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THE RELATIONSHIP AMONG
THE COGNITIVE DEVELOPMENT LEVEL, LEARNING STYLE,
ACHIEVEMENT, AND RETENTION
OF PRESERVICE ELEMENTARY TEACHERS
IN A CONTENT COURSE IN MATHEMATICS

A DISSERTATION

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ABSTRACT

The purpose of the present study was to examine three ideas. First, the relationship between learning style preferences and the level of cognitive development of preservice teachers who are currently enrolled in a content course in mathematics was investigated. Second, the effect of using a learning style model for structuring instruction of teaching preservice teachers was investigated. Finally, this study involved determining whether teaching strategies improved retention rates of material presented. The measures used included the Scale of Intellectual Development – IV to measure the cognitive development level based on Perry's model, the Learning Type Measure to measure preferred learning style, and the Hemispheric Mode Indicator to measure right- or left-brain dominance. A traditional instruction group and a learning style model group were established. The 4MAT Learning Style Model was used as treatment on the lower achieving group. Personal interviews and responses to essays were used as part of the evaluation. According to the results of the analyses, there appeared to be no correlation between the cognitive development level and the learning style preference for either group. In achievement gains, the two groups were compared using two separate unit tests, one on probability and one on statistics. For this study, the traditional group scored significantly better than the 4MAT group. On retention of material, the groups were compared using a form of equivalent tests for probability and statistics. Unlike the results of the achievement test, the results of the tests taken to measure retention indicate that there was no difference between the two groups. The degree of retention did not appear to be specific to any particular learning style.

THE RELATIONSHIP AMONG THE COGNITIVE DEVELOPMENT LEVEL, LEARNING STYLE PREFERENCES, ACHIEVEMENT, AND RETENTION OF PRESERVICE ELEMENTARY TEACHERS IN A CONTENT COURSE IN MATHEMATICS

CHAPTER I

INTRODUCTION TO THE PROBLEM

Recently a number of educational research organizations have written very disheartening reports for our nation's schools. These reports cover the continuum of achievements in education from the elementary school through the college levels. An analysis of the Third International Mathematics and Science Study (TIMSS) report published by the United States Department of Education (USDE) and the National Center for Education Statistics (NCES) reveals that American students fall far behind students from other countries especially in the achievement areas of mathematics and science (USDE, 1996). The situation in the United States of America may be even more troubled than revealed by this report. A study conducted by Yager (1991) disclosed that even students who scored well on standardized achievement tests were unable to integrate memorized facts or formulae into real-life situations. Thus, many students see little connection between what they learn in the classroom and problems that arise in life.

In a book published by the Mathematical Association of America entitled, *Heeding the Call for Change*, the statement is made that "the purpose of teaching, and its ultimate measure, is student learning. So in some sense one cannot discuss one without the other" (MAA, 1992, p. 198). This suggests the fact that students seem to be failing is an indictment of teaching as well. At Berkeley, Thomas Angelo (1991) conducted a study on the method of delivering educational concepts to undergraduate students in a large lecture hall setting. In this study, after the lecture only 20% of the students retained what the lecturer discussed. According to Angelo, note taking appeared to be a major deterrent to internalization of the information. Also, after eight minutes into the lecture, only 15% of the students appeared to be paying attention. Unfortunately, this is not an isolated classroom in the higher education environment. Typically, first-year students "carry with them a high school tradition of passive learning which emphasizes bite-size problems to be solved by techniques provided by the textbook section in which the problem appears" (MAA, 1992, p. 197). Furthermore, Project 2061 (1990, p. xvii) charges that the curricula in science and mathematics emphasize "the learning of answers more than the exploration of questions, memory at the expense of critical thought, bits and pieces of information instead of understanding in context, recitation over argument, reading in lieu of doing." It is obvious that the methods used currently in teaching mathematics and science are not always working. Methods that were perceived to be successful thirty years ago do not necessarily work as well today. "Lectures don't work nearly as well as many of us would like to think" (MAA, 1992, p. 9). There are several reasons why lecturing is often an ineffective method of instruction for some students and, therefore, renders learning difficult.

First, some students have difficulty grasping basic concepts in mathematics and often bring with them misconceptions constructed in earlier years. According to MAA (1992), instructors consistently overestimate the amount of conceptual learning that is taking place in their classes. Students rely on memorization and very seldom form connections to previous information. Instructors also underestimate the breadth of misconceptions held by the students and not yet resolved even after the course is completed. These misconceptions may not surface until an examination is given over content covered by the lecture. Once the score is made, the damage is done.

Second, "learning is constructive. To absorb the full impact of these three words, you have to push their implied metaphor to its limits: Concepts are constructs, learning is building" (MAA, 1992, p. 9). In order to help students build their conceptual knowledge base, one must realize that the foundation upon which to build is prior knowledge. If one assumes that no mind is an empty vessel, then in order to teach a student, one must consider what knowledge a student already possesses (Healy, 1990; MAA, 1991). According to a constructivist view of teaching and learning, learning takes place when students have actively constructed their own knowledge (MAA, 1992; NCTM, 1989; Treagust, Duit, & Fraser, 1996). An active approach to learning activities seems to improve the learning experience over a traditional textbook approach. Experiences in learning mathematics through an active approach may not ensure that more mathematics is learned, but rather that the student is able to use mathematics better in interpretation of problem-solving, selection of the proper procedure to use in a given situation, and adaptation to change if the situation requires it (Boaler, 1998).

This does not imply that some learning cannot occur in traditional settings, such as lecture environments, where learners are assumed to receive knowledge in a passive fashion. According to Treagust *et al.* (1996), "the major difference is that constructivist teaching and learning approaches explicitly aim to help students to make the constructions that lead to understanding of the scientific or mathematical points of view" (p. 5).

