation of Pearson’s correlation coefficient revealed a weak positive correlation between decision-action rate and physiological response rate at zero lead/lag on one of the “teaching” days, May 15, and weak negative relationship on May 20. Bivariate analysis of the decision-action rate and physiological response rates for May 15 showed a significant relationship between –7 lags and +10 lags, which indicated that the physiological response rate rose before and after a teacher-initiated change in instruction on that “teaching” day. No causality is inferred, but there is evidence for a relationship between the physiological response rate and the decision-action rate in a particular teaching context. Furthermore, context is important for this expert teacher's decision-action types and frequencies.

The simultaneous collection of data measuring decision-action behaviors, physiological activity, and elapsed time made it possible to describe a possible link between the activity levels of the teacher and her physiological arousal throughout a class period. The apparent importance of the instructional context for the teacher's observed decision-action rates and physiological arousal makes type of teaching strategy an additional essential element to be identified in future studies of improvisational decision-making. Salient features of the teacher's instruction in this study included:

- The teacher was apparently as active and attentive during student-centered group work as she was during teacher-centered direct instruction, since no significant differences were found between decision-action rates or physiological response rates for direct instruction as compared to group work. As the teacher said, "I have to keep monitoring, and the more I walk, the better behavior I have, the better results I get with them participating what they're supposed to be [doing]" (May 13 interview).
- The teacher tended to be at a slightly higher state of physiological arousal at the beginning of a class period compared to the end of class. Three possible explanations for the decrease in physiological arousal are a time dependent increase in fatigue, a decrease in anxiety during the class

period, or a decrease in attention as instruction proceeds.

- The teacher's decision-action rate was not always related to her physiological response rate, rather the relationship was context-dependent and related to the teaching strategy being used. A low activity level when monitoring group work was associated with a different physiological response and more stress than initiating a low teacher-initiated activity level while monitoring independent seatwork during a test.
- Measurement of teacher-initiated activity rates associated with teaching strategies and physiological arousal presents a possible way to quantitatively describe "withitness" or focused attention. A profile of a teacher's activity and physiological arousal could be derived from measurement of the teacher while performing a variety of teaching strategies and non-teaching tasks during the school day.
- There were factors such as instructional strategy and outside stress that varied from day to day and which could have a major impact on the teacher's activity level and physiological arousal. Exploration of the relationship of those factors will be necessary before day-to-day comparisons in instructional behavior and physiological arousal will be possible.

Elements of Planning Decisions

The qualitative data sources were mined for information about critical aspects characterizing this teacher's decision-making process during classroom instruction. This information was used to answer two of the research questions:

(1) How does a teacher integrate decisions made outside class into her classroom instruction?

(2) How does a teacher make improvisational decisions during class?

Both the selection of data pertinent to the research questions and the use of predetermined classification categories excluded much information that the teacher freely shared. This information included data such as working successfully with a team of teachers, the importance of professional development, and mentoring a first year teacher.

Categorical analysis was performed on the basis of three categories based on the Stallings Observation System major *how* codes: (1) academic decisions about the content to be taught, (2) organizational decisions about people and materials, and (3) behavioral management decisions. The three categories were then divided further into subcategories based on evidence from educational research that decisions made during instruction are qualitatively different from decisions made before or after instruction. Therefore, the next division of qualitative information distinguished when the teacher's decision occurred: (1) the decisions that were made before or after instruction and (2) the decisions that were made during instruction. The three by two classification scheme yielded six cells for coding evidence of the teacher's decisions according to the salient feature of the information. Not all the information fit neatly into the predetermined category cells. For instance, the code "team planning" was placed in the "academic" category, though some of the team planning involved organization of materials. Classification was made in these crossover codes according to the preponderance of the evidence. Seventeen decision codes are displayed in Table 30. Four of the codes contained teacher statements of unusual emphasis or feeling, indicating the importance the teacher placed on those types of decisions.

Table 30
Qualitative Information Categories and Codes

	Decision Categories and Codes	
SOS Categories	Codes for decisions made before instruction	Codes for decisions made during instruction
Academic	Team planning* Standards and state tests Personal beliefs and objectives*	Monitoring and improvisation Implementation of plans Being fair
Organizing	Materials* Students Time	Materials Students Time*
Behavior	Prevention of problems Rewarding good behavior Solving problems	Attention to all students Deciding when to intervene

* Codes which include statements expressed with strong feelings.

Academic Planning Before Instruction

Team planning. Academic planning was done by a team of four teachers, including three veterans and one novice. A fifth teacher in the grade level cluster area chose not to work with this team. Together the team of four planned objectives, determined schedules, designed task assignments, and prepared materials. They also filed all curricular and planning materials in a single plastic file crate to be used the next year, sometimes with modifications based on the current year's experiences. The team crate was a way to organize forms and activities for each teacher according to class assignment, preferences, and needs, and was viewed as a key to instructional survival as expressed by the teacher who said, "We live and die by this crate" (May 20 interview).

Standards and state tests. The second code in the "academic planning before instruction" cell is "standards and state tests" based on the explicit strategy the teacher described for planning to teach probability using the heuristics of organized lists and matrices at the end of the school year. She explained that probability is part of the Texas Essential Knowledge and Skills (TEKS), but was not tested on the Texas Assessment of Academic Skills (TAAS) in spring 2002 on the third grade exam; yet it would be tested in the future. Also, the students would need to be able to use organized lists and matrices to solve problems in the spring 2004 Texas Assessment of Knowledge and Skills (TAKS) test in fifth grade. Therefore, she planned her pre-TAAS instruction for success on the TAAS, then used the remainder of the year to include topics and skills the students would need to be successful taking future tests.

Personal beliefs and objectives. The third code in the "academic planning before instruction" cell is "personal beliefs and standards." This teacher was emphatic in describing her choices of appropriate activities for a math class and said that students should do only math in math class, with no exceptions. For example, the teacher's team decided in the middle of the week that she would have this particular class of students on Friday, May 17, which followed the last TEKS-centered academic unit of the school year. She described her choice of lesson: "I had to think of something that was acceptable to me, would engage them, and had to involve math, because I am the math teacher, and I don't want to baby-sit" (May 13 interview).

Academic Decisions During Instruction

The three decision codes found to describe the evidence for academic decisions during instruction included monitoring and improvisation, sequencing instruction, and being fair.

Monitoring and improvisation. This was a code that crossed over with the category of behavioral management. The teacher said, "I have to keep monitoring, and the more I walk, the better behavior I have, the better results I get with them participating in what they're supposed to be [doing]" (May 13 interview). The "monitoring and improvisation" code was placed in the academic category because most of the monitoring observed during class was associated with academic guidance and academic questions. Improvisation was paired with monitoring because it was during monitoring that the teacher appeared to pause in following her prepared academic plans to assess and address the academic needs of individual students. I asked her how she decided what kind of attention to give her students, and she replied that the attention was determined by the needs of the students, not by her. During one interview (May 13 interview) the teacher explained that she never taught a class the same way twice, yet she also said that there had been no surprises during the class. The way this teacher continuously walked from group to group checking work, asking questions, and addressing student needs was a familiar process to her, even though the particular interactions changed from student to student, and from class to class (May 13 interview).

On the last observation day at the end of the school year, the teacher found that one student was repeatedly off task as he attempted to figure out how many minutes were left to the school year. Instead of forcing the student to do what everyone else was doing, she told him that since he was doing a math problem, he could continue figuring out a solution, but that he would have to show his calculations and explain his reasoning. The teacher kept monitoring the rest of the class while solving the "minutes left in school" problem herself. When the student calculated incorrectly, the teacher helped him locate his own errors so he could correct them himself. The student changed from off-task behavior to engagement in intense problem-solving because this teacher could improvise her instruction to guide the student through an authentic student-selected math problem at the same time she was monitoring the rest of the class.

Implementation of plans. The teacher sequenced her whole class instruction by proceeding from teacher-centered to a student-centered instructional format. This instructional cycle was repeated several times during the lesson, the length of time for each part of the sequence determined by the attention span of the students, and each cycle building conceptually on the one before it. The teacher said, “Usually a lesson to me is teaching, then guided practice, then independent practice.” She described the increasing difficulty of each teaching/guiding/practice sequence this way: “I did it purposefully, you know. When you do math, you need to be kind of sequential, so I started with the easiest with one die, then went to the two die [sic], which was all easy; and now it’s going to the two die [sic] with multiplication, which is the hardest” (May 14 interview). The teacher made a distinction between teaching and guiding that became important for interpreting some of the quantitative data. She said, “Teaching to me is the probability lesson, that’s really teaching…there’s a difference between teaching and guiding” (June 21 stimulated recall interview). She felt that the enrichment activities that she taught the last three days were not real teaching, though she found it difficult to explain exactly how the “teaching” days were different from the “guiding” days.

Being fair. The third code in the “academic decisions during instruction” was “being fair.” The teacher modeled fair behavior and asked students to judge whether a game is “fair” on the basis of having an equal chance to win. If the teacher helped one student in the game, she then helped the other students on the team.

The following is Table 31 showing the elements of the teacher’ academic planning decisions before instruction and academic decisions made during instruction.

Table 31
Summary of Academic Decision Codes Identified by the Teacher

SOS Categories	Decision Categories and Codes	
	Decisions Before Instruction	**Decisions During Instruction**
Academic	Team planning* Standards and state tests Personal beliefs and objectives*	Monitoring and improvisation Implementation of plans Being fair

- Codes which include statements expressed with strong feelings.

Organizational Planning Before Instruction

Materials. The teacher expressed emphatically the importance of having all materials prepared and accessible before class. She was detailed in her descriptions of the preparation, storing, and organization of materials before class. The manipulative and printed materials were obtained far ahead of class from a variety of sources: distributed at workshops, team-prepared, teacher-made, teacher-purchased, and school-purchased. The materials were stored in labeled containers, and some were arranged by frequency of use while others were in alphabetical order. The "materials" code was included in the organizational category though the teacher stressed that if a teacher wastes time looking for papers or manipulatives, he or she will lose the attention of the class and have behavior problems; so she felt that advance organization of materials was important for avoiding behavior problems. Team planning was also associated with this "materials" code. Materials were prepared for in-school-suspension (ISS) by the team in advance of an administrative request because: the teachers were told at last minute that the work would be needed, the teachers were told that the work couldn't come from a textbook, the assignment had to be created by the teachers, and the period of time out of class for each student varied. The team met the challenge of providing last minute, time-intensive individual assignments by creating a common resource file of appropriate work for variable lengths of time.

Students. The second "organizational planning before instruction" code is "students" because the furniture, space, and instructional materials were strategically planned for the teaching/guiding/practice sequence of instruction. Six groups of five individual student desks were moved together to make large table-like areas for the students during group work and independent practice. A carpeted area was left open around the overhead projector at the front of the room where the teacher introduced each new concept and guided student practice while students sat in rows on the floor near the projector. This was also the area where the students returned after recording their results to share their outcomes with the entire class.

Time. The third "organizational planning before instruction" code is "time." The teacher knew both the attention span of her students and the time needed to teach content objectives. She planned instructional time by dividing the time into intervals long enough to teach conceptual chunks of a lesson and short enough for the attention span of elementary students.

Organizing Decisions During Instruction

Materials. The teacher demonstrated efficient routines for distributing and collecting materials during instruction. Papers were placed in order at the front of the room, and for some activities, a student from each table picked up materials for her or his table. During other activities, the students went to the front of the room to pick up a new paper upon completion of an assignment. The manipulatives were placed in plastic boxes the teacher could stack and distribute easily. The distribution and collection of all the materials were apparently routine for the students as well as the teacher.

One classroom incident crossed over from organizing materials to organizing students, as well as monitoring and improvising. The teacher found that five students finished an activity in half the time that the rest of the class was taking. The teacher explained later that if students finish a few minutes early, they go to a file at the front of the room to get an enrichment folder containing extra work. However, these five students finished so quickly that the teacher decided they needed to proceed to the next day's assignment. The teacher reorganized the students to sit at a separate table, then took the next day's materials from a cabinet so the students could continue working. The teacher reorganized the students and pulled together new materials while still monitoring and guiding the rest of the class.

Students. There is a separate code for "students" in the "organizing decisions during instruction" category because the teacher reorganized students to solve behavioral and instructional problems during class. On a few occasions, students would misbehave while working in a group. The teacher sometimes moved one student, and sometimes she reorganized the group. These changes stopped the misbehavior. Though the reorganization of the students occurred during class, the teacher's choice of students to move showed knowledge of the probable behavior of all students, since the moves stopped the behavior problems. The teacher also reorganized the students who were unusually quick finishing an activity and those who had special difficulty doing an activity.

Time. During instruction, the teacher stated and demonstrated the need to use every minute of class time for learning and doing math. The teacher switched to the next part of her instructional sequence as soon as every student was successful doing an activity, which meant that the students who worked faster did more activities, or switched to enrichment activities. When asked how she decided the length of instructional time periods, the teacher said, "I don't consciously sit down and think: 'Now I only want to talk a little bit.' But after all these years of teaching, I know that after five or ten minutes they're tuning me out, there is no use talking anymore. It helps just to give a little chunk of information, let them think about it, then give them another chunk of information, and let them work on it, and that's how I try to organize…think, work, think, work…" (May 13 interview). Table 32 summarizes the elements of the teacher's organizational decisions.

Table 32
Summary of Organizing Decision Codes Identified by the Teacher

SOS Categories	Decision Categories and Codes	
	Decisions Before Instruction	**Decisions During Instruction**
Organizing	Materials* Students Time	Materials Students Time*

* Codes which include statements expressed with strong feelings.

Behavior Management Planning Before Instruction

Prevention of problems. The teacher used multiple strategies to prevent behavior problems:

- The students knew the teacher's expectations.
- The students knew the consequences of misbehavior.
- The teacher demonstrated concern for the well-being of the students.
- The teacher planned academic goals of interest and value to the students.
- The teacher maintained a steady flow of instructional events.
- The teacher grouped students according to activities.

Rewarding good behavior. The teacher also prepared small recognition buttons and certificates for good behavior, however she was not effusive in her praise of students. She said that she believed that learning mathematics is a reward in itself and gives students a feeling of accomplishment.

Solving problems. The team of teachers was important for solving behavior problems, maintaining consistent and persistent expectations of acceptable behavior. Students received “C” bucks each week to be used for special privileges or lost due to misbehavior in any of the classrooms of the team teachers. The teachers maintained a single behavioral record for each student in order to track when and where the student was having problems. The record was also important documentation when parent-teacher conferences were needed to solve behavior problems.

Behavior Management Decisions During Instruction

Attention to all students. The teacher simultaneously taught and monitored students at the same time. She paid attention to the sounds and sights of the class throughout the class period. The teacher described this constant, alert status this way: “I’m monitoring for discipline most of the time and don’t even realize it. I know I do, but I don’t realize it. “Sit in your chair, put your bottom down, put your feet on the floor’… that’s a constant 24/7 everyday” (May 13 interview).

Deciding when to intervene. When the teacher noticed a problem, she redirected the student or the entire class, as appropriate. The intervention was obvious when she shut off the light, the class became silent, and she proceeded to correct the misbehavior. Other times, the intervention was not obvious to an outside observer. During the stimulated recall, the teacher showed me one sequence when she had just pointed a finger at a misbehaving child without saying anything, and the child stopped the misbehavior.

The following Table 33 summarizes the elements of the teacher's planning decisions concerning behavior management and her interactive classroom management decisions.

Table 33

Summary of Behavior Management Decision Codes Identified by the Teacher

SOS Categories	Decision Categories and Codes	
	Decisions Before Instruction	**Decisions During Instruction**
Behavior	Prevention of problems Rewarding good behavior Solving problems	Attention to all students Deciding when to intervene

* Codes which include statements expressed with strong feelings.