Currently, most American college classrooms resemble a one-person show in which the teacher is the dispenser of knowledge and the students are the receivers, passive and inattentive as shown in the research cited earlier. It appears that teachers seek to distribute the knowledge to their students in teacher-dominated lectures. In order to prove proficiency the students will regurgitate the information in a manner pleasing and acceptable to the teacher. Many times it seems that this regurgitation is done without meaning, application, or connections. How then can instruction be enhanced so that learning will occur with meaning, application, and connection for more students?

Instruction should encompass experiences that address *how* students learn, not just *what* they learn. The best source of this exploration is from the students themselves "because we believe there is no one else who can teach us how they think mathematically" (Treagust *et al.*, 1996, p. 66). The role of the teacher is to engage the student's interest by organizing information around conceptual problems and situations. Teachers assist students in a learning process in which connections are made to previous knowledge as students develop new insights. The teacher acts as a facilitator. The students are encouraged to ask their own questions, conduct their own investigations, and draw their own conclusions. They take an active part in the lesson and, hopefully, in the learning process.

It has always been the intention of educators to help students learn (Beamish, 1995; Healy, 1990; MAA, 1991; NCTM, 1989). If improvement in teaching and learning in the classroom is to occur, changes must take place that involve both teachers and students. Some of these changes may be difficult to implement because teachers tend to teach as they were taught (Berg, Huinker, & Neuman, 1993; Bush, 1989; NCTM, 1989; University of Chicago, 1992). Furthermore, "mathematicians follow habit more than evidence in their teaching styles: Even well documented reports of better methods are insufficient to influence mathematicians to change their teaching habits" (MAA, 1992, p. 200). The Mathematical Association of America issues a challenge to college-level teachers:

> We really don't know how to induce most students to rise to the challenge of mathematical thinking; we have much to learn about what works and what does not. To improve our understanding of the intellectual development of college mathematics students, mathematicians should increase their efforts to conduct research on how college students learn mathematics. (MAA, 1992, p. 200)

In order to investigate how college students learn mathematics, it seems important to know something of their developmental maturity. If the cognitive development of the student is at a concrete level and the instruction is at an abstract level, a gap may exist between the material that is assimilated, if any, and that which is delivered. According to a Piagetian theory of cognition and development, a learner will assimilate experiences that are similar to previous ones by applying existing schemes without trying anything new in the way of problem-solving. However, a learner will attend to and learn most from events that are mildly contrary to his/her current level of conception. This type of experience enables the learner to apply, at least in part, the existing schemes; however, the schemes can be modified appropriately according to the particular conditions of the new experience. This, according to Piagetian theory, is called accommodation. Moderate differences allow the learner to gain the most new knowledge. If the topic is too familiar, boredom may result. If the topic is too advanced, it may contain too much information for the learner to process (Lambert, Walker, Zimmerman, Cooper, Lambert, Gardner, & Slack, 1995). This is where the gap may occur. Therefore, ascertaining the level of cognitive development of the learner may be helpful in determining what information to present and possibly how to present it.

During the past several years, significant attention has been given to models that measure the cognitive development of the adult learner. The notion that learning mathematics is merely memorization of rules and procedures is held by about fifty percent of the student population (Tharp & Lovell, 1995). How does this notion of learning mathematics relate to the student's cognitive development level?

According to Perry, Donovan, Kelsey, Paterson, Statkiewicz, & Allen (1986), "the developmental sequence is both invariable and irreversible, and development initially requires interaction with physical objects" (p. 74). How one relates to authority along with fundamental conjectures about the nature of knowledge, characterizes Perry's theory on the progression of cognitive development. As the undergraduate student encounters discord in the learning experience, s/he must make a decision whether to meet the challenge or not. The way the student makes the decision is related to his or her stage of development (Perry *et al.,* 1986). Perry's concept of cognitive growth in terms of one's relationship to authority and conjectures about the nature of knowledge compares to Piaget's explanation of assimilation and accommodation. For example, Perry (1981) states, "If one knows one's Commitments are to flow and fluctuate and conflict and reform, is one committed at all? This is the first of many paradoxes the students encounter in working out their Commitments" (p. 96). Likewise, transitions between stages in Perry's model display similarities to Piagetian accommodation.

Perry asserts that there are well-defined stages through which students progress in their learning process. The perception a student possesses concerning his/her relationship to him/herself and what s/he believes knowledge to be reveals the level of cognitive development. Four levels characterize this development. Perry called these progressive stages of development: *Dualism, multiplicity, relativism*, and *commitment in relativism* (Kloss, 1994). If the student believes knowledge to be absolute, right or wrong, then s/he is at the dualistic stage. As the student modifies her/his concept of what knowledge is, s/he determines that uncertainties and connections in knowledge exist and that professors can make mistakes. The student then progresses from a vertical representation of knowledge based on power to a horizontal one based on interchange.

In a study referenced by Kloss (1994) and conducted by Jerry Gaff in 1991, entitled *New life for the college curriculum: Assessing achievements and furthering progress in the reform of general education*, general education reform was an issue. Gaff asked the faculty to describe their typical general education students. Ordinarily, general education courses service the first two years of the plan of study for the traditional college student. The faculty reported that at this level students were passive. For the most part, the students needed to be instructed step-by-step concerning the assignments. They also avoided making their own conjectures when asked to draw conclusions. Gaff recognized this behavior as characteristic of a learner at the *dualistic* level of Perry's scheme. Upon explanation of the model to the faculty, the attitude of the faculty changed positively toward the students. Understanding why the students responded in class as they did enabled the faculty to account for the students' inefficiency (Kloss, 1994).

Tharp *et al.* (1995), noted that, according to Perry's scheme, fifty percent of students who considered mathematics as rule-based and an activity in memorization were at the dualistic stage. In order to transition them to a more active stage of development, the educator should be aware of their cognitive development. College instructors should understand that the typical freshman student, according to this study, is not at a stage of development that would enable him or her to perform complicated mental operations. Also, if the instructor presents two conflicting interpretations of a concept, this can be misunderstood by and confusing to the typical freshman student who is at the *dualistic* stage of development. This situation may allow the instructor to challenge the student and stretch his/her cognitive powers. Students can be assisted in growing from one stage to another. Awareness of the cognitive development level may also encourage the instructor to investigate possible differences in the student population within the classroom in order to reach each student better. This is one of the challenges of the National Council of Teachers of Mathematics (NCTM) that teachers of mathematics reach all learners (Gonzalez, 1994; NCTM, 1989; Tharp *et al.*, 1995).

In order for instructors to reach all learners, knowing the cognitive development level of students may prove beneficial. Additionally, knowing how to assist the learner progressively through stages of cognitive development may also be equally important. "What students learn is fundamentally connected with how they learn it. Students' opportunities to learn mathematics are a function of the setting and the kinds of tasks and discourse in which they participate" (NCTM, 1991, p. 21). The abstraction of mathematics requires that in order to be successful in its study, one must progress further than the dualistic level of cognitive development. Experiences that challenge a learner to assimilate and accommodate information may also enhance transition to a higher level of cognitive development. These experiences may need to be presented in different ways so that all learners can be successful.

Research indicates that students learn in different ways (Ayersman, 1993; Beamish, 1995; Callan, 1996; Davidson, 1990; Dunn, Giannitti, Murray, Rossi, Geisert, & Quinn, 1990; Dunn & Griggs, 1990; Dunn, Sklar, Beaudry, & Bruno, 1990; Healy, 1990; Henson & Brothwick, 1984; Higgs, Givonetti, & Williams, 1994; Lenehan, Dunn, Ingham, Signer, & Murray, 1994; Matthews, 1994; NCTM, 1989; NCTM, 1991; Perry, 1994; Pettigrew & Buell, 1989). Instruction should deal with strengths and weaknesses of the learner during the learning process. In many cases, modes of learning remain a mystery both to the educator and to the learner. Exploration of learning styles has grown from the need to comprehend and benefit from individual modes of learning to how to apply the theory of learning styles in the classroom to enhance learning. Since many students learn differently, the educational process should help students take advantage of their strengths and build up their weaknesses in the course of learning (Ayersman, 1993; Beamish, 1995; Healy, 1990).

According to Keefe (1984), in past centuries, teachers taught and students learned. If the latter did not happen, it was considered no fault of the teachers. No revision of methods was deemed necessary. Certainly educational research before 1950 centered on the learner and the subject. There appeared to be no inclination to investigate teaching style (Henson & Borthwick, 1984). Within the last twenty-five years, extensive research by Rita Dunn at St. John's University has examined the way students learn. Dunn defines learning style as "the way in which information is absorbed and retained; that is, it describes not 'what' the learner learns but 'how' the learner learns" (Perry, 1994, p. 1). These stable characteristics of the learner may vary depending on the task and the particular situation. Patterns of perception and responses to stimuli appear to be consistent for most individuals in the learning process (Henson & Borthwick, 1984;

Perry, 1994; Pettigrew & Buell, 1984). Learning styles are relevant in most educational situations in which the learner processes information. "To support the concept of individualism, educators need to support, value, and nurture the unique combinations of special abilities or intelligences of each 'differing' individual student" (Beamish, 1995, p. 31).

Higher education institutions are currently faced with the challenge of balancing standards and impartiality among a student populace with many differences. High school grades and performance on various tests help predict areas of study in which the student should be successful, but very little consideration has been given to the possibility that instructional approaches may also contribute to the student's success or failure in the pursuit of a particular major (Matthews, 1994). Considerations of these instructional approaches involving choices and decisions by teachers in the classroom should include knowledge of the topic, knowledge of the student, and knowledge of the learning process (Pettigrew & Buell, 1989). Knowledge of the student includes awareness of the student's cognitive development level to help insure that gaps do not occur between reception and presentation of experiences. The teacher's knowledge of the topic is very seldom an issue at the higher education level. Knowledge of the learning process includes an awareness that not all students learn in the same fashion and that instructional variations in presentation of information may result in success in the classroom from both sides of the desk.

The present study is concerned with preservice elementary teachers who are learning mathematical concepts perhaps for the first time. Most of these students are freshmen or sophomores and would agree that up until now they have learned mathematics by memorization; many of them believe that mathematics is a rule-based discipline and that if one follows the 'rules,' one will obtain the 'correct' answer. When asked to explain a mathematical procedure, most of these students will say, "doing it this way gives you the right answer;" or "that's what the rule says to do;" or "this is the way I always do it." These are characteristics of the *dualistic* learner as described earlier. Mathematics topics beyond the concrete level usually prove to be too challenging and therefore defeating for this type of learner.

Using methods of instruction which vary from, and yet do not necessarily exclude, the lecture method may empower the learner and enable him or her to advance to more abstract notions of mathematics. This would be evident in cognitive stage progression and depth of understanding. For the preservice teacher, presentation of mathematical concepts using a variety of instructional strategies at the collegiate level may have long range benefits for the current reform movement in mathematics education.

Research Questions

How do changes in instructional strategies that focus on diversity of students' learning styles impact the level of cognitive development, achievement, and retention of those students enrolled in a mathematics content course for preservice elementary school teachers? More specifically:

1. What is the relationship between learning style preference and level of cognitive development? Does the use of a teaching style model designed to accommodate different learning styles of students bring about a transition in the level of cognitive development?

2. Does the use of a learning style model for teaching impact the achievement of those students enrolled in a mathematics content course for preservice elementary school teachers? If so, is the degree of impact specific to any particular learning style type?

3. Does the use of a learning style model for teaching impact the retention of material presented to those students enrolled in a mathematics content course for

preservice elementary school teachers? If so, is the degree of retention specific to any particular learning style type?