Summary of Qualitative Analysis

The teacher stressed the importance of shared decision-making. She said that team work, preparation and organization of materials, and choosing appropriate math (and only math!) activities for class were important for her success as a teacher (May 13 interview). Once the teacher was engaged in active instruction, her emphasis shifted to using every available minute for math activities. (Classroom observations May 13, 14, 15, 17, 20, and 21). Though the teacher did not emphasize her monitoring and improvising during instruction, she spent an extraordinary amount of time paying attention to what students were doing, monitoring to see how successful they were, engaging them in discussions about their activities, recording their results, and checking to be sure that they were on task (Classroom observations May 13, 14, 15, 17, 20, and 21). The decisions made before instruction were different from decisions made during instruction, but the two categories were interconnected: planning decisions set the overall script for the instruction, and the decisions during instruction impacted future plans. Decisions in the three categories based on SOS *how* codes, (1) academic decisions about the content to be taught, (2) organizational decisions about people and materials, and (3) behavioral management decisions, were found to be frequently interconnected. Academic decisions affected behavioral decisions, as demonstrated by the teacher's choice of instructional sequences impacting the rapid and orderly movement of students between teacher-centered to student-centered activities. Organizational decisions affected both academic and behavioral decisions. For instance, the teacher emphasized the necessity for having all instructional materials prepared and readily available to maximize instructional time and prevent the loss of student attention.

Discussion of Research Question 1

How does a teacher integrate decisions made outside class into her classroom instruction?

Qualitative data provided evidence of four integrative decision processes having a significant impact on instruction. The processes varied in both the type of strategic planning needed for implementation and the teacher's attention needed for implementation during instruction. First, academic team planning and external curriculum standards were integrated into classroom instruction through some of the enacted instructional sequences. Second, the teacher’s identity as “The Math Teacher” provided a consistent rationale for all classroom activities. Third, the teacher’s use of routines was prevalent during academic instruction; organization of materials, students, and time; and managing student behavior. Fourth, the teacher prepared every detail of the physical environment she possibly could so that minimal time was needed for adjusting the physical environment during instruction (see Table 34).

Table 34
Evidence of Instructional Integration Processes from Qualitative Data

Decisions Before Instruction (SOS Categories)	Instructional Integration Processes
Academic Q Codes** Team planning* Standards and state tests Teacher as a person*	Academic (a) Plan, implement, and adjust instructional sequences (b) Fulfilling “The Math Teacher” identity and role (c) Use of routines to monitor for student progress
Organizing Q Codes** Materials* Students Time	Organizing (d) Preparation of the physical environment (very important, but requires little effort in class) (c) [repeat] Use of routines to distribute materials and move students
Behavior Q Codes** Prevention of problems Rewarding good behavior Solving problems	Behavior (c) [repeat] Use of routines to handle behavior

*Codes which include statements expressed with strong feelings.

**“Q” is qualitative analysis.

Preparation of the physical environment. The first integrative decision process involved the advance preparation of both teaching materials and the physical setup of the classroom. The teacher identified these as essential for effective instruction, although they required little or no attention during instruction. Teacher self-report information and classroom observations highlighted the considerable effort the teacher made before class to organize and prepare materials she identified as needed for effective instruction. She prepared the instructional materials and made them readily available to maximize instructional time and keep students' attention. The organization and preparation of the materials and classroom setup required advanced planning which occurred from minutes to months before classroom implementation. The teacher anticipated the need for materials, acquired the materials, organized and prepared the materials for efficient distribution, collection, and storage.

One example was the teacher's choice of manipulatives. The teacher selected and prepared manipulative materials for effective instruction with maximum efficiency and minimum expense. She knew where to buy inexpensive materials and how to make inexpensive manipulatives. She knew which materials were worth the cost in time and/or money to promote successful student outcomes. Furthermore, the teacher chose and implemented procedures to make the distribution and storage of materials time and space efficient, low cost, and easy to access. Some of the manipulatives had been acquired years before classroom implementation. The teacher did not necessarily anticipate her need for the materials years in advance, rather the long term use reflected a judgment of value of the items after classroom use, and retention of the materials for years.

The teacher was proactive during the advance preparation process. She actively sought information about the selection of math manipulatives. She was not directed by an outside authority to use certain manipulatives, rather she directed her own search for effective materials. Much of this knowledge and skill was acquired subsequent to college graduation and teacher certification. She read, took courses, went to workshops, and consulted with colleagues to hear new ideas about teaching math. She did not adopt everything she learned, rather she evaluated which information was useful and adopted appropriate ideas for her students.

The teacher also made decisions about materials for “unplanned” occurrences during class, such as students being placed in in-school-suspension (ISS), students needing makeup work, and students taking more or less time than the class norm to finish assignments. The teacher reported that she preferred to be ready for “unplanned” occurrences by preparing files of instructional materials ahead of the need or request. The teacher could predict that some students would finish their work more quickly than others, some students would be assigned to in-school suspension (ISS), and students would be sick and need to make up work; even though the teacher could not predict exactly which students and when the students would need the individualized assignments. It took a great deal of effort to prepare individual enrichment folders and ISS materials for all lessons, indicating the importance the teacher placed on having materials prepared ahead of time.

In addition to instructional materials, decisions about the physical placement of students supported the teacher’s pedagogy. Students were deliberately placed in areas of the classroom to facilitate the instructional process. The teacher organized desks in groups of five, spaced the groups, and angled the desks to create a mutual table-like work area for small group work. The five groups of five desks were located around the edge of the room with space for the teacher to walk around each group allowing access to every student in the room. The front chalkboard, overhead projector, and teacher's desk were adjacent to a clear area where students sat during direct instruction. The physical placement of students was planned as carefully as instructional content and pedagogy. The teacher intentionally arranged individual desks to make functional tables for group work and the desks were placed intentionally for teacher access during group work, while leaving space at the front of the room for direct instruction. The physical setup did not require any observable instructional time to alter due to the well-thought out planning and decision-making. The teacher occasionally moved students, but never the desks during the five observation days.

Instructional sequences. The teacher made decisions about instructional sequences before class that required in-class monitoring of individual and group progress. The teacher's instructional decisions about the scope, sequence, and pedagogy of the lesson were made before class and were deliberate. She monitored the students' achievement of short term goals and adjusted the lesson during the class as needed. The teacher demonstrably followed a predetermined mental plan, but could adjust it in the context of student needs.

In interviews, the teacher expressed a clear vision of the scope and sequence of the lessons, both during the classroom period and in the framework of longer time periods for development of mathematical knowledge and skills. The scope and sequence were planned for both the abilities of her students as well as content objectives. The teacher set an instructional pace to maintain the interest of students, presented concepts in achievable short duration activities, and followed her plan leading to extended conceptual development. The teacher planned and taught basic mathematical operations in the context of higher level thinking skills such as organizing data, finding patterns, predicting outcomes, and evaluating fairness of tests. The teacher chose activities that would interest students, reinforce knowledge and skills, and achieve learning objectives. Though the content of the probability lesson during the first two observation days introduced new concepts to the students, the teacher planned for the students to use previously acquired knowledge and skills in new ways. It was obvious that students could perform basic mathematical operations rapidly and accurately. They could arrange data in organized lists and matrices, and they freely entered into mathematical dialog discussing the patterns of data and fairness of outcomes. Monitoring the sequence and timing of instruction also demonstrated the teacher's ability to multitask as she simultaneously used her knowledge of students, mathematical content, and pedagogical content to implement effective lessons over limited discrete time sequences.

Instructional implementation of planned lessons was characterized by brief, frequent communication with individual students during teacher-centered instruction. During the days identified by the as "teaching" days, the teacher polled every student repeatedly in large group settings to collect student-generated data for consolidation and whole-group analysis. Most of the extended teacher-student conversations during each of the five observation days occurred during monitoring of group work. The teacher reported constant communication with students throughout the lesson to be important, which she demonstrated in the proportion of instructional time she spent monitoring and questioning students.

The teacher individualized instruction by means of monitoring individual students and by planning multiple paths to math achievement. The teacher used enrichment folders and impromptu math problem-solving to keep students engaged in learning math. The teacher was flexible about ways to learn math, and inflexible about including non math-related content in time allotted as math class. The teacher had explicit criteria that every math lesson had to meet, set before class, and used during class to decide the appropriateness of student activities.

The teacher made prior decisions to teach math in multiple modalities. Three modalities were observed and identified: (a) teaching for content outcomes, (b) guiding for enrichment experiences, and (c) formal student assessment. The teacher adjusted her teaching modality to her instructional objectives. Distinctly different types and rates of teacher behaviors were observed during the different instructional modes; but upon follow-up questioning about the difference between “teaching” and “guiding,” the teacher agreed that both could be planned according to math education standards, both required student achievement, and both involved a combination of direct instruction and monitoring. The teacher had difficulty pointing out specific differences to contrast the “teaching” and “guiding” modes of instruction, yet she was emphatic in her assertion the “teaching” was different from “guiding.”

Use of routines to solve recurrent logistical problems. The teacher used routines familiar to students to solve recurrent logistical problems of moving people and materials around the classroom during a lesson. The teacher's use of routines minimized "dead time" in multiple ways: advance preparation of materials, efficient distribution and collection procedures, expectations of students, her own clear idea of the scope and sequence of a lesson, and readjustment of a lesson to avoid lost time. The teacher did not explicitly plan these routines, yet they were part of her instructional repertoire before class and required some monitoring during classroom to implement.

Personal abilities, beliefs, and standards. The teacher identified herself as "the math teacher" and her observed behavior was consistent with her role as an instructional specialist and expert teacher. The teacher had highly developed intra-personal skills as evidenced by her proactive control of her own professional development. The teacher could diagnose herself, embark on professional development to improve her perceived deficiencies or to enrich her instruction, and adapt other educators' ideas to meet her own students' needs. The teacher used both formal and informal professional development experiences outside the classroom to enrich her instruction.

The teacher also showed high interpersonal skills as she maintained productive and effective collegial relationships that benefited all the grade level team members and their students. Her team divided the content-area teaching assignments according to expertise and preference of each teacher, switching classes as needed to achieve each teacher's learning goals. The teachers also used a behavior management plan for students that included input from each teacher. The teachers divided work, shared materials, and created team resources. The out-of-class teamwork impacted the teacher's instructional success.

The teacher valued both the students and their math achievement, which impacted her classroom instruction. The teacher interacted with students in the process of learning in multiple ways: watching students work, talking to students about their work, listening to students talk about their work, lightly touching students in acknowledgement, and participating in math activities with the students. The teacher communicated, "I care about what you are doing" in multiple ways. Furthermore, the teacher demonstrated consistent respect for the process of learning for all students in the class. Slower students were given enough time to finish their work, while students who finished work quickly had other activities and their enrichment folders to extend their learning of mathematics beyond the basic lesson.

The teacher characterized herself as the "math teacher," so that every activity, even "fun" activities, had to be math related. The teacher took pride in her math expertise, pedagogical content knowledge, and the math achievement of her students. Her belief that class time was a valuable resource not to be wasted was demonstrated by the teacher's use of every minute available for math instruction. On one observation day immediately before class dismissal, the teacher reminded the students to keep working because there were still two minutes of class left. The teacher chose instructional tasks before class, with the result that classroom time was largely devoted to implementing instructional sequences and interacting with students.

In summary, four major integration processes were found for using pre-instruction decisions during classroom instruction: (a) planning, implementing, and adjusting instructional sequences, (b) fulfilling “The Math Teacher” role, (c) use of routines to monitor students and solve logistical problems, and (d) preparing the physical environment to support instruction. Only one of the processes required focused attention—implementing and adjusting planned instructional sequences. The other three processes were a belief system (“The Math Teacher” role) which provided a standard for judging what could and could not be included in class, a set of routines to manage students and materials, and maintenance of a physical environment designed to support the other processes.

Discussion of Research Question 2

How does a teacher make improvisational decisions during class?

The second research question was answered by analysis of two forms of data recorded during instruction, i.e., observational data (SOS codes and field notes) and physiological response data. Improvisational decisions consisted of (a) diagnosis of appropriate situations for established routines, and (b) diagnosis of unusual situations requiring appropriate responses.

Proactive and reactive improvisational decisions. The teacher was both proactive and reactive in her improvisational decisions. Some decisions were routine and foreseen, such as the use of enrichment folders and asking students who did not understand directions to remain at front of class for another explanation. Other decisions were reactive, such as deciding that a small group of students who finished an activity 30 minutes before the end of class should go onto the next day's lesson, rather than start work in their enrichment folders. The teacher was proactive for improvisational decisions that occurred frequently, and was reactive for single incident situations during the five observation days.

Attention and perception. Improvisational decisions required the teacher to perceive that action was needed, then decide on an appropriate action. The perception component was not a passive process. The teacher actively attended to students and sought information from students in order to assess their success completing their tasks. She also actively scanned the room and listened for off-task behavior while simultaneously checking student work.

Academic intervention. The teacher redirected and guided students to keep them achieving learning objectives. The teacher intervened in students' work when (a) they weren't following directions, (b) they had problems understanding what they were supposed to do, or (c) they finished quickly. The teacher intervened when students were not achieving instructional goals or when they achieved the goals much quicker than other students. She seemed to have an internal criterion of an acceptable learning rate and intervened when students were not learning at that rate. Academic improvisational decisions appeared to require the teacher monitoring students one-on-one. If several students needed redirection, then the teacher apparently decided that the entire class would need redirection. She said "freeze and listen" to get the attention of the entire class and give them clarification.

Behavioral intervention. The teacher redirected students when their behavior was out of limits. The teacher intervened in student behavior for safety, bothering fellow students, off- task behavior, or not moving from one activity to another in an appropriate manner (time-wasting). The teacher had clear expectations of correct behavior, intervening when her expectations were not met, again demonstrating her "withitness." Her behavioral corrections were made while walking by students and across the room from students. Apparently she did not have to be close to a student to recognize off-task behavior and correct it.

In summary, some of this teacher's improvisational decisions were reactive to environmental input—mainly student feedback information, and some of the teacher's improvisational decisions were proactive, apparently based on experience.

Discussion of Research Question 3

Do improvisational decisions elicit a physiological response?

The third research question was answered by relating observational data to physiological data during instruction.

Daily mean physiological response rates and instruction. There was no distinguishable relationship between the mean physiological response and the daily mean decision-action rates or the teaching modality in day-by-day comparisons. The teacher generated different mean physiological response rates for each class period unrelated to the overall type of instruction, even though the decision-action rates were different on the two teaching days compared to the three guiding days.

Two intriguing sets of physiological response rate data warrant further investigation. One data set was the teacher's physiological response rate on May 20 which reached maximal levels, occurring on a Monday when she had insufficient sleep due to staying up with a sick pet. While the focus of this study was instructional decisions, it is possible that physical and emotional stress from those non-instructional causes impacted her instruction. The other data set was obtained while the teacher watched a video of her teaching. The "stimulated recall" interview was not representative of either the physical or cognitive processes the teacher demonstrated while teaching. The mean physiological response rate of the teacher through five days of instruction was 88 peaks per minute, with a range of 74-110 peaks per minute. In contrast was the teacher's mean physiological response rate during the stimulated recall interview was 68 peaks per minute, with a range of 50-78 peaks per minute. The highest mean physiological response rate during the interview, 78 peaks per minute, barely exceeded the minimum rate during instruction, which was 74 peaks per minute. The teacher was seated during the interview in contrast to standing during instruction. Furthermore, the teacher was responding to the interviewer and describing her actions in a videotape recording in contrast to leading a classroom of about twenty-five children. While interviews and self-report data continue to be a primary information source in much education research, other data (such as physiological data) could be enlightening to compare the tacit knowledge processes that contribute to teachers' active instructional behaviors in contrast to reports by teachers describing their instructional behavior in interviews.