The next chapter will present a review of the cognitive development theories of Piaget and Perry. Perry's model focuses upon the intellectual 'depth' of the material being presented to students. An illustration of 'depth' can be provided by a brief examination of the educational process of the beginning college mathematics student. With the study of algebra the student learns to solve simple, well-defined structured problems. The solutions, for the most part, are procedural and systematic with a definitive answer. In later studies, for example in geometry, the student learns to work a more complex problem in which there may be more than one solution, such as in proof writing. In attempting to meet performance objectives, the student is faced with a situation in which there is no single right answer, but there are incorrect answers.

Justification for using Perry's model will be given, and a review of research suggests that students have characteristic strengths and preferences in the ways they take in and process information. Various approaches to exploring learning styles will be presented in the next chapter. The 4MAT model, developed by Bernice McCarthy in 1972, is a teaching model that integrates Kolb's learning style model with brain hemisphericity. The selection of the 4MAT learning style inventory will be justified.

CHAPTER II

REVIEW OF THE LITERATURE

In the previous chapter, it was suggested that we, as educators, should examine and explore a variety of instructional methods in higher education. Knowing more about students' cognitive development and exploring a variety of instructional strategies that vary from the traditional lecture format may help resolve some of the academic tensions for our students. The question posed for this research is: How do changes in instructional strategies which focus on diversity of students' learning styles impact the level of cognitive development, achievement, and retention of those students enrolled in a mathematics content course for preservice elementary teachers?

In this chapter a review of literature as it relates to cognitive development of college students, learning styles, and teaching strategies is presented. Sections of the chapter include (1) constructivism and mathematics education; (2) cognitive development and assessment of college students; (3) learning style research in education; (4) the 4MAT system of instruction; and (5) focus of the present study.

Constructivism and Mathematics Education

Learning is a personal experience. "A body of knowledge is continually under construction, and some nucleus of it is firmly established" (Noddings, 1990, p. 12). It is a continually changing experience through which the learner constantly updates information. The processes of updating information and of building upon prior knowledge are characteristics of the philosophical perspective on knowledge and learning known as constructivism.

"Constructivists believe that students construct their own meanings of mathematical concepts and procedures when they are given the opportunity to become actively involved in learning. Teachers facilitate students' active construction rather than dispense rules and algorithms" (Prevost, 1993, p. 75). Constructivists rely on cognitive psychology for much of their theoretical underpinnings.

Developmental constructivism owes much of its current conception to the works of Piaget (English & Halford, 1995; Jaworski, 1994; Noddings, 1990). Piaget's best-known accomplishments were for his extensive studies on the developmental stages through which children progress in the learning process. Each stage represents a different way in which the world is understood. The first stage is the sensorimotor stage and consists of the period from birth to about two years of age. The second stage is the preoperational stage and spans the period from two years to seven years of age. The span from seven years of age to about twelve is the concrete operations stage (English & Halford, 1995). Actual events, situations, and objects concern the concrete operational thinker (Hembree, 1990). The formal operational thinker, on the other hand, can use imagination and intuition to stretch his/her thinking. Abstract presentations or issues are manageable for the thinker at this level. The span of this level is from about 13 years of age to adulthood. Some speculate that only about half of the students entering college are at the formal operational level (Shodahl & Diers, 1984; Humbree, 1990).

According to English and Halford (1995), Piaget suggested that interaction with the social and physical environment helps develop these deep-seated basic structures of thinking. Piagetian tasks such as conservation were taught to children attending early childhood programs in hopes of advancing the learner to appropriate stages for progressive educational success. However, problems arose in this training. It seemed that gaps existed between the Piagetian tasks and school mathematics tasks and that the theory did not provide means for bridging these gaps. Mastering Piagetian tasks does not necessarily improve performance in school mathematics (English & Halford, 1995).

In later periods, Piaget did comment on the processes a child uses in learning mathematics. Logicomathematical experiences are used in the learning process in these later structures. Here the child engages in reflective abstraction, an essential component of the constructivist meaning of arithmetic (English & Halford, 1995; Noddings, 1990). A child is unaware of many of the methods used for problem solving. For mathematical thinking to develop, the child needs to become observant of these processes. This is related to the concept of metacognition, or thinking about one's own thinking (English & Halford, 1995). Figure 2.1 provides a brief outline of each stage of cognitive development and the characteristics associated with the stage.

FIGURE 2.1
PIAGET'S COGNITIVE DEVELOPMENTAL MODEL

Developmental Stage	Projected age	Characteristics
Sensorimotor Stage	Birth – 1.5 to 2 years	Problems are solved by using the sensory systems and motor activity. Knowledge of objects comes from action upon them.
Preoperational Stage	1.5 to 2 – 8 years	Develops symbolic functioning. Degree of correspondence is highly concrete. Can apply schemes to nonimmediate events.
Concrete Operational	8 – 13 years	Can solve a variety of tasks. Conservation of number. Mental operations: Negation, reciprocation, and identity. Thinks sequentially.
Formal Operational	13 – adult	Can solve a problem by applying a rule. Has the ability to consider hypothetical abstract problems. Thinks simultaneously.

Knowledge results from individual construction. Our collective experiences comprise what we know. Each new concept encountered either adds to the collection or threatens its validity. For each person this collection consists of the formulation of personal experiential situations (Jaworski, 1994). As experiences change, then modifications may occur in the constructions (Beamish, 1995; Jaworski, 1994; NCTM 1991). However, participation in mathematical activities does not necessarily mean that one is involved in construction. Teachers must investigate the responses of their students in order to determine the level of understanding or misunderstanding (Jaworski, 1994; NCTM, 1989). Noddings (1990) states in her research, "In order to teach well, we need to know what our students are thinking, how they produce the chain of little marks we see on their papers, and what they can do (or want to do) with the material we present to them" (p. 15).