Time dependent relationships between physiological response rates and decision-action rates. There was a tendency for the physiological response rate to rise 3.5 minutes before a decision, continuing until 5.0 minutes after the decision on the May 15 “teaching” day. The other teaching day, May 14, also showed a positive, though not significant, relationship between physiological response rate and decision-action rate. Both of these days showed stronger autocorrelation relationships than the “guiding” days, which indicates that on those two days, the physiological response rates tended to be a function of the preceding rates in the time series. The extended rise in physiological response rates that persisted after a fall in decision-action rate suggests that the psychophysiological mechanisms associated with teacher-initiated changes in behavior both precede and follow observable changes in behavior. Although the term “physiological response rate” has been used in this study, causality is not implied between the two variables. Rather, these results suggest the cognitive processes in the teacher’s central nervous system associated with high rates of teacher-initiated changes in behavior also trigger a autonomic nervous system (ANS) response in the teacher. It is not possible to characterize the emotional component of the ANS response. The teacher did not display or express strong emotion during the mutual rises in both decision-action rate and physiological response rates. A sympathetic nervous system response (part of the ANS) has been reported to be associated with either strong emotion or increased attention (Kalat, 1995).

The most striking relationship between physiological response rate and decision-action rate was found in the May 15 class data set using a t-test to compare the equality of means of the data recorded while the teacher used two different instructional strategies, i.e., direct instruction and test monitoring. On May 15, her physiological response rate was a mean of 88.15 peaks per minute during direct instruction with a mean of 8.37 teacher-initiated actions generated per 30 second interval. There were no "AX" SOS codes indicating teacher movement during the 27 intervals of direct instruction. During test monitoring, the reverse pattern appeared with the physiological response rate decreasing as the teachers "AX" SOS codes were predominant in 28 of the 32 intervals coded. The teacher's physiological response rate decreased to 79.56 peaks per minute and the mean number of teacher-initiated actions generated per 30 second interval decreased to 0.97 while the teacher walked around the room observing students writing their essays. The decrease in both physiological response rate and decision-action rate with the switch from direct instruction to test monitoring were significant at the 0.01 level (2-tailed).

There was no significant or consistent relationship between the physiological response and decision-action rate for the three "guiding" days. The observable behaviors were significantly different for those days, yet there was no relationship found between the change in decision-action rate and physiological response rate. The three "guiding" days were at the end of the school, which is a stressful time for teachers. The teacher initiated more behavioral corrections on those three days with 8% of her decision-actions being "9B" SOS codes, however, her physiological response rates were not proportionately high.

In summary, context was found to be important for the bivariate relationship. The teacher’s instructional intent and actions apparently were the important attributes impacting the interaction between decision-action rate and physiological response rate.

Summary of Results

Nonexperimental quantitative data sources were combined with qualitative data collected from teacher interviews and classroom observations to describe elements of an expert teacher’s decision-making process. Instructional interaction variables using an adapted Stallings Observation System were recorded simultaneously with skin voltage measurements for use in multiple time series analyses to describe an expert teacher’s interactive decision-making process. The mean and standard deviation of decision-action rates for teacher-categorized “teaching days” were higher than the rates on “guiding” days. At peak decision-action rates, the teacher made one teacher-initiated change in behavior per second. Bivariate analysis of decision-action rates and physiological response rates for one “teaching” day showed a significant relationship from -7 lags to +10 lags. T-tests for equality of means revealed significant differences at the 0.01 level (2-tailed) for both physiological response rates and decision-action rates recorded during direct instruction versus test monitoring, with lower levels for test monitoring.

Both qualitative and quantitative data sources were used to describe the teacher's instructional decisions, and were found to be complementary (see Table 35). For example, qualitative analysis identified four decision-element codes the teacher discussed with expressed emotion and not one of them "behavior" decisions category. The lack of expressed emotion in "behavior decisions during instruction" cell of the qualitative analysis matched the minimal "9" SOS codes for student correction during interactive instruction and a lack of evidence of a relationship between the teacher's physiological response rates and corrective behaviors. Thus both the qualitative and quantitative evidence indicates that this teacher is not stressed by classroom management decisions. The combination of SOS codes and qualitative analysis codes provided a way to observe how interactive decisions are related to the teacher's self-report information:

Table 35

Integration of Qualitative Decision Codes with Quantitative Measurements

	Decision Categories with Q** Codes and SOS Codes	
SOS Categories	**Decisions Before Instruction**	**Decisions During Instruction**
Academic	Q Codes Team planning* Standards and state tests Personal beliefs and objectives*	Q Codes Monitoring and improvisation Implementation of plans Being fair SOS Codes 28-38% “12” Monitoring (both “A” and “B”) 11-25% “1Q” Direct Question 9-19% “1” Command (both “A” and “O”) 6-16% “4” Instruct/Lecture 5-23% “7” Praise/Acknowledgment
Organizing	Q Codes Materials* Students Time	Q Codes Materials Students Time* SOS Codes 9-19% “1” Command (both “A” and “O”)
Behavior	Q Codes Prevention of problems Rewarding good behavior Solving problems	Q Codes Attention to all students Deciding when to intervene SOS Codes 28-38% “12” Monitoring (both “A” and “B”) 2-8% “9” Correction (0 “N” negative codes)

*Codes which include statements expressed with strong feelings.

**“Q” is qualitative analysis.

The teacher’s self-report information provided a description of instructional distinctions, not always apparent to the observer, combined with a disregard for some of the spectacular feats she accomplished during instruction. For instance, the teacher appeared to be teaching all five days of observation, but her identification of the instructional days as either “teaching days” or “guiding” days in an interview was important for the interpretation of the observed differences in decision-action rates found in the classroom observations. The decision-action rate patterns on time series graphs were also visibly different for the “teaching” versus “guiding” days. At peak decision-action rates on one “teaching” day, the teacher made 30 teacher-initiated changes in behavior in a single 30-second interval, while the peak the other “teaching” day was 28 changes in 30 seconds. In contrast, the peak decision-action rates on “non-teaching” days didn’t exceed 10 changes per 30-second interval. The teacher has repeatedly said that she was not aware of her rapid questioning of students when she was asked about her questioning technique after the classroom observations (June 21 stimulated recall interview).

No overall trends were found in the decision-action rate data during each individual instructional period, and minimal trends in the physiological response rate data. Calculation of Pearson’s correlation coefficient revealed a weak positive correlation between decision-action rate and physiological response rate at zero lead/lag on one of the “teaching” days, May 15. Bivariate analysis of the decision-action rate and physiological response rates for May 15 showed a significant relationship between –7 lags (up to 3.5 minutes before a teacher initiated SOS code change) to +10 lags (up to 5 minutes after a teacher initiated SOS code change), which indicated that the physiological response rate rose before and after a teacher-initiated change in instruction on that “teaching” day. This is a relationship that would have been missed if the data were not collected simultaneously in a timed schedule appropriate for bivariate time series analysis.

Collection of student data was not a focus of this study, yet student outcomes were found to drive the decision-making processes for this teacher. On May 15, the teacher asked her students to answer the question “What is probability?” The following was written by one of the regular third grade students and read by the teacher in the interview following instruction May 15:

> Probability is chance, at least most of it is, the other part of probability is math. The math section of probability is fractions and percentages like ¾ of cookies in a jar are chocolate chip and 25% is [sic] oatmeal raisin. See? Fractions are percentages. To find out if the game you played is fair and to see how many possible outcomes there are, you could use a matrix or an organized list. A matrix is good for when you don’t have many numbers, unlike an organized list which is good for a larger group of numbers. Some examples are when we rolled one die and someone was odd and someone was even. There were three odd and three even numbers, so it was a fair game, but when we did two die [sic] and multiplied the two numbers each roll, we found it was not fair because in all there were 36 outcomes or combinations and 27 were even and 9 were odd. How unfair! (May 15 interview)

On the day this student wrote his essay, May15, the teacher was generating an average of 4.07 ± 4.27 decision-actions per 30-second interval (about 8 decision-actions per minute); her mean physiological response rate was 82.82 ± 5.36 skin voltage peaks per minute; over 75% of her decision-actions were direct questioning, encouraging, and monitoring students; and her heart rate and respiration tended to rise three minutes before a rise in her teacher-initiated actions, remaining elevated about five minutes after the rise in decision-actions. However, this data did not adequately describe the strategy-specific instruction of the teacher. When she was engaged in direct instruction, her physiological response rate was 88.15 peaks/minute and her decision-action rate was 8.37 teacher-initiated decision-actions per 30-second interval. When she assigned the essay and began walking around the classroom monitoring her students, her physiological response rate decreased to 79.56 peaks/minute and her decision-action rate decreased to 0.97 teacher-initiated decision-actions per 30-second interval. The measured change provided an indication which teaching strategy required more effort and engagement and which did not.

At the cognitive level of enacting an extended sequence of direct instruction, the teacher was using a pre-planned instructional script, active behavioral and academic monitoring, and direct questioning allied with encouragement and support to teach her students. Her rapid decision-actions integrated a number of feedback systems including her monitoring routines and strategic decisions to question students, culminating in a feedback activity used for assessment when she asked, “What is probability?” (May 15 classroom observation). In contrast, the subsequent test monitoring strategy consisted of walking by groups of students, observing their work, and infrequently making general comments to remind the class what they had learned about writing a good essay. The contrast emerged at every level of data collection: qualitative information, SOS code rates, and skin voltage peaks per minute.

CHAPTER V

SUMMARY, CONCLUSIONS, AND DISCUSSIONS

Teachers' decision-making is the heart of expert instruction. The teachers' academic preparation, personal beliefs, practical experience, and information processing skills impact the moment when a teacher decides to initiate an action during instruction. That instructional decision then becomes part of the teacher's experience and has an impact on future decisions—and it is the teacher's brain where all the perceiving-thinking-deciding-experiencing is integrated into memory. However, explanations for the development and expression of expert decision-making commonly disregard the underlying physiological processes in the brain contributing to expert cognition. These underlying physiological processes of teachers' thinking, based on organic structures, dependent on metabolic systems, and developing in response to stimulation, have been found useful to explain cognition in the fields of psychology and medicine.

Basic epistemological differences in education research have led to a separation of research approaches while the complexity of teachers' decision-making processes demands a holistic approach to understand the connected, multi-layered, sometimes dynamic relationship of decision-making. Salomon (1991) wrote, "There is a distinction to be made that transcends the one between the quantitative and qualitative research paradigms. It is a distinction between the kind of research that suits best the study of causal relations among selected variables and the study of complex learning environments undergoing change" (p. 10). The fluid, dynamic nature of teachers' decision-making requires data collection methods capable of documenting the frequency of these decision processes for appropriate time periods. One promising analytic technique is the dynamic systems approach to the study of teachers' thinking. "Systems theory takes a very different stance about mind, emotion and action. First of all, it recognizes mind and behavior as subsystems operating within larger systems, usually viewed at difference levels of analysis…" (Lazarus, 1999, p. 22). Each system contains many variables with complex relationships. "Causal actions are reciprocal, and the same variable sometimes acts as an independent variable or cause, at other times as a mediator, and at still other times as a dependent variable or effect, though never at the same instant" (Lazarus, 1999, p. 22). At best, a controlled experiment will identify the relationship between variables in a limited part of a system for a limited time. At worst, a controlled experiment will lead to abandonment of potential fields of study when systems do not yield results that can be described as simple cause and effect explanations. In contrast, qualitative research methodologies dependent on participant self-reports are also limited. Not all the subsystems determining the teachers' decision-making process are accessible to the conscious mind. The tacit knowledge of a teacher is important for expert decision-making, though not necessarily part of the reflective conscious mind readily accessible during interviews.

Answers to Research Questions and Discussion

This exploratory case study of an expert elementary mathematics teacher's instructional decisions used mixed methods to identify and compare relationships between elements in her decision-making processes. Information sources included self-report data collected during teacher interviews, classroom observations, and descriptions of classroom instruction with simultaneous measurement of the teacher's physiological activity. The questions guiding this study were:

1. How does a teacher integrate decisions made outside class into her classroom instruction?
2. How does a teacher make improvisational decisions during class?
3. Do improvisational decisions elicit a physiological response?

The answers to these guiding questions will be discussed separately below, followed by a discussion of the findings, comparison of the findings with other research on decision-making, discussion of the practical implications of the study, and suggestions for future research on instructional decision-making.

Research question 1. How does a teacher integrate decisions made outside class into her classroom instruction?

Qualitative data sources provided evidence of four ways that decisions the teacher made outside class were integrated into instruction:

- Instructional sequences were planned outside the class as thoughts and written plans, then implemented as teacher behaviors during the class.
- The teacher's "Math Teacher" identity was developed prior to class, then used to evaluate the appropriateness of learning activities in class.
- Previously acquired routines were predominately used to manage students and materials.

- The physical environment was arranged to support efficient movement of students and materials, requiring almost no adjustments during instruction.

Thus the salient integration processes included implementation of plans, a belief system, a set of routines, and arrangement of the physical environment to support instruction. The first process, the implementation of plans, required most of the teacher's attention. The teacher was constantly judging the success of the students and choosing appropriate instructional strategies for individuals and groups of students. The other three processes were critically important to instruction, but required little attention in class.

Research question 2. How does a teacher make improvisational decisions during class?

The second research question was answered by analysis of observational data (SOS codes and field notes) recorded during instruction. Improvisational decisions were both proactive and reactive.

- Reactive decisions were made in response to environmental cues.
- Proactive decisions were apparently enacted on the basis of the teacher's experience and plans.

There were a wide variety of visual and auditory cues in the classroom. The teacher was not mindlessly reacting to physical stimuli, rather she actively processed information to decide which student behaviors required intervention. Furthermore, the teacher made proactive decisions about when and how to enact her instructional plans.

Research question 3. Do improvisational decisions elicit a physiological response?

The third research question was answered by relating observational data to physiological data recorded during instruction. Instructional context was found to be important for the relationship between improvisational decisions and the teacher's physiological response. The teacher's instructional intent and teaching strategy apparently were the important attributes determining the interaction between decision-action rate and physiological response rate.

- On May 15, both the teacher's physiological response rate and decision-action rate recorded during direct instruction showed a significant decrease (0.01 level of significance) when the teacher switched to test monitoring.
- A weak negative relationship was found between decision-action rates and physiological response rates on for the May 20 guiding day.
- Four out of five days showed a minimal, but significant negative trend in physiological response rates from the beginning to the end of the class period without a corresponding decrease in decision-action rate.

Both pleasant and unpleasant events are associated with sympathetic nervous system arousal and increase in heart rate, so assumptions about the emotional experience of the teacher for an increase in heart rate cannot be made (Kalat, 1995). Table 36 summarizes the research questions and major research findings.

Table 36
Relationship of the Three Research Questions to Results

<table>
<tr><td colspan="2">Decisions Made Outside Class
Decisions Made Outside Class Integrated Into Classroom Instruction (Question 1)
• Planning instructional sequences
• Evaluating events using Math teacher identity
• Acquiring routines for classroom management
• Arranging the physical environment to support instruction</td></tr>
<tr><td colspan="2">Improvisational Decisions Made During Class
Improvisational Decision-Making (Question 2)</td></tr>
<tr><td>Proactive Instructional Intent: Teach

Major Instructional Implementation Strategies (includes both proactive and reactive decision-actions):
1. Direct Instruction
2. Group Work
3. Test Monitoring (May 15)

Decision-Action Rates:
• Guiding Day<Teaching Day
• Test Monitoring< direct Instruction (May 15)*

Physiological Response Rate Patterns:
• Time ↑, Arousal ↓ (May 15)*
• Test Monitoring< direct Instruction (May 15)*

Improvisational Decision-Making and Physiological Arousal (Question 3)
• Decision-action Rate (Strategy Specific)↓, Physiological Arousal ↓ (May 15)*</td><td>Proactive Instructional Intent: Guide

Major Instructional Implementation Strategies (includes both proactive and reactive decision-actions):
1. Direct Instruction
2. Group Work

Decision-Action Rates:
• Guiding Day<Teaching Day

Physiological Response Rate Pattern:
• Time ↑, Physiological Arousal ↓ (May 17, 20 & 21)*</td></tr>
</table>

* significant at 0.01 level (2-tailed)

Connections to Other Research Findings

Comparison to research on instructional decision-making. The design of this study differed from other instructional decision-making research described in this section in the number of subjects, periods of observation, and operational definition of a decision used in the research. Past research on instructional decision-making studied more teachers for shorter periods of time, collecting data during 15-minute to one-hour periods (Clark & Peterson, 1986). The teacher in this study was interviewed, observed, and measured for five one-hour class periods, with a follow-up interview. Large differences in decision-action rates were found throughout each class period and from day-to-day of instruction. A sample time of 15 minutes to one hour would not have adequately characterized the instructional decision-making of this teacher, since her decision-making was not a homogeneous process in rate or type during this study.

Furthermore, in this case study an improvisational decision was defined as a teacher-initiated change in SOS code. Clark and Peterson (1986) reported that despite diverse methodologies, the investigators in past research had “converged on a definition of an interactive decision as a deliberate choice to implement a specific action” (p.274). Past research on teachers' decision-making showed that their decisions involved unconscious processing of experiences preceding and allied with conscious reasoning strategies (Alexander & Murphy, 1998; Calderhead, 1996; Fenstermacher & Richardson, 1993; Fenstermacher and Soltis, 1998; Korthagen & Lagenwerf, 1996; Lederman & Gess-Newsome, 1991; Tobin & Jakubowski, 1992). The transformation from deliberate, conscious decisions to automaticity of action is a characteristic of successful teachers’ interactive instruction. Sternberg and Horvath (1995) described a basic difference between expert and novice teachers in their ability to solve problems efficiently, “That is, experts can do more in less time (or with less apparent effort) than can novices” (p. 12). While it may be argued that low-cognitive demand behaviors such as polling students for their answers should not be considered “real” decisions, these behaviors may have a lasting impact on students who repeatedly make authentic contributions to the knowledge of the entire class. It is a challenge for any teacher with a large class to ask for and receive individual feedback from every student in the room several times during a one-hour class period. The teacher in this study was not born knowing how to efficiently call on all the students in her class, rather at some time in her professional development she decided that this technique was desirable, she implemented the technique, and has used the method often enough that she automatically uses the method in appropriate situations.

Teachers simultaneously address multiple objectives from classroom management to conceptual development in their plans while using information about students, academic content, and available resources to create a practical plan designed to work in a real classroom. Expert teachers are creative and flexible in their plans, with alternate ways of looking at problems and construction of adaptable plans suitable for different contexts (Calderhead, 1996). According to Borko and Livingston (1989), the expert teacher is characterized by the “ability to select particular strategies, routines, and information”…”during actual teaching and learning interactions, based on specific classroom occurrences” (p. 485). A teacher in a classroom simultaneously enacts a planned instructional script largely from memory, evaluates the success of the script, and decides which changes to make in future scripts. The cognitive and pedagogical strategies found to be used by this teacher were similar to those found in studies of other expert teachers. The teacher in this study demonstrated deep understanding of her subject area and the ability to implement effective pedagogical strategies for her students. She demonstrated day-to-day and class-long focused attention on the learning processes of her students.

In past decision-making research, teachers' decision rates (defined differently) were found to occur at a rate of one decision every two minutes (Clark & Peterson, 1986). The decision-action rates of the teacher in this study were far higher and had distinctive frequency patterns according to type of instruction. On one "teaching" day the teacher made an average of 5.76 decision-actions per 30-second interval or twenty-three decision-actions every two minutes compared to the published rates of one decision every two minutes. The difference in rates may have been due in part to the extraordinary intensity of this teacher's instruction on that day, the operational definition of a decision-action in this study, or may be a result of measuring observable instructional behavior rather than asking teachers to report their thoughts. The definition of an interactive decision in this study didn't require teacher self-report information in contrast to the summary of research on interactive decisions by Clark and Peterson (1986). Using observable teacher-initiated change as an operational definition of a decision-action in this study made it possible to quantify the high frequency of these actions during both routine and non routine instruction without relying on the teacher to report all of his or her own actions.

Comparison to a time series study of teaching effectiveness. There is at least one study using a time series design to assess teaching effectiveness. Lin and Lawrenz (1999) used repeated multiple choice test performance of chemistry students to assess the teaching effectiveness of three teachers. The students answered one question at a time, fourteen times in a one-month period. The researchers contended that student achievement on the fourteen multiple choice items was a reliable measure of the teacher's effectiveness. Unlike this case study, Lin and Lawrenz (1999) did not perform a time series analysis based on direct measurement of the participating teachers' instruction.

Discussion of data collection issues. Past research studies have used both qualitative and quantitative methodologies to study teacher decision-making, but did not use simultaneous collection of data from multiple sources. The design of this study was described by Creswell (1994) as a "mixed-methodology design" approach (pp. 177-178). The qualitative and quantitative paradigms were mixed during every phase of this study, including the literature review, data collection, and data analysis. The interviews were conducted, coded, and analyzed using qualitative methodology, and heart rate was also recorded during one of the interviews. Both qualitative and quantitative data was also collected during the classroom observations. SOS coding of instruction and physiological recordings of the teacher's physiological responses were simultaneously collected with observation notes in order to understand the teacher's actions.

Connections between the qualitative and quantitative methodologies were facilitated by using predetermined qualitative categories which also represented major SOS categories, one of the quantitative measurement systems (Creswell, 1994). The mixed methodology was judged to be essential to this study. The hierarchy of consciousness in decision-making, from the automaticity of instructional habits to the deliberate consideration of multiple criteria in lesson planning, required methods for full spectrum data collection and analysis. To rephrase an old adage, "Know the teacher by both her deeds and her words." The SOS codes provided a way to know the teacher's deeds, or actions, and the interviews provided a way for the teacher's to explain her decisions in her own words.

During the data analysis phase of this research, the qualitative and quantitative methodologies were used in a repeated step-wise process. The thousands of frames of physiological recordings and SOS data took extended amounts of time to partition into appropriate time intervals, calculate time interval rates, and statistically describe the rates. Understanding the teacher's decision-making process was secondary to processing massive amounts of quantitative data; but after the decision and physiological response rates were calculated, it was the qualitative information that made it possible to interpret the quantitative data. Some of the teacher's comments that did not seem significant when the interviews were first recorded became important for understanding the quantitative measurements. For instance, the teacher's comments about "teaching" and "guiding" days of instruction came at the end of the follow-up interview, almost as an afterthought. To the observer, the teacher was apparently intensively teaching all five days of classroom data collection; but to the teacher, the last three days of instruction were distinctly different from the first two days. The SOS decision-action rate data supported differences between “teaching” and “guiding” instructional modes that were understood by the teacher, though initially missed by the observer.

Comparative research designs, including experimental and quasi-experimental designs, do not inherently contain the type of longitudinal data collection needed to trace complex processes over time. Time series studies may also be inadequate for characterizing a dynamic system, if the data collection is limited in scope or inappropriate. Selection of significant variables of instruction and appropriate time intervals for collection of data will be a necessary first step in modeling a dynamic system of instruction. The research presented here is part of that exploratory first step, to identify and measure changes in instructional variables at regular time intervals. Dynamic systems identified in other fields of study, such as biology, have been found to be more than the sum of their parts. Timed simultaneous collection of data to characterize instructional decisions will be necessary to create dynamic models of instruction.

Physiology and teaching performance. The teacher’s physiological response during some types of instruction and not others suggests implications for application of the Yerkes-Dodson Law (1908) of the relationship between stress and performance in the context of instructional decisions. The Yerkes-Dodson Law is an inverted U-shaped curve for the performance of an individual from low to high stress conditions (see Figure 25).

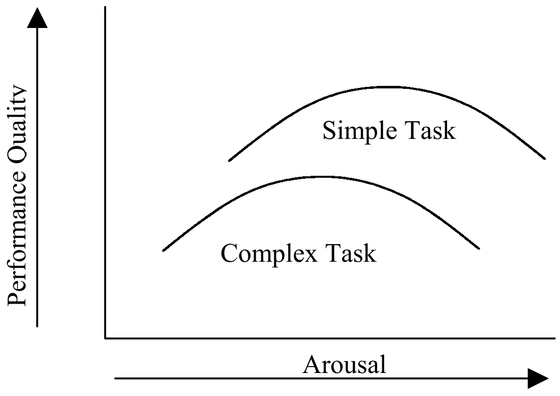


Figure 25. **Yerkes-Dodson Law (adapted from Kantowitz & Sorkin, 1983, p. 606).**

Task performance is poorest at both the lowest and highest arousal conditions, while maximum performance occurs under medium arousal conditions. A little anxiety helps performance, while apathy and panic do not. The elevated physiological response rate evidence indicated a sustained ANS arousal during intense instruction characterized by high rates of teacher-student interactions during the May 15 direct instruction strategy compared to the test monitoring strategy that day. Both pleasant and unpleasant events are associated with ANS arousal, so assumptions of the emotional context for the sympathetic arousal cannot be made here (Kalat, 1995). However, it is tempting to propose an explanation of the ANS involvement as a physiological mechanism that comes into play when the teacher needs it to achieve an acceptable level of performance quality.

An information processing model (Shavelson & Stern, 1981) was used to plan this study because of the obvious applications of such a model for describing the sequence of events and extensive use of routines in the teacher's improvisational decision-making. The speed and effectiveness of her responses to behavioral, organizational, and academic problems indicated an extraordinary repertoire of instructional "sub-routines" that did not require extended deliberation, rather were activated in appropriate situations. There are places in the Shavelson and Stern (1981) model that require focused attention on the part of the teacher, including the "cue observation" when the teacher is actively or passively observing cues exhibited by students. After the teacher observes the cue, she must make a series of judgments about timing and appropriate action. This is the point where Damasio's Somatic Marker Hypothesis may explain the efficiency and effectiveness of an expert teacher's decision-making process (Damasio, 1999). Studies of brain function during decision-making have shown that possible outcomes are connected to emotional and visceral cues based on past experience (Damasio, 1999). Before a decision becomes a conscious choice, the brain has already evaluated and prioritized outcomes to locate choices that "feel" good (Damasio, 1999). Healthy brains suppress dangerous and ridiculous choices while favoring actions previously associated with good outcomes to emerge in the teacher's consciousness for consideration in her decision-making process. The experienced, expert teacher has a real advantage at the steps in the Shavelson and Stern (1981) model where the questions "Is immediate action necessary?" and "Is a routine available?" must be answered to enact a routine. She has the extensive subconscious memory of past events associated with past emotional and physiological cues to select the best choices for action. In one interview, the teacher said that there had been no "surprises" when she taught the lesson, even though she had never taught that exact lesson before. This was a teacher who was so familiar with the system of elementary mathematics instruction, that even though the particulars of content questions and classroom management changed, the instructional events were well within her personal parameters of what to expect teaching a lesson.

One interesting outcome of this study was the lack of a significant difference between the physiological response rates and decision-action rates for direct instruction versus group work. There is no evidence that the teacher was not as aroused or “with-it” monitoring group work as she was directing instruction at the front of the class. Although the two instructional strategies were different, the teacher was apparently as engaged teaching individuals and small groups as she was teaching the whole class. The physiological response rates provided a non-inferential data source to support this view of an expert teacher constantly interacting and paying attention to her students whatever the physical grouping.

Implications for Practice

This study supports the model for teacher development described in the NCTM (1991) standards for professional development which included these suggestions:

- accept the expertise of successful teachers and learn from them;
- help teachers develop good habits through an iterative process of professional development; and

- help teachers diagnose problems and choose solutions in order to apply effort where it is needed, find the most efficient ways to solve recurrent problems and jobs.

The sharing of expertise can be a challenge when much of the expertise is in the form of tacit knowledge. Accepting and learning from expert teachers should encompass acceptance of all the levels of their expertise, from routine habits to reflective strategies. Clark and Peterson (1986) suggested that “perhaps we should focus our experimental research not on training teachers in interactive decision making but rather on training teachers to perceive, analyze, and transform their perceptions of the classroom in ways similar to those used by effective teachers” (p. 281). It is assumed in this research that those perceiving, analyzing, and transforming functions are the processes that contribute to interactive decisions. The expert in this study performed those processes extremely rapidly, and she apparently learned those skills while teaching in the past. Novice teachers could benefit from the development of perceptual skills, focused attention techniques, and cognitive strategies for simplifying interactive instruction *before* becoming responsible for the education of a class of students. Veteran teachers could also benefit from analysis of their decision-making system. Systemic analysis of the instructional components of teachers seeking to improve their teaching could help the teachers identify the factors that limit the efficacy of their teaching systems.

Critical Discussion of this Study

A single case study is limited by its lack of generalizability. The properties and mechanisms found in this study might apply to other teachers and classrooms, or they may be specific to a single situation. The types and methods of data collection limited the information that was collected. Decisions had to be observed, recorded, or reported for inclusion in the data. Because of the operational definition of a decision-action as a change in teacher initiated SOS codes, instructional decisions to persist in a behavior were not recorded as decisions. In addition, the authenticity of the study was limited by the effect of the researcher-observer and recording equipment on the natural behavior of the classroom participants. One day, the teacher spoke to the observer for several minutes about lesson planning during the class period, and the students occasionally made comments about having a video camera in the classroom.

Sources of error. Sources of error in classroom observations may include errors of observers who tend to rate inaccurately, primacy and recency effects, logical errors, failure to acknowledge the effect of an observer, unwarranted generalizations, unrepresentative sampling, failure to account for the effect of the observation context, poorly designed observation systems, lack of appreciation for the speed of events, lack of consideration of the simultaneous nature of an event, and failure to correct for observer drift in coding technique (Evertson & Green,1986).

There was only one researcher collecting data and observing the classes, so errors of the researcher could affect the reliability and validity of the data. In this study, observer consistency measurements indicated the repeatability of the observer's coding technique. The percent agreement for the total number of decision-actions coded during the data collection compared to samples recorded eighteen months after the classroom observations and video-editing was 96.6%. A Pearson *r* correlation was computed for 22 post observation sample intervals compared to original recordings. The correlation coefficient was 0.857, which is significant at the 0.01 level (2-tailed). All the post-observation percentages of SOS code types fell within the range of the original observations, except for the 9B correction code which was 1% over the original range. Deviations from the original recordings indicate that the observer is a source of error.

The speed of events during some instructional intervals was greater than the coding speed of the observer. Videotapes of instruction were essential for editing those high frequency intervals, determining the timing of the decision-actions, and verifying the instructional sequences. However, videotape is not the same as being present in a classroom as an observer. The need to use the videotape for editing the SOS data is another potential source of error in this study.

The speed and variety of this teacher's instructional behaviors showed the ability of this teacher to multitask during instruction, simultaneously manipulating multiple sources of knowledge and rules for application of that knowledge. When this teacher was helping and guiding one group of students, she monitored the rest of the class by watching and listening. Occasionally she appeared to hear or see some behavior that needed to be corrected. Then she would use a variety of techniques to redirect the behavior, from speaking to students to changing student groups. During the stimulated recall interview, the teacher noticed on the videotape that while she was teaching a lesson at the overhead projector, she corrected one student by silently pointing her finger at the student. The student ceased the misbehavior and that was the end of the incident. This incident was not recorded in the SOS codes because the researcher's attention was on the teacher's instruction, missing the brief correction of the student, which required minimal action by the teacher. Since the action was one decision-action on a day when 555 frames of SOS code were observed and recorded, the omission of the finger pointing incident did not have major impact on the data collected, but is certainly a limitation of this study which has been previously described in Chapter III. The teacher was able to both instruct and correct behavior at the same time, but the SOS codes are a linear series of codes, without the capacity to simultaneously code two (or more) behaviors. Though difficult to measure, the teacher's multitasking behavior has implications for assessment of instructional skills necessary for successful instruction.