The NCTM *Curriculum and Evaluation Standards for School Mathematics* emphasizes the significance of children being actively involved in their learning. That is, they should "construct, modify, and integrate ideas by interacting with the physical world, materials, and other children" (NCTM, 1989, p. 17). The constructivist's perspective maintains that learners must construct conceptual knowledge from their own experience (Jaworski, 1994; English & Halford, 1995). For this reason we should give the learner opportunities to reflect upon and reconstruct their established ways of thinking (English & Halford, 1995).

How students learn is directly connected to *what* they learn. The classroom environment and the course of events within the classroom offer opportunities for learning to take place (NCTM, 1991; NCTM, 1989). But we must keep in mind that today's students are products of a different youth culture than that which was experienced by most college professors. Surrounded by video games, computers, MTV, and cyberspace, the youth of today seem to be over-stimulated and have difficulty with concentration for an extended period of time. This may be why the lecture/recitation mode of instruction does not work as well for some students today as it once did.

Most college students, however, seem to be willing to experiment with new ideas and new ways of learning. As teachers of collegiate mathematics we should always think about *what* we teach, but this call for change challenges us, likewise, to think about *how* we teach. Mathematical thinking and mathematical skills should be taught hand-in-hand. Individuals should be taught to speculate and investigate their intuitions (NCTM, 1989; Peck & Connell, 1991). What are the best ways to engage students in constructing their own knowledge? Are there better ways of introducing important subject matter than by the traditional lecture method? How can we help the student connect this subject matter to previously constructed knowledge?

Cognitive Development and Assessment of College Students

In order to help students learn how to construct their own knowledge, the instructor's awareness of the students' stage of cognitive development may be beneficial. If a gap occurs between the students' level of development and the instructor's level of instruction, construction of knowledge and connection of information to previous knowledge may be hindered. Many psychologists and researchers argue that Piagetian reasoning is not sufficient to account for ways adults learn. The suggestion is that more advanced reasoning skills develop after the development of formal thought (Perry *et al.*, 1986). William Perry proposes that post-adolescent students develop cognitively at different stages (Daragan & Stevens, 1996). The schemes of Piaget and Perry define developmental change within each respective scheme by analyzing different kinds of interactions. Interactions with physical objects foster development within the Piagetian scheme, whereas interactions with authority figures and peers foster development within Perry's scheme (Perry *et al.*, 1986). Therefore, a student's inability to achieve the goals prescribed by the instructor may be a result of developmental differences. Figure 2.2 shows a comparison of levels of development between Piaget's model and Perry's model.

FIGURE 2.2
COMPARISON OF LEVELS OF DEVELOPMENT

Piaget's levels of development	Perry's levels of development
Sensorimotor period	
Preoperational period	
Concrete Operational period	Dualism stage
	Multiplicity stage
Formal Operational period	Relational stage
	Commitment and empathy stage

In recent years, Perry's model of cognitive development has gained notoriety in the fields of higher education and applied psychology (Lavallee, Gourde, & Rodier, 1990). This model was derived from a four-year study of undergraduate male students at Harvard University. The model parallels Piaget's structural conjectures and methodologies as they apply to young adults. Studies have been conducted (Lavallee *et al.*, 1990) to confirm the significance of Perry's model in evaluating the cognitive and ethical development of young university students. Consistent relationships between levels of education and positions of stage development have been found.

Perry's model consists of four stages or positions of cognitive and moral development. These stages include nine positions that describe how a person understands and makes meaning of information gained. "Each position includes and transcends the earlier ones, as the earlier ones cannot do with the later. This fact defines the movement as development rather than mere changes or 'phases' " (Perry, 1981, p. 78). The first stage or position is known as *dualism*.

In the *dualistic* stage the learner depends upon the authority for correct answers. Individuals in this stage tend to view issues as right or wrong. Acceptance of more than one solution is not viable at this level of cognitive development (Daragan & Stevens, 1996; Henderson, 1992; Moore, 1990; Perry, 1981). In this stage the learner's capability is to receive and know facts. In this passive position, the learner's concept of knowledge is that it is just a collection of facts and all knowledge is known. The instructor and possibly the textbook are the primary sources of authority (Henderson, 1992; Moore, 1990; Perry, 1981). A learner in the *dualistic* stage views the classroom setting as a give-and-take environment: The instructor gives information, and the learner receives it. Then, assessment of learning is based on testing exactly what was taught. Structure within the classroom setting is important. This learner expects the classroom to be a structured environment and, in general, prefers the lecture method of instruction. The major emphasis placed on learning is *what* to learn as opposed to how to learn or how to think (Moore, 1990).

The second stage of Perry's model is called *multiciplicity*. The learner in this stage recognizes that there may be more than one possible solution to a problem. There is still a sense that knowledge is right or wrong, and the learner views the instructor as the final authority. The learner also believes that there possibly is knowledge that has not been discovered yet. Practicality is an important factor in the learning process (Henderson, 1992; Moore, 1990), and is the responsibility of the learner to figure out how to perform the process to ensure the correct answer. This learner begins to accept a less structured atmosphere in the classroom and supports more than one method of teaching and method of assessment. Hard work is the assumed key to success in acquiring knowledge for the learner in the multiplicity stage. Many in this stage rely on rote procedures as a way to learn rather than learning for understanding (Gonzales, 1994; Moore, 1990; Perry, 1981). Therefore, the major emphasis on learning is *how* to learn rather than learning for understanding (Moore, 1990).

Relativism is the label used for the third stage of development according to Perry's model. Learners at this stage are able to make decisions on their own and accept the consequences of those decisions. Views that contradict their own can be admissible as possible alternatives. These learners view the instructor or authority as a model of how to think. More responsibility for learning is assumed by the learner in the relativism stage, and a more active role is taken by the learner concerning course content and process. All are viewed as having a right to their own opinion. Therefore, peers as well as authorities are sources of learning (Gonzales, 1994; Henderson, 1992; Moore, 1990; Perry, 1981). It is the responsibility of the learner to think independently, and the learner begins to realize that critical evaluation must be made of all information (Daragan & Stevens, 1996), so the classroom setting for this student can be much more flexible. In the learning process, this student begins to analyze the information. Therefore, the major emphasis on learning is *how to think.* Assessments such as essays are welcomed and may be viewed as a means of self-expression (Moore, 1990).

The final stage is *commitment and empathy* (Gonzales, 1994). These learners have sensitivity for other people and society and are aware of their impact on other people. They have made major decisions and accept the consequences of their actions. This learner struggles for expertise and approves of learning just for the sake of learning; the process of learning is considered a serious matter. The student at this stage is highly motivated, and this motivation is usually intrinsic. Seminar settings are most enjoyable for the learner at this stage. Feedback is a critical issue; this learner desires analysis of his/her opinions and points of view. The grade is important to this student; but the learning experience is more consequential (Gonzales, 1994; Moore, 1990). The emphasis placed on learning is "how to think in context" (Moore, 1990, p. 9). It is at this stage that students realize that instructors do not have all the right answers. The learner analyzes information, recognizes biases of experts, and readily adjusts his/her thinking when new evidence demands it (Daragan & Stevens, 1996; Kloss, 1994). According to Perry (1981), the learner in the *commitment* stage now realizes "Authorities are not asking for the Right Answer; They want us to *think* about things in a certain way, *supporting* opinion with data" (p. 79). Figure 2.3 shows Perry's scheme of cognitive development.

FIGURE 2.3
PERRY'S SCHEME OF COGNITIVE DEVELOPMENT

Stages of Development	Description
Dualism	Good versus bad; right versus wrong; all that is not success is failure
Position 1	Authorities know everything; work hard; learn right answers
Position 2	True Authorities must be right; others are deceitful; if I am right, others are different, and then they must be wrong.
Position 3	Some uncertainties and varying opinions are real and justifiable temporarily, even for Authority.
Multiplicity	In areas where correct answers are not yet known, differences of opinion and values are recognized as justifiable.
Position 4	No one is wrong, if Authorities do not have the right answers; in some cases, the right answer is not what the Authority is looking for, they are looking for how we *think* about things.
Position 5	Everything is comparative but not equally valid. Understanding context is a desirable thing;
Relativism	Frequently refer to forward movement in terms of commitment.
Position 6	Student becomes aware of some sort of spiritual strength. Alternatives are carefully thought about and choices are narrowed.
Position 7	Students are prepared to make choices. They act consequently. Usually first commitment is made here.
Commitment	Affirmation of choices made in the previous stage.
Position 8	Priorities are established among numerous commitments.

Table 2.3 – *Continued.*

Stages of Development	Description
Position 9	Balance is achieved among commitments. Usually occurs when adults are beyond undergraduate years.

Although several researchers divide or name the stages differently, the basic characteristics remain the same for each stage. It is debatable whether it is even possible for a student to progress more than one level within one semester. According to Perry (1981) and Kloss (1994), students may not progress at all. It is believed that one does not digress totally within the model. If any digression does occur, it is thought to be only one level back. That is, a student may "retreat" to a previous level for various reasons yet still retain the enrichment gained from that cognitive level. Perry (1981, p. 92) called this a "reaction of alienation." A student may even react negatively to the developmental process.

Another reaction of alienation is labeled *escape*. In this transitional state for the adult learner "self is lost through the very effort to hold onto it in the face of inexorable change in the world's appearance. It is a space of meaninglessness between received belief and creative faith" (Perry, 1981, p. 92). According to Perry (1981), these are times of transition between the stages of cognitive development. In general, most development begins to slow down at about the middle of the scale. Kloss (1994, p. 154) states that "growth creates a sense of loss in students, the loss of a certainty that has sustained them and been a refuge in an increasingly complex and confusing world." Therefore, educators need to be sensitive to the learner's potential reaction of alienation as they progress through these stages.

In research cited by Lavallee *et al.* (1990), 202 female students were tested using Perry's scale; only about 25% reached higher levels of development. The majority of those women tested at the *multiplicity* stage, with only 5% testing at the *commitment* stage. In research done by Lavallee *et al.* (1990), 150 females participated in the study. Seventy-four of the volunteer participants were first-time students varying in ages. Seventy-six volunteer participants were regular university students who had attended the university for two years. The focus of the study was to determine the nature of cognitive development of women and the role higher education and social transformations play in attaining high positions on Perry's developmental scale. The study involved extensive personal interviews of all the participants. The findings revealed that education alone cannot explain advancement in cognitive development. The study found that many women, not just university students, had reached comparable cognitive development levels. This attainment occurred through experiences in life as well as education. The study found that for both groups, celibacy was the only common factor which may be predictive of cognitive development. Complexity of the experience and intricacy of the individual make the cognitive growth process a nonlinear model. Cognitive development is not circular either; it is better described as a helix. The expanding radius demonstrates that "when we face the same old issues we do so from a different and broader perspective" (Perry, 1981, p. 97).

There are basic similarities and differences when considering Piaget's theory and Perry's theory. Perry acknowledges the influence of Piaget in his work. Both theories feature stage development that is considered sequential in terms of intellectual development, and both characterize cognitive maturity by the connections a learner makes with his/her environment (Perry, *et al.*, 1986).

As educators we should realize that our students are at varying stages of development. A better understanding of where the student is in the cognitive development model may enable the educator to plan activities that might enhance the learner's growth. Since different stages indicate different needs, the challenge for the educator is to "communicate with students who make meaning in different ways and to provide differential opportunities for their progress" (Perry, 1981, p. 107). This certainly presents a challenge for the educator.