One anticipated threat to validity was the possibility that teacher movement would cause an increase in the physiological response rate unrelated to instruction. However, on May 15, the teacher's physiological response rate decreased when the teacher began moving around the room as she monitored and guided the students writing their essays. In contrast, fatigue may well have a significant impact on the physiological response of the teacher, as suggested by the teacher's elevated physiological response rate throughout the class period on May 20 after little sleep the previous night. Though a causal relationship between fatigue and physiological response rate during instruction cannot be made with the data collected in this study, the possibility remains that out-of-classroom physical or emotional stress may significantly impact a teacher's performance in the classroom.

The 30-second interval used in this investigation is relatively long compared to other time series studies using physiological recordings. Research on the relationship between heart rate data and talking shows a peak in heart rate six seconds after the onset of speech, i.e., a six-second lag relationship (Warner, 1998). The thirty second interval used in this study cannot show lead or lag relationships which are less than 30 seconds, and therefore lead or lag relationships under thirty seconds appear to be zero lag or instantaneous, even though they are not. The weak positive correlation of decision-action rate with physiological response rate on May 15 and the weak negative correlation on May 20 suggest that high frequency interactions may be occurring in less than 30 seconds in some instructional situations.

It is possible for a single case study to be idiosyncratic. The instruction of a single teacher may be unique each day and when teaching different classes. The teacher in this study said in an interview that she never teaches the same lesson from year to year. The observed lessons were never taught exactly the same way before and they never will be taught that way again. On the other hand, recurring “habitudes” for maximizing student academic feedback and behavioral engagement in the lessons were consistently observed.

Recommended Changes in the Research Design

Follow-up studies would benefit from the following changes in the research design:

- The SOS codes should be recorded to measure the amount of time for a behavior, not just changes in codes.
- There is a missing level in the observation hierarchy between the SOS records and the teacher interviews. There should be a formal observation instrument to measure of the instructional strategies the teacher is using throughout the lesson, such as teacher-centered versus student-centered instruction, or open-ended inquiry versus lecture.
- Editing, describing, and timing instruction would benefit from clear videotapes of multiple views of the instruction.
- Physiological responses should be measured with medical instruments for different time periods including teaching and non-teaching activities.
- More teachers should be observed and measured for multiple days when they are engaging in different types of instruction.

Implications for Future Research

Interest continues in the research into teachers' decision-making processes because instructional decision-making is central to expert teaching. Porter (2002) wrote:

> Teachers, as they interact with students, are the ultimate arbiters of what is taught (and how). They make decisions about how much time to allocate to a particular school subject, what topics to cover, when and in what order, to what standards of achievement, and to which students. (p. 3)

The changing relationships within a system and sensitivity of the system to initial conditions could be a promising research approach for understanding how instruction really works. According to a common adage, it is important to get off on the right foot. Many novice teachers never survive in the educational system long enough to become expert teachers (Marshall & Marshall, 2003). It would be intriguing to measure the physiological responses of novice teachers as they meet and deal with the challenges of teaching for the first time, then compare their responses to the same situations at a later date when they have adapted to the education environment.

On May 15, decision-making behaviors were found to be related to physiological responses, raising more questions about how the teacher was different on that day from other days. May 15 was a day of instructional contrasts. The teacher taught intensively for the first part of that class as she finished the unit on probability, which involved intense instruction and rapid teacher-initiated changes in her interactions with students. After the intense instruction, the instructional pace slowed down as the teacher moved around the classroom and monitored students. A wealth of information was derived from the one day when different degrees of teacher-student interactivity and instructional intent occurred. The following sections lists recommendations for future studies with the understanding that all these experimental designs should benefit from instructional heterogeneity.

The following are suggestions for future research studies:

- Explore the relationship between stress and decision-making performance (the Yerkes-Dodson Law), with the hypothesis that too much stress or not enough stress will adversely affect quality of teacher's decisions.
- Compare psychophysiological arousal of teachers during instruction versus talking about instructional decisions in an interview.
- Create data-driven dynamic models of variables in a teacher's decision-making system in a classroom context.
- Look at the physiological responses of students during different phases of instruction and relate their physiology and behavior to learning outcomes.

Summary

A missing component in research on teachers' decision-making has been a comprehensive explanation of how expert teachers use tacit, unconscious, knowledge to make their decisions. In order to describe a teacher's decision-making process at multiple levels of awareness, a combination of physiological recordings, coded observations of instruction, and teacher self-report data were used as information sources for this case study. A positive relationship was found between the physiological arousal and decision-actions depending on instructional context. The study of instruction now has the prospect for using new advances in the study of human motivation, attention, and intuition from the field of neuropsychology to better understand instructional decision-making systems of teachers. A teacher's knowledge, experience, values, and skills all impact moment-to-moment decision-making during interactive instruction, but examining those elusive moments have been a neglected area of research.

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APPENDIX A

DECISION-ACTION RATE AND PHYSIOLOGICAL RESPONSE RATE DATA FOR EACH OBSERVATION DAY

Table 37
Decision-Action Rate and Physiological Response Rate Data for Each Observation Day

Elapsed Time (sec)	Decision-Action Rates					Physiological Response Rates					
	May14	May 15	May 17	May 20	May 21	May14	May 15	May 17	May 20	May 21	June 21
30	3	4	4	2	5	90	84	92	100	82	76
60	6	2	4	3	5	88	88	90	96	90	72
90	4	5	3	3	2	86	88	88	100	84	68
120	9	7	3	0	4	84	86	90	98	86	66
150	0	17	1	4	3	80	86	92	102	86	70
180	1	8	1	2	4	84	86	92	108	86	70
210	8	5	4	4	1	82	82	94	96	82	72
240	3	6	3	4	3	80	84	92	98	88	68
270	6	6	1	4	3	86	82	94	98	82	72
300	7	8	3	4	0	82	80	92	90	84	78
330	3	7	3	4	3	80	86	96	94	84	68
360	5	3	3	4	2	84	90	94	100	88	72
390	6	5	8	1	4	82	94	92	100	88	70
420	6	7	4	2	3	86	94	94	110	86	68
450	4	4	6	3	4	92	84	88	100	88	66
480	3	5	1	2	0	102	84	92	102	86	66
510	4	5	2	3	1	100	88	92	96	86	68
540	4	11	3	3	1	94	88	86	98	86	72
570	5	6	2	4	3	96	86	86	96	84	64
600	5	10	3	2	1	88	88	94	88	82	70
630	3	7	1	3	1	92	90	96	94	86	70
660	4	3	0	3	4	96	90	92	90	86	72
690	3	12	1	5	4	88	94	90	92	96	64
720	5	13	4	5	1	84	98	92	86	92	64
750	6	30	4	2	4	88	92	88	86	88	68

Table 37 (continued)

Elapsed Time (sec)	Decision-Action Rates					Physiological Response Rates					
	May14	May 15	May 17	May 20	May 21	May14	May 15	May 17	May 20	May 21	June 21
780	4	18	2	2	4	94	86	88	94	88	70
810	2	7	2	4	5	102	92	82	88	84	56
840	5	4	2	4	3	96	86	82	88	82	70
870	17	7	3	3	6	98	90	84	100	90	76
900	24	5	4	3	1	100	94	86	90	94	72
930	17	2	3	4	5	98	84	86	86	90	74
960	5	3	4	4	4	94	82	84	86	86	70
990	12	2	4	3	5	98	88	90	84	86	70
1020	6	3	4	3	4	100	86	90	86	86	72
1050	3	4	4	4	5	94	84	84	86	84	72
1080	5	1	3	3	2	96	78	90	88	88	70
1110	4	0	4	4	4	96	80	90	92	92	64
1140	5	3	10	2	4	92	84	98	96	82	68
1170	7	2	2	1	4	88	82	98	96	82	66
1200	4	2	3	1	2	96	80	98	90	86	66
1230	4	0	3	2	4	106	78	90	98	86	68
1260	11	2	0	0	5	102	86	86	100	84	68
1290	3	0	7	2	3	104	82	86	100	84	72
1320	4	0	0	1	1	92	78	88	94	94	70
1350	7	0	0	1	1	86	78	90	90	86	68
1380	6	0	0	2	4	94	76	88	98	82	74
1410	5	4	1	4	2	90	80	88	90	88	72
1440	6	0	5	3	2	94	82	92	100	90	66
1470	4	2	4	6	2	86	76	84	88	84	78
1500	5	0	5	3	3	86	78	90	92	98	78
1530	.	0	2	4	2	94	78	90	92	86	64
1560	.	0	2	4	6	100	82	90	94	84	68
1590	.	0	3	4	3	106	82	92	88	88	60

Table 37 (continued)

Elapsed Time (sec)	Decision-Action Rates					Physiological Response Rates					
	May14	May 15	May 17	May 20	May 21	May14	May 15	May 17	May 20	May 21	June 21
1620	.	0	4	2	4	100	76	86	94	90	70
1650	.	0	4	2	3	94	84	90	94	84	70
1680	.	0	3	4	1	98	84	84	90	88	66
1710	.	2	3	3	0	96	82	88	94	88	68
1740	.	0	3	2	2	94	76	88	94	84	66
1770	.	0	3	5	3	98	80	84	94	86	70
1800	.	0	5	5	3	100	80	86	88	84	72
1830	.	1	3	4	2	104	76	88	92	84	58
1860	.	1	4	3	2	98	80	88	90	82	66
1890	.	2	2	3	2	96	74	84	90	82	68
1920	.	0	4	1	2	100	76	94	96	80	70
1950	.	0	4	3	4	88	78	84	94	82	64
1980	.	5	4	3	4	104	76	82	90	86	64
2010	.	3	6	6	7	100	76	86	90	88	68
2040	.	4	5	4	6	94	76	90	88	84	68
2070	.	4	3	4	4	94	74	92	86	86	50
2100	.	5	3	1	4	88	78	88	88	86	60
2130	.	4	3	1	3	92	78	94	84	82	66
2160	.	0	4	4	3	92	78	92	86	80	68
2190	.	1	3	2	2	92	80	94	86	84	58
2220	.	2	10	4	2	90	78	92	86	88	66
2250	.	1	4	4	5	90	96	86	92	84	68
2280	.	3	4	2	3	84	96	92	94	80	74
2310	.	4	3	2	3	82	80	90	90	80	.
2340	.	4	2	4	2	82	82	84	92	84	.
2370	.	2	4	4	3	86	78	90	86	84	.
2400	.	5	5	5	4	86	80	84	86	88	.
2430	.	4	6	7	1	88	82	90	86	86	.

Table 37 (continued)

Elapsed Time (sec	Decision-Action Rates					Physiological Response Rates					
	May14	May 15	May 17	May 20	May 21	May14	May 15	May 17	May 20	May 21	June 21
2460	.	2	6	4	3	82	82	86	86	82	.
2490	.	3	6	2	3	90	80	82	90	80	.
2520	.	4	1	4	2	88	86	90	90	82	.
2550	.	3	0	5	3	88	84	88	96	80	.
2580	.	3	2	3	3	86	80	92	96	86	.
2610	.	5	6	5	3	92	76	88	92	82	.
2640	.	5	1	1	3	92	82	88	96	78	.
2670	.	4	4	4	3	94	76	90	96	82	.
2700	.	5	3	4	2	90	76	88	96	80	.
2730	.	5	4	2	5	92	80	98	86	86	.
2760	.	1	3	3	4	88	82	90	88	78	.
2790	.	4	3	4	5	96	82	82	90	78	.
2820	.	3	3	0	4	96	78	84	94	80	.
2850	.	4	4	1	2	94	76	84	98	86	.
2880	.	5	5	2	2	88	84	94	96	84	.
2910	.	1	5	4	6	82	82	88	90	78	.
2940	.	5	5	4	2	86	80	90	90	80	.
2970	.	8	3	4	3	92	86	86	90	80	.
3000	.	5	3	6	4	100	76	88	94	80	.
3030	.	5	3	3	3	94	82	88	94	82	.
3060	.	11	4	3	1	94	84	84	94	80	.
3090	.	5	3	4	3	98	84	90	90	82	.
3120	.	4	3	2	4	94	84	92	88	84	.
3150	.	3	.	4	1	94	80	92	88	82	.
3180	.	.	.	3	4	90	84	86	88	82	.
3210	.	.	.	6	1	88	80	92	98	80	.
3240	.	.	.	5	2	86	92	92	98	80	.

Table 37 (continued)

Elapsed Time (sec)	Decision-Action Rates					Physiological Response Rates					
	May14	May 15	May 17	May 20	May 21	May14	May 15	May 17	May 20	May 21	June 21
3270	.	.	.	3	2	82	84	92	102	80	.
3300	.	.	.	4	1	86	90	88	98	80	.
3330	.	.	.	5	2	80	.	88	96	76	.
3360	.	.	.	2	3	96	.	.	92	86	.
3390	.	.	.	3	3	84	.	.	94	86	.
3420	.	.	.	5	2	84	.	.	96	76	.
3450	.	.	.	3	1	86	.	.	96	82	.
3480	.	.	.	5	2	86	.	.	94	82	.
3510	.	.	.	6	.	86	.	.	90	78	.
3540	.	.	.	3	.	84	.	.	96	.	.
3570	.	.	.	6	.	84	.	.	92	.	.
3600	.	.	.	4	.	.	.	.	.	.	.

APPENDIX B

DECISION-ACTION RATE RECORDINGS AND CALCULATIONS FOR MAY 15

Table 38

Decision-Action Rate Recordings and Calculations for May 15

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
	9:51:00			9:53 AM	T	E	4	A							
					T	E	4	A		0	0	0	0		
					T	E	4	A		0	0	0	0		
					T	E	4	A		0	0	0	0		reminding of what should be in paper
					T	E	4	A		0	0	0	0		
					T	E	4	A		0	0	0	0		
					T	E	4	A		0	0	0	0		
					T	E	4	A		0	0	0	0		
	9:53:00			9:54 AM	T	F	1	O		1	1	1	1		GIVES PAPER TO ONE STUDENT
					M	T	3	O		1	0	1	1		
					T	F	1	O		1	1	2	2		
					M	T	3	O		1	0	2	2		
					T	S	9	B		1	1	3	3		
					M	T	3	B		1	0	3	3		
					T	E	4	A		1	1	4	4		
					T	E	4	A		0	0	4	4		
					T	E	1Q	A		1	1	5	5		
					S	T	3	A		1	0	5	5		
					T	E	7	A		1	1	6	6		
	9:55:00			9:56 AM	T	E	4	A		1	1	7	7		INSTRUCTIONS, YOU MAY BEGIN
					T	E	12	A		1	1	8	8		
					T	S	12	AX		1	1	9	9		
					T	E	12	AX		1	1	10	10		
					T	S	12	A		1	1	11	11		
					T	F	1Q	A		1	1	12	12		
					M	T	3	A		1	0	12	12		
					T	M	6	A		1	1	13	13		
					T	S	12	AX		1	1	14	14		
					T	S	12	A		1	1	15	15		
					F	T	1Q	A		1	0	15	15		
					T	M	3	A		1	1	16	16		
					T	M	1Q	A		1	1	17	17		
					M	T	3	A		1	0	17	17		
					T	M	7	A		1	1	18	18		
					F	T	1Q	A		1	0	18	18		
					T	M	3	A		1	1	19	19		WHAT'S 2 TIMES 6?