In addition to various levels of cognitive development, another way learners may differ is the method by which they receive and process information. To enhance cognitive growth, instructor awareness of various styles of learning may aid in the development of instruction that integrates cognitive stage development with the ways in which students learn.

Learning Styles Research in Education

There are several models of learning styles that have been developed to characterize differences in a student's preferred approach to learning. This research focuses on the following perspectives of learning styles: Sensory modalities emphasize use of the senses; the Canfield Model emphasizes conditions, content, modes, and expectations; the Dunn Model focuses on classroom experiences; Gardner's Theory on multiple intelligence is directed toward neurological processes; Kolb's Model emphasizes distinctive behaviors and dualities; Hemisphericity focuses on left- and right-brain dominance; and the 4MAT Model integrates Kolb's Model and Hemisphericity. The models have different characteristics, but tend to overlap in many areas. A detailed discussion of each model is provided below.

Sensory Modalities Learning Style Model

Educational research in the late 1970s and early 1980s began to investigate modality-based learning. In this style, the learner prefers to receive information through one or more of the senses (Ayersman, 1993). Although use of some of the senses is obviously necessary in most learning situations, in the discussion of learning styles, preferences of conditions that enhance learning are the focus. Sensory modalities are defined by most researchers as auditory, visual, tactical and kinesthetic. According to Callan (1996), auditory learners remember most of what is taught orally. About 30 percent of students are auditory learners; this implies that 70 percent of learners are not auditory learners and, therefore, will forget what they are told soon after the experience. Materials that are new or difficult are usually presented in a lecture format. Unless this information is presented in at least one other mode, many students may have difficulty with learning the material. Visual learners remember material best when it is presented optically. Tactical learners learn best by using hands-on activities. Kinesthetic learners learn best when the situation involves the entire body. Activities such as role playing in which the student acts out a part, or field trips, would meet the needs of the kinesthetic learner. This type of learner has the most difficulty processing new material unless the educator meets the challenge of incorporating whole body activities into the lesson presentation.

A modality study conducted by Shrum (1985) involved twenty college freshmen enrolled in a second language course. There were twelve females and eight males. The students and teacher were given the Swassing-Barbe Modality Index (SMBI) test to determine primary and secondary sensory modality. No significant differences were found in modality and semester grade, SAT score, self-assessed modality, gender, or teacher modality. The instructor's primary modality was auditory with visual and kinesthetic of equal secondary strength. Of the students tested, six were kinesthetic, three were visual, and three were auditory. Eight students' test scores indicated that they had mixed modalities; that is, these college students had learned to use their visual strengths to offset their auditory weaknesses. Shrum concluded that modalities tend to blend together as one matures. Also, anxiety did not appear to be a significant factor of mismatched teaching and learning modalities. According to this study, presenting the same material in different modes may benefit all students in the classroom and alleviate frustration for the student who has not yet learned to integrate modalities.

Canfield Learning Style Model

Another type of learning style model focuses on external environmental influences. Multidimensional aspects of the learning environment include conditions of the room, content of topic, modes of the student and teacher, and expectations of the student and teacher. The Canfield model was developed in order to measure these aspects (Ayersman, 1993). This model is based on the components of Maslow's hierarchy of needs and McClelland's theory of achievement motivation (Matthews, 1994).

The Canfield instruments for measuring learning styles of students and teaching styles of educators can be used to assess preferences of secondary school students, college students, and instructors (Gruber & Carriuolo, 1991). The Learning Styles Inventory (LSI) for students is a self-reporting questionnaire consisting of 30 items. Students describe their learning preferences based on their educational experience. The instrument is a Likert scale model on a four point scale (Matthews, 1994).

The Canfield LSI measures three basic domains using 21 scales of measurement. The scales include eight preferred Conditions of Learning, four preferred Areas of Interest, four preferred Modes of Learning and five preferred Expectations for Course Grades. The Conditions for Learning measures learning preferences involving peers, organization, goal setting, competition, instructor, detail independence, and authority. The Areas of Interest measures learning preferences involving numeric, qualitative, inanimate, and people. The Modes of Learning offer choices of listening, reading, iconic, and direct experience as learning preferences. The Expectations for Course Grades offer preferences of A, B, C, D (Matthews, 1994; Gruber & Carriuolo, 1991). Figure 2.4 shows the three basic domains of the Canfield LSI.

FIGURE 2.4
CANFIELD MODEL OF LEARNER'S EDUCATIONAL PREFERENCES

Scales	Description
Conditions of Learning	Peers, Organization, Goal Setting, Competition, Instructor, Detailed Independence, Authority
Areas of Interest	Numeric, Qualitative, Inanimate, People
Modes of Learning	Listening, Reading, Iconic, Direct Experience
Expectation for Course Grades	A, B, C, D

In the Canfield study conducted by Matthews (1994), 2332 students participated. Students were classified according to major. The major categories consisted of mathematics, science, business, humanities, social science, and education. The students were administered the Canfield Learning Styles Inventory. Percentages were computed to show the proportion of students in nine learning typologies within the disciplines among the six categories. The learning typologies were: Social, Independent, Applied, Conceptual,and Neutral Preference. The researchers also grouped the students into two continua categories: Social/Applied, Social/Conceptual, Independent/Applied, and Independent/Conceptual as shown in Figure 2.5.