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
					T	M	6	A		1	1	20	20		
					F	T	1Q	A		1	0	20	20		
					T	M	3	A		1	1	21	21		
					T	M	6	A		1	1	22	22		
					T	S	12	A		1	1	23	23		
					T	S	12	AX		1	1	24	24		
					T	F	9	B		1	1	25	25		PUT BINDER DOWN
					M	T	3	B		1	0	25	25		
				9:59 AM	T	E	12	A		1	1	26	26		
					T	S	12	AX		1	1	27	27		
					T	S	12	A		1	1	28	28		
					T	F	6	A		1	1	29	29		
					T	S	12	A		1	1	30	30		
					T	S	12	AX		1	1	31	31		
										1	0	31	31		BUZZER
	10:00:35	10:00:35	0:00:00						T	0	0	31	31		**TRIGGER**
0	**10:01:00**		0:00:25	10:03 AM	T	F	4	A		1	1	32	1		
0					T	M	4	A		1	1	33	2		HELPING A STUDENT
0					T	M	4	A		0	0	33	2		
0					T	M	1	A		1	1	34	3		
0					M	T	3	A		1	0	34	3		
0					T	M	4	A		1	1	35	4	4	
1	**10:01:31**		0:00:56		T	S	1	O		1	1	36	1		Come SIT DOWN both of you
1					S	T	3	O		1	0	36	1		
1	**10:01:55**		0:01:20		T	S	1	O		1	1	37	2	2	in a row please
2	**10:02:00**		0:01:25		S	T	3	O		1	0	37	0		
2					T	F	1	O		1	1	38	1		
2					M	T	3	O		1	0	38	1		
2					T	S	1	O		1	1	39	2		
2					S	T	3	O		1	0	39	2		
2					T	E	1Q	O		1	1	40	3		anybody have my dice yet?
2					L	T	3	O		1	0	40	3		
2					T	L	1	O		1	1	41	4		
2					L	T	3	O		1	0	41	4		
2					T	L	1	O		1	1	42	5		
2					L	T	3	O		1	0	42	5	5	
3	**10:02:30**		0:01:55		T	E	6	O		1	1	43	1		I'LL WAIT LADIES PLEASE come
3	**10:02:39**		0:02:04	10:04 AM	T	S	1Q	A		1	1	44	2		Teresa's pair-who won?
3					S	T	3	A		1	0	44	2		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
3					T	S	7	A		1	1	45	3		writes result on board
3					F	T	1Q	A		1	0	45	3		
3					T	M	3	A		1	1	46	4		
3					T	S	1Q	A		1	1	47	5		
3					S	T	3	A		1	0	47	5		
3					T	S	7	A		1	1	48	6		
3					T	S	1Q	A		1	1	49	7		
3					S	T	3	A		1	0	49	7	7	
4	**10:03:00**		0:02:25		T	S	7	A		1	1	50	1		
4					T	S	1Q	A		1	1	51	2		
4					S	T	3	A		1	0	51	2		
4					T	S	7	A		1	1	52	3		
4					T	S	1Q	A		1	1	53	4		
4					S	T	3	A		1	0	53	4		
4					T	S	7	A		1	1	54	5		
4					T	S	1Q	A		1	1	55	6		
4					S	T	3	A		1	0	55	6		
4					T	S	7	A		1	1	56	7		
4					T	S	1Q	A		1	1	57	8		
4					S	T	3	A		1	0	57	8		
4					T	S	7	A		1	1	58	9		
4					T	S	1Q	A		1	1	59	10		
4					S	T	3	A		1	0	59	10		
4					T	S	7	A		1	1	60	11		
4					T	S	1Q	A		1	1	61	12		
4					S	T	3	A		1	0	61	12		
4					T	S	7	A		1	1	62	13		
4					T	S	1Q	A		1	1	63	14		
4					S	T	3	A		1	0	63	14		
4					T	S	7	A		1	1	64	15		
4					T	S	1Q	A		1	1	65	16		
4					S	T	3	A		1	0	65	16		
4					T	S	7	A		1	1	66	17	17	
5	**10:03:30**		0:02:55		T	S	1Q	A		1	1	67	1		
5					S	T	3	A		1	0	67	1		
5					T	S	7	A		1	1	68	2		
5	**10:03:40**		0:03:05		T	E	1	O		1	1	69	3		SO, LOOK AT THESE RESULTS
5					L	T	3	O		1	0	69	3		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
5					T	E	1Q	A		1	1	70	4		
5					S	T	3	A		1	0	70	4		
5					T	E	2	A		1	1	71	5		why all evens?
5					S	T	3	A		1	0	71	5		
5					T	S	7	A		1	1	72	6		
5					T	L	9	B		1	1	73	7		RAISE YOUR HANDS
5					L	T	3	B		1	0	73	7		
5					T	E	2Q	A		1	1	74	8		
5					S	T	3	A		1	0	74	8	8	
6	**10:04:00**		0:03:25		T	F	9	B		1	1	75	1		Tyler sit over there
6					M	T	3	A		1	0	75	1		
6					T	E	2	A		1	1	76	2		How would I write this as a probability outcome?
6					T	E	6	A		1	1	77	3		How many possible outcomes
6					M	T	3	A		1	0	77	3		
6					T	E	1Q	A		1	1	78	4		What % was odd?
6					L	T	3	A		1	0	78	4		
6					T	E	7	A		1	1	79	5	5	
7	**10:04:30**		0:03:55		T	E	1Q	A		1	1	80	1		What % was even?
7					L	T	3	A		1	0	80	1		
7					T	E	6	A		1	1	81	2		
7					T	E	1Q	A		1	1	82	3		
7					L	T	3	A		1	0	82	3		
7					T	E	7	A		1	1	83	4		
7	**10:04:47**		0:04:12		T	E	2	A		1	1	84	5		If you were the odd person, was it a fair game?
7					T	E	6	A		1	1	85	6		repeats question
7					T	E	6	A		0	0	85	6		
7					F	T	3	A		1	0	85	6	6	says yes
8	**10:05:00**		0:04:25		T	M	6	A		1	1	86	1		Bianca?
8					T	F	2	A		1	1	87	2		
8					M	T	3	A		1	0	87	2		Tyler says no
8					T	M	2	A		1	1	88	3		WHY NOT?
8					M	T	3	A		1	0	88	3		
8					T	M	7	A		1	1	89	4		
8	**10:05:20**		0:04:45	10:08 AM	T	E	1	A		1	1	90	5		Stop. Think
8					T	F	1	B		1	1	91	6		
8					M	T	3	B		1	0	91	6	6	
9	**10:05:30**		0:04:55		T	F	1Q	A		1	1	92	1		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
9					M	T	3	A		1	0	92	1		
9					T	F	2Q	A		1	1	93	2		
9					M	T	3	A		1	0	93	2		
9					T	M	6	A		1	1	94	3		
9					T	M	6	A		0	0	94	3		
9					T	E	2	A		1	1	95	4		What were the possibilities?
9					S	T	3	A		1	0	95	4		
9					T	E	6	A		1	1	96	5		
9					S	T	6	A		1	0	96	5		
9	**10:05:55**		0:05:20	10:08 AM	T	E	4	A		1	1	97	6		
9					T	E	1Q	A		1	1	98	7		
9					S	T	3	A		1	0	98	7		
9					T	E	7	A		1	1	99	8	8	
10	**10:06:00**		0:05:25		T	E	1Q	A		1	1	100	1		teacher explains as she modifies the chart on board
10					S	T	3	A		1	0	100	1		
10					T	E	7	A		1	1	101	2		
10					T	E	1Q	A		1	1	102	3		
10					S	T	3	A		1	0	102	3		
10					T	E	7	A		1	1	103	4		
10					T	E	1Q	A		1	1	104	5		
10					S	T	3	A		1	0	104	5		
10					T	E	7	A		1	1	105	6		
10					T	E	1Q	A		1	1	106	7	7	
11	**10:06:30**		0:05:55		S	T	3	A		1	0	106	0		
11					T	E	7	A		1	1	107	1		
11					T	E	4	A		1	1	108	2		
11					T	E	4	A		0	0	108	2		
11	**10:06:50**		0:06:15		T	E	4	A		0	0	108	2		I messed it up
11					F	T	6	A		1	0	108	2		
11					T	M	6	A		1	1	109	3	3	
12	**10:07:00**		0:06:25		T	E	6	A		1	1	110	1		let me do it this way
12					T	E	6	O		1	1	111	2		
12					T	E	2	A		1	1	112	3		starts sentence, student finishes it
12					F	T	3	A		1	0	112	3		
12					T	M	7	A		1	1	113	4		
12					T	E	4	A		1	1	114	5		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
12					T	E	4	A		0	0	114	5		
12					F	T	6	A		1	0	114	5	5	
13	**10:07:30**		0:06:55		T	E	4	A		1	1	115	1		
13					T	E	4	A		0	0	115	1		
13					T	E	1Q	A		1	1	116	2		
13					F	T	3	A		1	0	116	2		
13					T	M	7	A		1	1	117	3		
13					T	E	6	A		1	1	118	4		
13					T	E	6	A		0	0	118	4		
13					T	E	1Q	A		1	1	119	5		
13					F	T	3	A		1	0	119	5		
13					T	E	4	A		1	1	120	6		
13					T	M	7	A		1	1	121	7	7	
14	**10:08:00**		0:07:25		T	E	4	A		1	1	122	1		IF I WRITE ALL THE ADDITION...
14					T	E	2	A		1	1	123	2		
14					F	T	3	A		1	0	123	2		
14					T	M	7	A		1	1	124	3		
14					T	E	2	A		1	1	125	4		
14					S	T	3	A		1	0	125	4	4	
15	**10:08:30**		0:07:55		T	S	7	A		1	1	126	1		
15					T	E	2	A		1	1	127	2		
15					S	T	3	A		1	0	127	2		
15					T	S	7	A		1	1	128	3		
15					T	E	2	A		1	1	129	4		
15					S	T	3	A		1	0	129	4		
15					T	S	7	A		1	1	130	5	5	
16	**10:09:00**		0:08:25		T	E	2	A		1	1	131	1		
16					S	T	3	A		1	0	131	1		
16					T	S	7	A		1	1	132	2		
16	**10:09:13**		0:08:38	10:11 AM	S	T	6	A		1	0	132	2		students call out
16	**10:09:20**		0:08:45		T	S	9	B		1	1	133	3		one at a time
16					E	T	3	B		1	0	133	3		
16					T	E	2	A		1	1	134	4		teacher has students adding combinations as she writes them on the board
16					F	T	3	A		1	0	134	4		
16					T	M	7	A		1	1	135	5	5	

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
17	**10:09:30**		0:08:55		T	E	2	A		1	1	136	1		
17					F	T	3	A		1	0	136	1		
17					T	M	7	A		1	1	137	2		
17					T	E	2	A		1	1	138	3		
17					F	T	3	A		1	0	138	3		
17					T	E	2	A		1	1	139	4		
17					F	T	3	A		1	0	139	4		
17					T	M	7	A		1	1	140	5		
17					T	E	2	A		1	1	141	6		
17					F	T	3	A		1	0	141	6		
17					T	M	7	A		1	1	142	7		
17					T	E	2	A		1	1	143	8		
17					F	T	3	A		1	0	143	8		
17					T	M	7	A		1	1	144	9		
17					T	E	2	A		1	1	145	10		
17	**10:09:55**		0:09:20		S	T	3	A		1	0	145	10		answer in unison
17					T	S	7	A		1	1	146	11	11	
18	**10:10:00**		0:09:25		T	E	2	A		1	1	147	1		
18					F	T	3	A		1	0	147	1		
18					T	M	7	A		1	1	148	2		
18					T	E	2	A		1	1	149	3		
18					F	T	3	A		1	0	149	3		
18					T	M	7	A		1	1	150	4		
18					T	E	2	A		1	1	151	5		
18					F	T	3	A		1	0	151	5		
18					T	M	7	A		1	1	152	6	6	
19	**10:10:30**		0:09:55		T	E	2	A		1	1	153	1		
19					F	T	3	A		1	0	153	1		
19					T	M	7	A		1	1	154	2		
19					T	E	2	A		1	1	155	3		
19					F	T	3	A		1	0	155	3		
19					T	M	7	A		1	1	156	4		
19					T	E	2	A		1	1	157	5		
19					F	T	3	A		1	0	157	5		
19					T	M	7	A		1	1	158	6		
19					T	E	2	A		1	1	159	7		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
19					F	T	3	A		1	0	159	7		
19					T	M	7	A		1	1	160	8		
19	**10:10:50**		0:10:15		T	E	2	A		1	1	161	9		who have I not heard from? Alexander
19					F	T	3	A		1	0	161	9		
19					T	M	7	A		1	1	162	10	10	
20	**10:11:00**		0:10:25		T	E	2	A		1	1	163	1		
20					F	T	3	A		1	0	163	1		
20					T	M	7	A		1	1	164	2		
20					T	E	2	A		1	1	165	3		
20					F	T	3	A		1	0	165	3		
20					T	M	7	A		1	1	166	4		
20	**10:11:20**		0:10:45		T	E	2	A		1	1	167	5		who have I not heard from? Joshua
20					F	T	3	A		1	0	167	5		
20					T	M	7	A		1	1	168	6		
20					T	E	6	A		1	1	169	7	7	
21	**10:11:30**		0:10:55		T	E	6	A		0	0	169	0		Does anybody remember from Monday what are the possibilities?
21					T	F	2	A		1	1	170	1		
21					F	T	3	A		1	0	170	1		
21					T	M	7	A		1	1	171	2		
21					T	E	6	A		1	1	172	3	3	
22	**10:12:00**		0:11:25		T	E	6	O		1	1	173	1		
22					T	E	1Q	A		1	1	174	2		
22					L	T	3	A		1	0	174	2		
22	**10:12:10**		0:11:35		T	L	9	B		1	1	175	3		use class voices
22					T	L	7	B		1	1	176	4		
22					T	E	1Q	A		1	1	177	5		
22					L	T	3	A		1	0	177	5		
22					T	L	7	A		1	1	178	6		
22					T	E	1Q	A		1	1	179	7		
22					L	T	3	A		1	0	179	7		
22					T	L	7	A		1	1	180	8		
22					T	E	1Q	A		1	1	181	9		
22					L	T	3	A		1	0	181	9		
22					T	L	7	A		1	1	182	10		
22					T	E	1Q	A		1	1	183	11		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
22					L	T	3	A		1	0	183	11		
22					T	L	7	A		1	1	184	12	12	
23	**10:12:30**		0:11:55		T	E	2	A		1	1	185	1		so far does it look fair?
23					L	T	3	A		1	0	185	1		
23					T	E	6	A		1	1	186	2		
23					T	E	1Q	A		1	1	187	3		
23					L	T	3	A		1	0	187	3		
23					T	E	7	A		1	1	188	4		
23	**10:12:45**		0:12:10		T	F	9	B		1	1	189	5		
23					M	T	3	B		1	0	189	5		
23					T	E	1Q	A		1	1	190	6		
23					L	T	3	A		1	0	190	6		
23					T	E	7	A		1	1	191	7		
23					T	E	1Q	A		1	1	192	8		
23					L	T	3	A		1	0	192	8		
23					T	E	7	A		1	1	193	9		
23					T	E	1Q	A		1	1	194	10		
23					L	T	3	A		1	0	194	10		
23					T	E	7	A		1	1	195	11		
23					T	E	1Q	A		1	1	196	12		
23					L	T	3	A		1	0	196	12		
23					T	E	7	A		1	1	197	13	13	
24	**10:13:00**		0:12:25		T	E	1Q	A		1	1	198	1		
24					L	T	3	A		1	0	198	1		
24					T	E	7	A		1	1	199	2		
24					T	E	1Q	A		1	1	200	3		
24					L	T	3	A		1	0	200	3		
24					T	E	7	A		1	1	201	4		
24					T	E	1Q	A		1	1	202	5		
24					L	T	3	A		1	0	202	5		
24					T	E	7	A		1	1	203	6		
24					T	E	1Q	A		1	1	204	7		
24					L	T	3	A		1	0	204	7		
24					T	E	7	A		1	1	205	8		
24					T	E	1Q	A		1	1	206	9		
24					L	T	3	A		1	0	206	9		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
24					T	E	7	A		1	1	207	10		
24					T	E	1Q	A		1	1	208	11		
24					L	T	3	A		1	0	208	11		
24					T	E	7	A		1	1	209	12		
24					T	E	1Q	A		1	1	210	13		
24					L	T	3	A		1	0	210	13		
24					T	E	7	A		1	1	211	14		
24					T	E	1Q	A		1	1	212	15		
24					L	T	3	A		1	0	212	15		
24					T	E	7	A		1	1	213	16		
24					T	E	1Q	A		1	1	214	17		
24					L	T	3	A		1	0	214	17		
24					T	E	7	A		1	1	215	18		
24					T	E	1Q	A		1	1	216	19		
24					L	T	3	A		1	0	216	19		
24					T	E	7	A		1	1	217	20		
24					T	E	1Q	A		1	1	218	21		
24					L	T	3	A		1	0	218	21		
24					T	E	7	A		1	1	219	22		
24					T	E	1Q	A		1	1	220	23		
24					L	T	3	A		1	0	220	23		
24					T	E	7	A		1	1	221	24		
24					T	E	1Q	A		1	1	222	25		
24					L	T	3	A		1	0	222	25		
24					T	E	7	A		1	1	223	26		
24					T	E	1Q	A		1	1	224	27		
24					L	T	3	A		1	0	224	27		
24					T	E	7	A		1	1	225	28		
24					T	E	1Q	A		1	1	226	29		
24					L	T	3	A		1	0	226	29		
24					T	E	7	A		1	1	227	30	30	
25	**10:13:30**		0:12:55		T	E	1Q	A		1	1	228	1		
25					L	T	3	A		1	0	228	1		
25					T	E	7	A		1	1	229	2		
25					T	E	1Q	A		1	1	230	3		
25					L	T	3	A		1	0	230	3		
25					T	E	7	A		1	1	231	4		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
25					T	E	1Q	A		1	1	232	5		
25					L	T	3	A		1	0	232	5		
25					T	E	7	A		1	1	233	6		
25					T	E	1Q	A		1	1	234	7		
25					L	T	3	A		1	0	234	7		
25					T	E	7	A		1	1	235	8		
25					T	E	1Q	A		1	1	236	9		
25					L	T	3	A		1	0	236	9		
25					T	E	7	A		1	1	237	10		
25					T	E	1Q	A		1	1	238	11		
25					L	T	3	A		1	0	238	11		
25					T	E	7	A		1	1	239	12		
25	**10:13:50**		0:13:15		T	E	1Q	A		1	1	240	13		
25					L	T	3	A		1	0	240	13		
25					T	E	7	A		1	1	241	14		
25					T	E	1Q	A		1	1	242	15		
25					L	T	3	A		1	0	242	15		
25					T	E	7	A		1	1	243	16		
25					T	E	1Q	A		1	1	244	17		
25					L	T	3	A		1	0	244	17		
25					T	E	7	A		1	1	245	18	18	
26	**10:14:00**		0:13:25	10:16 AM	T	E	4	A		1	1	246	1		counting all even combinations
26					T	E	9	B		1	1	247	2		CLASS VOICES
26					E	T	3	B		1	0	247	2		
26					T	E	1	A		1	1	248	3		LET'S COUNT ALL THE EVENS
26					E	T	3	A		1	0	248	3		
26					T	E	7	A		1	1	249	4		
26					T	E	4	A		1	1	250	5		
26					T	E	9	B		1	1	251	6		EXCUSE ME
26					E	T	3	B		1	0	251	6		
26					E	T	3	A		1	0	251	6		
26					T	E	1	A		1	1	252	7	7	LET'S COUNT THE ODDS
27	**10:14:30**		0:13:55		E	T	3	A		1	0	252	0		
27					T	E	7	A		1	1	253	1		
27					T	E	6	A		1	1	254	2		
27	**10:14:45**		0:14:10		T	E	4	A		1	1	255	3		9 odd 36 total

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
27					T	E	4	A		0	0	255	3		
27					T	E	1Q	A		1	1	256	4		
27					L	T	3	A		1	0	256	4	4	WHOLE CLASS RESPONSE
28	**10:15:00**		0:14:25		T	E	4	A		1	1	257	1		
28	**10:15:05**		0:14:30		T	E	4	A		0	0	257	1		think of this as a pie
28					T	E	1Q	A		1	1	258	2		
28					L	T	3	A		1	0	258	2		
28					T	E	7	A		1	1	259	3		
28					T	E	1Q	A		1	1	260	4		
28					L	T	3	A		1	0	260	4		
28					T	E	7	A		1	1	261	5		
28					T	E	4	A		1	1	262	6		
28					T	E	6	A		1	1	263	7	7	
29	**10:15:30**		0:14:55		S	T	6	A		1	0	263	0		
29	**10:15:32**		0:14:57		T	E	4	A		1	1	264	1		
29	**10:15:35**		0:15:00		T	E	1Q	A		1	1	265	2		IS THIS A FAIR ACTIVITY?
29					S	T	3	A		1	0	265	2		
29					T	E	7	A		1	1	266	3		
29					T	E	6	A		1	1	267	4		NOT EVEN 50-50 CHANCE
29					T	E	2	A		1	1	268	5	5	
30	**10:16:00**		0:15:25	10:18 AM	T	E	6	A		1	1	269	1		explains the activity
30					T	E	1	O		1	1	270	2	2	
31	**10:16:30**		0:15:55		T	E	1	O		0	0	270	0		
31					T	F	1	A		1	1	271	1		Tyler go to your normal chair
31					M	T	3	A		1	0	271	1		
31					T	S	1	O		1	1	272	2		
31					S	T	3	O		1	0	272	2		
31					T	S	6	O		1	1	273	3	3	
32	**10:17:00**		0:16:25		T	F	1	A		1	1	274	1		teacher is handing out papers, then students return to their chairs
32					M	T	3	A		1	0	274	1		
32					T	F	1	A		1	1	275	2		
32					M	T	3	A		1	0	275	2	2	

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
33	**10:17:30**		0:16:55	10:20 AM	T	E	12	A		1	1	276	1		
33					T	S	1	O		1	1	277	2		
33					S	T	3	O		1	0	277	2		
33					T	S	6	O		1	1	278	3	3	
34	**10:18:00**		0:17:25		T	S	6	O		0	0	278	0		
34					T	F	1	O		1	1	279	1		
34					M	T	3	O		1	0	279	1		
34					T	S	6	O		1	1	280	2		
34	**10:18:20**		0:17:45		T	E	1	A		1	1	281	3		write an essay about what probability is
34					E	T	3	A		1	0	281	3		
34					T	E	12	A		1	1	282	4	4	
35	**10:18:30**		0:17:55		T	E	12	AX		1	1	283	1		
35					T	E	12	AX		0	0	283	1	1	
36	**10:19:00**		0:18:25		T	E	12	AX		0	0	283	0		
36					T	E	12	AX		0	0	283	0		
36					T	E	12	AX		0	0	283	0	0	
37	**10:19:30**				T	E	12	AX		0	0	283	0		
37					T	E	12	AX		0	0	283	0		
37					T	E	12	AX		0	0	283	0		
37	**10:19:50**		0:19:15		T	F	6	AG		1	1	284	1		write about what probability is
37					T	E	12	A		1	1	285	2		
37					T	E	12	AX		1	1	286	3	3	
38	**10:20:00**		0:19:25		T	E	12	AX		0	0	286	0		
38					T	E	12	AX		0	0	286	0		
38	**10:20:20**		0:19:45		T	E	6	AG		1	1	287	1		remember to write about all the factors
38				10:22 AM	T	E	12	AX		1	1	288	2		
38					T	E	12	AX		0	0	288	2	2	
39	**10:20:30**		0:19:55		T	E	12	AX		0	0	288	0		
39					T	E	12	AX		0	0	288	0		
39	**10:20:50**		0:20:15		F	T	1Q	O		1	0	288	0		
39					T	M	3	O		1	1	289	1		
39					T	E	12	AX		1	1	290	2	2	
40	**10:21:00**		0:20:25	10:23 AM	T	E	12	AX		0	0	290	0		
40					T	E	12	AX		0	0	290	0	0	
41	**10:21:30**		0:20:55		T	E	12	AX		0	0	290	0		
41					T	E	12	AX		0	0	290	0		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
41	**10:21:40**		0:21:05	10:23 AM	T	O				1	1	291	1		erases front board
41					T	E	12	AX		1	1	292	2		
41					T	E	12	AX		0	0	292	2	2	
42	**10:22:00**		0:21:25	10:24 AM	T	E	12	AX		0	0	292	0		
42					T	E	12	AX		0	0	292	0		
42					T	E	12	AX		0	0	292	0	0	
43	**10:22:30**		0:21:55		T	E	12	AX		0	0	292	0		
43					T	E	12	AX		0	0	292	0	0	
44	**10:23:00**		0:22:25		T	E	12	AX		0	0	292	0		
44					T	E	12	AX		0	0	292	0	0	
45	**10:23:30**		0:22:55		T	E	12	AX		0	0	292	0		
45				10:25 AM	T	E	12	AX		0	0	292	0	0	
46	**10:24:00**		0:23:25		T	F	6	A		1	1	293	1		NOT APPROPRIATE PARAGRAPHS? YOU NUMBER PARAGRAPHS? (TO STUDENT)
46					T	E	12	AX		1	1	294	2		
46				10:27 AM	T	F	6	AG		1	1	295	3		gives student guidance
46					T	E	12	AX		1	1	296	4	4	
47	**10:24:30**		0:23:55		T	E	12	AX		0	0	296	0		
47					T	E	12	AX		0	0	296	0		
47				10:28 AM	T	E	12	AX		0	0	296	0	0	
48	**10:25:00**		0:24:25		T	F	6	O		1	1	297	1		
48					T	E	12	AX		1	1	298	2	2	
49	**10:25:30**		0:24:55		T	E	12	AX		0	0	298	0		
49					T	E	12	AX		0	0	298	0		
49					T	E	12	AX		0	0	298	0	0	
50	**10:26:00**		0:25:25		T	E	12	AX		0	0	298	0		
50					T	E	12	AX		0	0	298	0	0	
51	**10:26:30**		0:25:55		T	E	12	AX		0	0	298	0		
51	**10:26:40**		0:26:05	10:28 AM	T	F	1	O		1	1	299	1		paper bothering student
51					M	T	3	O		1	0	299	1		
51					T	M	1	O		1	1	300	2		give it to me
51					M	T	3	O		1	0	300	2		
51					T	E	12	AX		1	1	301	3	0	
52	**10:27:00**		0:26:25	10:29 AM	T	E	12	AX		0	0	301	0		
52					T	E	12	AX		0	0	301	0	0	
53	**10:27:30**		0:26:55		T	E	12	AX		0	0	301	0		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
53					T	E	12	AX		0	0	301	0		
53					T	E	12	AX		0	0	301	0	0	
54	**10:28:00**		0:27:25		T	E	12	AX		0	0	301	0		
54					T	E	12	AX		0	0	301	0		
54					T	E	12	AX		0	0	301	0		
54	**10:28:20**		0:27:45		T	F	1Q	O		1	1	302	1		would you like another paper?
54					M	T	3	O		1	0	302	1		
54					T	M	7	O		1	1	303	2	0	gets another paper for student
55	**10:28:30**		0:27:55		T	E	12	AX		1	1	304	1		
55					T	E	12	AX		0	0	304	1		
55					T	E	12	AX		0	0	304	1		
55					T	E	12	AX		0	0	304	1		
55					T	E	12	AX		0	0	304	1	0	
56	**10:29:00**		0:28:25		F	T	6	O		1	0	304	0		student hands in paper
56					T	M	7	O		1	1	305	1		
56					T	E	12	AX		1	1	306	2	2	
57	**10:29:30**		0:28:55	10:32 AM	T	E	12	AX		0	0	306	0		
57					T	E	12	AX		0	0	306	0		
57					T	E	12	AX		0	0	306	0	0	
58	**10:30:00**				T	E	12	AX		0	0	306	0		
58					T	E	12	AX		0	0	306	0		
58					T	E	12	AX		0	0	306	0	0	
59	**10:30:30**		0:29:55		T	E	12	AX		0	0	306	0		
59					T	E	12	AX		0	0	306	0		
59					T	E	12	AX		0	0	306	0		
59					T	E	12	AX		0	0	306	0	0	
60	**10:31:00**		0:30:25	10:33 AM	T	E	12	A		1	1	307	1		
60					T	E	12	A		0	0	307	1		
60					T	E	12	A		0	0	307	1	1	
61	**10:31:30**		0:30:55		T	E	12	A		0	0	307	0		
61					T	E	12	AX		1	1	308	1		
61					T	E	12	AX		0	0	308	1	1	
62	**10:32:00**		0:31:25	10:34 AM	T	E	12	A		1	1	309	1		
62					T	E	12	AX		1	1	310	2		
62					T	E	12	AX		0	0	310	2	2	
63	**10:32:30**		0:31:55		T	E	12	AX		0	0	310	0		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
63					T	E	12	AX		0	0	310	0		
63					T	E	12	AX		0	0	310	0	0	
64	**10:33:00**		0:32:25		T	E	12	AX		0	0	310	0		
64					T	E	12	AX		0	0	310	0		
64					T	E	12	AX		0	0	310	0	0	
65	**10:33:30**		0:32:55	10:34 AM	F	T	1Q	A		1	0	310	0		
65					T	M	3	A		1	1	311	1		
65					T	M	7	AX		1	1	312	2		that would be great
65					T	E	12	AX		1	1	313	3		
65					T	F	6	A		1	1	314	4		
65	**10:33:50**		0:33:15	10:35 AM	T	M	6	A		1	1	315	5		a picture goes a long way (entire class hears hint)
65					T	M	6	A		0	0	315	5	5	
66	**10:34:00**		0:33:25		T	E	12	AX		1	1	316	1		
66					F	T	1Q	O		1	0	316	1		
66					T	M	3	O		1	1	317	2		examples are great
66					T	S	6	A		1	1	318	3	3	
67	**10:34:30**		0:33:55		F	T	1Q	A		1	0	318	0		is this enough
67					T	M	10	A		1	1	319	1		I can't tell you
67					T	E	12	AX		1	1	320	2		
67					F	T	1Q	O		1	0	320	2		should we use the exact same thing we did?
67					T	M	3	O		1	1	321	3		
67					M	T	6	O		1	0	321	3		
67					T	M	6	O		1	1	322	4	4	
68	**10:35:00**		0:34:25		T	M	6	O		0	0	322	0		no, more points for new examples
68					F	T	1Q	O		1	0	322	0		
68					T	M	3	O		1	1	323	1		
68					T	M	6	O		1	1	324	2		
68					T	E	12	AX		1	1	325	3		
68					T	E	6	O		1	1	326	4	4	REMEMBER ALL THOSE FACTORS WE TALKED ABOUT
69	**10:35:30**		0:34:55		F	T	1Q	A		1	0	326	0		
69					T	M	3	A		1	1	327	1		
69					T	M	7	A		1	1	328	2		teacher examines student paper
69					F	T	1Q	A		1	0	328	2		
69					T	M	3	A		1	1	329	3		
69					T	M	6	A		1	1	330	4		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
69					T	E	12	AX		1	1	331	5	5	
70	**10:36:00**		0:35:25		F	T	1Q	A		1	0	331	0		
70				10:39 AM	T	M	3	A		1	1	332	1		
70					T	M	6	A		1	1	333	2		
70					T	E	6	O		1	1	334	3		
70					T	E	12	AX		1	1	335	4		
70					T	E	12	AX		0	0	335	4	4	
71	**10:36:30**		0:35:55		T	E	12	AX		0	0	335	0		
71					T	E	12	AX		0	0	335	0		
71					T	E	12	AX		0	0	335	0	0	
72	**10:37:00**		0:36:25		T	E	12	AX		0	0	335	0		
72					F	T	1Q	O		1	0	335	0		
72					M	T	3	O		1	0	335	0		
72					T	E	12	AX		1	1	336	1		
72					T	E	12	AX		0	0	336	1		
72					T	E	12	AX		0	0	336	1	1	
73	**10:37:30**		0:36:55		T	E	12	AX		0	0	336	0		
73					T	E	12	AX		0	0	336	0		
73	**10:37:45**		0:37:10		F	T	1Q	A		1	0	336	0		you need to label this
73					T	M	3	A		1	1	337	1		
73					T	M	6	A		1	1	338	2		
73					T	M	6	A		0	0	338	2	2	
74	**10:38:00**		0:37:25		T	E	12	AX		1	1	339	1		
74				10:40 AM	T	E	12	AX		0	0	339	1		
74					T	E	12	AX		0	0	339	1	1	
75	**10:38:30**		0:37:55		T	E	12	AX		0	0	339	0		
75					T	E	12	AX		0	0	339	0		
75	**10:38:40**		0:38:05		T	F	1Q	O		1	1	340	1		did you read and edit?
75					M	T	3	O		1	0	340	1		
75					T	M	6	O		1	1	341	2		
75					T	M	1	O		1	1	342	3		you will be hidalgo/s partner
75					M	T	3	O		1	0	342	3	3	
76	**10:39:00**		0:38:25		T	S	4	A		1	1	343	1		
76					T	S	4	A		0	0	343	1		
76					T	S	1Q	O		1	1	344	2		
76					S	T	3	O		1	0	344	2		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
76					T	S	6	O		1	1	345	3		
76					T	S	4	A		1	1	346	4	4	
77	**10:39:30**		0:38:55		T	S	1	O		1	1	347	1		directions for work, send groups out into cluster
77					S	T	3	O		1	0	347	1		
77					T	S	6	O		1	1	348	2		
77					T	S	6	O		0	0	348	2		
77	**10:39:50**		0:39:15		T	F	1Q	O		1	1	349	3		you read and edited? You'll have to wait for the next person to finish to be your problem
77					M	T	3	O		1	0	349	3		
77					T	M	6	O		1	1	350	4		read the questions very carefully
77					T	M	6	O		0	0	350	4	4	
78	**10:40:00**		0:39:25		T	F	1Q	O		1	1	351	1		
78					M	T	3	O		1	0	351	1		
78					T	M	6	O		1	1	352	2	2	
79	**10:40:30**		0:39:55		T	F	1Q	O		1	1	353	1		you read and edited? You'll have to wait for the next person to finish to be your problem
79					M	T	3	O		1	0	353	1		
79					T	M	1	O		1	1	354	2		read the questions very carefully
79					M	T	3	O		1	0	354	2		
79					T	E	12	AX		1	1	355	3		
79					F	T	1Q	O		1	0	355	3		
79					T	M	3	O		1	1	356	4		
79					T	E	12	AX		1	1	357	5	5	
80	**10:41:00**		0:40:25	10:43 AM	T	S	1	O		1	1	358	1		directions to move
80					S	T	3	O		1	0	358	1		
80					T	S	1	O		1	1	359	2		
80					S	T	3	O		1	0	359	2		
80					T	F	1Q	O		1	1	360	3		
80					M	T	3	O		1	0	360	3		
80					T	M	4	O		1	1	361	4	4	
81	**10:41:30**		0:40:55		T	F	1	O		1	1	362	1		
81					M	T	3	O		1	0	362	1		
81					T	S	1	O		1	1	363	2		
81					S	T	3	O		1	0	363	2	2	
82	**10:42:00**		0:41:25		T	S	9	B		1	1	364	1		right there at that table

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
82					S	T	3	B		1	0	364	1		
82					T	E	12	AX		1	1	365	2		
82					T	F	1	O		1	1	366	3		
82					M	T	3	O		1	0	366	3	3	
83	**10:42:30**		0:41:55		T	S	1Q	O		1	1	367	1		
83					S	T	3	O		1	0	367	1		
83					T	S	1	O		1	1	368	2		
83					S	T	3	O		1	0	368	2		
83	**10:42:40**		0:42:05		T	S	6	O		1	1	369	3		teacher goes to cluster to direct student work
83	**10:42:50**		0:42:15	10:44 AM	T	S	6	O		0	0	369	3		
83				10:45 AM	T	S	12	AX		1	1	370	4	4	
84	**10:43:00**		0:42:25		T	S	12	AX		0	0	370	0		
84					T	S	12	AX		0	0	370	0		
84					T	F	6	O		1	1	371	1		(teacher voice)
84					M	T	6	O		1	0	371	1		
84	**10:43:20**		0:42:45		T	E	12	AX		1	1	372	2		teacher reenters
84					T	E	12	AX		0	0	372	2		
84					T	F	6	O		1	1	373	3		
84					M	T	6	O		1	0	373	3	3	
85	**10:43:30**		0:42:55		T	F	1Q	A		1	1	374	1		(teacher is helping students who are having trouble finishing their essay)
85					M	T	3	A		1	0	374	1		
85					T	M	1Q	A		1	1	375	2		
85					M	T	3	A		1	0	375	2		
85					T	M	6	AG		1	1	376	3	3	
86	**10:44:00**		0:43:25		T	S	6	A		1	1	377	1		
86					T	F	6	A		1	1	378	2		
86					M	T	6	A		1	0	378	2		
86					T	M	1Q	A		1	1	379	3		
86					M	T	3	A		1	0	379	3		
86					T	M	6	A		1	1	380	4		
86					M	T	6	A		1	0	380	4		
86					T	M	6	A		1	1	381	5		
86					M	T	6	A		1	0	381	5	5	
87	**10:44:30**		0:43:55	10:47 AM	T	M	1Q	A		1	1	382	1		teacher is checking the last to finish to ask questions and tell them what they should do

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
87					M	T	3	A		1	0	382	1		
87					T	S	6	A		1	1	383	2		
87				10:48 AM	F	T	1Q	A		1	0	383	2		
87					T	M	1	O		1	1	384	3		let's read it together Holly
87					T	M	6	AG		1	1	385	4		helps holly individually
87					T	M	6	AG		0	0	385	4		
87					T	S	12	A		1	1	386	5	5	
88	10:45:00		0:44:25		T	F	1Q	A		1	1	387	1		(OTHER STUDENTS AT TABLE ALSO LISTEN and RESPOND)
88					M	T	3	A		1	0	387	1		
88					T	F	6	AG		1	1	388	2		
88					T	M	6	AG		1	1	389	3		
88					F	T	1Q	A		1	0	389	3		
88					T	M	3	A		1	1	390	4	4	
89	10:45:30		0:44:55		T	M	6	AG		1	1	391	1		
89					T	M	6	AG		0	0	391	1		
89					T	S	1	O		1	1	392	2		
89					S	T	3	O		1	0	392	2		
89					T	S	12	AX		1	1	393	3		
89					T	F	1Q	O		1	1	394	4		
89					M	T	3	O		1	0	394	4		
89					T	M	6	O		1	1	395	5	5	
90	10:46:00		0:45:25		T	F	1Q	O		1	1	396	1		
90					M	T	3	O		1	0	396	1		
90					T	M	6	O		1	1	397	2		
90					T	S	12	AX		1	1	398	3		
90					F	T	1Q	O		1	0	398	3		
90					T	M	3	O		1	1	399	4		
90					T	M	6	O		1	1	400	5	5	
91	10:46:30		0:45:55		T	M	6	O		0	0	400	0		
91					T	M	6	AG		1	1	401	1		
91					T	M	6	AG		0	0	401	1		
91					T	M	6	AG		0	0	401	1	1	
92	10:47:00		0:46:25		T	M	6	AG		0	0	401	0		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
92					T	M	1Q	A		1	1	402	1		
92					M	T	3	A		1	0	402	1		
92					T	M	6	AP		1	1	403	2		
92					T	M	1Q	A		1	1	404	3		
92					M	T	3	A		1	0	404	3		
92					T	M	6	AG		1	1	405	4		
92					T	M	6	AG		0	0	405	4	4	
93	10:47:30		0:46:55		T	M	1Q	A		1	1	406	1		
93					M	T	3	A		1	0	406	1		
93					T	M	6	AG		1	1	407	2		
93					T	M	6	AG		0	0	407	2		
93					T	E	12	A		1	1	408	3	3	
94	10:48:00		0:47:25		T	F	1Q	A		1	1	409	1		
94					M	T	3	A		1	0	409	1		
94					T	M	6	AG		1	1	410	2		
94					T	M	6	AG		0	0	410	2		
94					T	E	12	AX		1	1	411	3		
94					T	M	6	AG		1	1	412	4	4	
95	10:48:30		0:47:55		T	S	9	B		1	1	413	1		excuse whoa
95					S	T	3	B		1	0	413	1		
95					T	F	1Q	A		1	1	414	2		
95					M	T	3	A		1	0	414	2		
95					T	M	6	AG		1	1	415	3		
95					T	M	6	AG		0	0	415	3		
95	10:48:50		0:48:15	10:50 AM	T	F	1	O		1	1	416	4		you'll have to sit at this table here
95					M	T	3	O		1	0	416	4		
95					T	S	6	AG		1	1	417	5	5	
96	10:49:00		0:48:25		T	S	6	AG		0	0	417	0		
96					T	S	1Q	A		1	1	418	1		
96					M	T	3	A		1	0	418	1		
96					M	T	6	A		1	0	418	1		
96					M	T	6	A		0	0	418	1	1	
97	10:49:30		0:48:55		T	M	7	A		1	1	419	1		
97					T	M	6	A		1	1	420	2		
97					M	T	3	A		1	0	420	2		
97					T	M	7	A		1	1	421	3		

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
97					T	M	6	AG		1	1	422	4		
97					T	M	1Q	A		1	1	423	5		
97					M	T	3	A		1	0	423	5	5	
98	**10:50:00**		0:49:25		T	M	7	A		1	1	424	1		you don't have the right answer either
98					T	S	6	AG		1	1	425	2		
98					T	S	6	A		1	1	426	3		
98					T	F	1Q	A		1	1	427	4		
98					M	T	3	A		1	0	427	4		
98					T	M	7	A		1	1	428	5		
98					T	M	1Q	A		1	1	429	6		
98					M	T	3	A		1	0	429	6		
98					T	M	7	A		1	1	430	7		
98					T	M	6	AG		1	1	431	8	8	
99	**10:50:30**		0:49:55		T	F	1Q	A		1	1	432	1		
99					M	T	3	A		1	0	432	1		
99					T	M	7	A		1	1	433	2		
99					T	M	1Q	A		1	1	434	3		
99					M	T	3	A		1	0	434	3		
99					T	M	7	A		1	1	435	4		
99					T	M	6	AG		1	1	436	5	5	
100	**10:51:00**		0:50:25		T	M	1Q	A		1	1	437	1		
100					M	T	3	A		1	0	437	1		
100					T	M	7	A		1	1	438	2		
100					T	M	6	AG		1	1	439	3		
100					T	M	1Q	A		1	1	440	4		
100					M	T	3	A		1	0	440	4		
100					T	M	7	A		1	1	441	5	5	
101	**10:51:30**		0:50:55		T	M	1Q	A		1	1	442	1		
101					M	T	3	A		1	0	442	1		
101					T	M	7	A		1	1	443	2		
101					T	M	6	AG		1	1	444	3		
101					T	M	1Q	A		1	1	445	4		
101					M	T	3	A		1	0	445	4		
101					T	M	7	A		1	1	446	5		
101					T	S	12	O		1	1	447	6		
101	**10:51:50**		0:51:15		T	S	1Q	O		1	1	448	7		you three want to work together?

Table 38 (continued)

Interval Number	Video Verification		Elapsed time (hr:min: sec)	Elapsed computer time	who	whom	what	how		Code Change	Teacher Initiated Code Change	Summation of Teacher Initiated Code Changes	# of Teacher Initiated Codes Changes/ Interval	DECISION RATE	SOS Comments
101					S	T	3	O		1	0	448	7		
101					T	S	6	O		1	1	449	8		
101					T	F	1Q	O		1	1	450	9		
101					M	T	3	O		1	0	450	9		
101					T	M	7	O		1	1	451	10		
101					T	S	1	O		1	1	452	11		
101					S	T	3	O		1	0	452	11	11	
102	**10:52:00**		0:51:25		T	E	12	O		1	1	453	1		
102					T	E	6	O		1	1	454	2		we still have two minutes
102	**10:52:10**		0:51:35		T	E	9	B		1	1	455	3		teacher turns out light
102					L	T	3	B		1	0	455	3		STUDENTS QUIET DOWN
102					T	S	6	O		1	1	456	4		talks to students out in cluster
102					T	E	12	O		1	1	457	5	5	TEACHER IS ALSO MONITORING CLASSROOM
103	**10:52:30**		0:51:55	10:54 AM	T	S	6	O		1	1	458	1		talks to students out in cluster
103	**10:52:45**		0:52:10		T	E	6	O		1	1	459	2		you have two AND A HALF minutes
103					T	F	1	O		1	1	460	3		sit on carpet
103					M	T	3	O		1	0	460	3		
103					T	F	1	O		1	1	461	4		
103					M	T	3	O		1	0	461	4		
103					F	T	1Q	O		1	0	461	4		
103					M	T	3	O		1	0	461	4	4	
104	**10:53:00**		0:52:25		T	F	1	O		1	1	462	1		
104					M	T	3	O		1	0	462	1		
104					T	F	1	O		1	1	463	2		
104					M	T	3	O		1	0	463	2		
104					F	T	1Q	O		1	0	463	2		
104					M	T	3	O		1	0	463	2		
104					T	S	6	AG		1	1	464	3		sits with group to help them with the activity
104					T	S	6	AG		0	0	464	3		
104					T	S	6	AG		0	0	464	3	3	
105	**10:53:30**		0:52:55		T	S	6	AG		0	0	464	0		
105					T	S	6	AG		0	0	464	0		
105										1	0	464	0		
105				10:55 AM	T	E	1	O		1	1	465	1		ok freeze

VITA

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EDUCATION/TRAINING

Institution	Degree	Year(s)	Field of Study
UCLA	B.A.	1965-68	Psychology
University of Hartford	M.A.	1970-72	Biology
Sam Houston State University	Secondary Teaching Certificate	1984	Education
	Educational Supervision	1991-92	Education
Texas A&M University	Ph.D.	1992-2004	Curriculum & Instruction

RESEARCH AND PROFESSIONAL EXPERIENCE

1969-70	Teacher, Immaculate Heart of Mary School, Big Spring, Texas
1970-71	Teaching Assistant, Department of Biology, University of Hartford
1972	Teacher, Sacred Heart Academy, Biloxi, Mississippi
1973	Teacher, Notre Dame High School, Biloxi, Mississippi
1977-79	Research Assistant, University of Texas Medical School, Houston, Texas
1980	Adjunct Faculty, North Harris County Community College
1981	Jensen, D. & Castro, G. (1980). *Trichinella spiralis:* Generation in the presence of Rat Serum of Factors chemotactic for rat cells. Experimental Parasitology
1984	Geological Assistant (contract), ERCO, Houston, Texas
1984	Outstanding Secondary Education Student, Sam Houston State University
1984-95	Teacher, Oak Ridge HS, Conroe ISD, Texas
1988	Conroe Independent School District Second Mile Award
1989-90	Curriculum Writer (contract), Modern Biology, Holt, Rinehart, & Winston
1989-90	Adjunct Faculty, North Harris County Community College, Texas
1991-95	Science Department Chairperson, Oak Ridge HS, Conroe ISD, Texas
1991	Region VI Secondary Teacher of the Year, Texas
1995-1997	Graduate Assistant, GTE Internet Project-Texas Alliance, TAMU
1996	Instructor, Secondary Science Education Methods, TAMU
1996-1997	SOS Observer (contract) of K-8 classroom teachers, TAMU
1997-1998	Graduate Assistant, NSBRI Project Coordinator, TAMU
1998-2000	Project Coordinator, ECPI and SMI Projects, Rice University
2001-2003	Principal Investigator, MTM Project, Rice University
2001-2003	Project Coordinator, NSBRI Project, Rice University
2004	Director, TExES Success Institute, Rice University
2004	Co-Director, Wiess School of Natural Sciences Precollege Science