FIGURE 2.5
CANFIELD MODEL INSTRUCTOR AND LEARNER TYPES

Type	Learning and instruction preferences
Social	Preference: Extensive opportunities to work with peers; Not preference: Applied or conceptual approaches; Instruction: Cooperative learning activities, teamwork
Independent	Preference: Work alone toward personal goals; Not preference: Applied or conceptual approaches. Instruction: Self-selected, self-paced programs
Applied	Preference: Work on activities directly related to real experiences; Not preference: Social or independent approaches. Instruction: Practicums, team labs
Conceptual	Preference: Work in highly organized language-oriented materials; Not preference: Social or independent approaches; Instruction: Lectures, readings
Social/Applied	Preference: Activities which closely resemble real-world problems; Instruction: Role playing, group problem solving, practicums
Social/Conceptual	Preference: Group activities in highly structured language-oriented materials; Instruction: balance lecture and discussion
Independent/Applied	Preference: Work alone on activities which resemble real problems; Instruction: Individual labs, unsupervised practicums

Figure 2.5 – *Continued.*

Type	Learning and instruction preferences
Independent/Conceptual	Preference: Work alone in highly organized language-oriented materials; Instruction: Independent reading, literature searches;
Neutral Preference	No clear areas of strong preference, may find it difficult to get involved at times.

Students majoring in mathematics and science tended to fall into the applied category more often than those majoring in humanities, social science, and education. Education majors fell into the conceptual category. Although both men and women in mathematics tended to be applied, women were more independent in their style of learning. In social science and education, the social combination of categories contained high proportions of participants. Women tended to select the conceptual and independent categories more frequently than men did. In mathematics and science, African Americans preferred conceptual styles. Caucasian Americans preferred the applied styles. Humanities and education revealed no significant differences between races. There were unbalanced enrollments in mathematics and education. The ratio of men to women enrolled in mathematics was 2.5 to 1. The ratio of women to men enrolled in education was 4 to 1. Caucasian Americans enrolled in mathematics twice as often as African Americans proportionally (Matthews, 1994).

Matthews (1994) asserts that educators claim that if teachers were flexible and innovative in the educational approaches, many students would be successful in majors that might have excluded them for various reasons. It was suggested that if instructors could match the course content, assignments, and presentation of material to the learning styles of the students, perhaps more students would achieve success within the chosen major. This would enhance achievement, help retain students at the college level, and offer greater satisfaction for the student and greater feelings of accomplishment for the instructor.

Research on learning styles suggests that an instructor use information obtained from the self-reported inventory to modify content presentations and classroom conditions to make them more congruent with the learning style preferences of students. According to Holland, cited by Matthews (1994), people tend to be content in occupations and remain in them longer when there is a match in job skills and personal traits. This has major implications for the classroom environment and the planning of the instructor at the college level. No longer should we be satisfied with presenting material in one fashion and expecting success of our students. In order to retain more students at the college level, we may need to make adjustments in teaching techniques.

Dunn Learning Style Model

This approach to evaluating learning styles was developed by Rita Dunn in the 1970's at St. John's University. The styles are defined in terms of individual student responses to 23 elements of instructional conditions. Immediate environment includes noise level, temperature, light, and classroom design. Emotionality environment encompasses motivation, persistence, responsibility, and structure. Methods of grouping identify the grouping preferences, which include learning with peers, learning with adults present, learning in combined ways, being motivated by the teacher, being motivated by a parent, or possibly desiring to learn alone. The physiological characteristics are much like the sensory modality characteristics. These include auditory, visual, tactile, kinesthetic, time of day preferences, energy levels, intake, and mobility. Global/analytic, hemispheric, and impulsive/reflective preferences are categorized as psychological inclinations. Figure 2.6 shows the identification of preferences according to Dunn.

FIGURE 2.6
DUNN LEARNING STYLE PREFERENCES

Learning Type	Instructional Environments
Immediate Environment	Noise level, temperature, light, design
Emotionality	Motivation, persistence, responsibility, structure
Grouping Preferences	Learning alone, learning with peers, learning with adults present, learning in combined ways, being motivated by the teacher, being motivated by a parent
Physiological Characteristics	Auditory, Visual, Tactile, Kinesthetic perceptual preferences, time of day, energy highs or lows, intake and mobility;
Psychological inclinations	Global/analytic, hemispheric preference, impulsive/reflective

The Learning Style Inventory (LSI) is possibly the most widely used instrument in education. It is used to analyze the learning process primarily on the secondary and elementary level. The LSI is easy to administer and has high reliability. Questions are based on a 5-point Likert scale and take about 30 to 40 minutes to complete. Scores that are calculated on the self-reported questionnaire as extremely high indicate a preference for a particular style. Scores that calculate as low indicate a low preference for that condition. If the calculated score is in the middle range, no preference for that style is indicated (Dunn, Giannitti *et al.*, 1990; Lenehan *et al.*, 1994).

There is much research that employs the Dunn model to evaluate learning styles. One such study by Dunn, Giannitti *et al.* (1990), investigated how grouping students affected the way students processed information. This study revealed that students who were grouped according to their learning style preferences had higher achievement scores and better attitudes than the students who were mismatched according to their preferences. One interesting discovery in this study was that students who showed no preference to grouping actually performed better when they studied independently than they did when they studied with their peers. Their attitudes also were better when they studied alone.

In a study by Lenehan *et al.* (1994), the effect of matching homework activities with the learner's style of processing information was investigated. It was hypothesized that the match would increase achievement and curiosity, and reduce anger and anxiety. The Dunn LSI was used to evaluate the preferences of 203 first-year nursing students. These students were predominantly female, full-time students. The participants were randomly divided into two groups. The 4MAT group participants were assigned homework without any analysis of their learning preferences. The experimental group participants were shown how to use their learning style preferences to study their homework. The experimental group achieved significantly better scores in the science courses than the 4MAT group. The experimental group also had a higher overall grade point average, which may indicate that the knowledge of learning preferences carried across other subject areas as well since the groups were considered equal when the experiment began. The interest level increased in the experimental group and decreased in the 4MAT group, while the anxiety level decreased in the experimental group and increased in the 4MAT group. These findings support identifying learning styles of college students and then using that knowledge to help students develop methods of studying their homework.

Gardner's Multiple Intelligence Theory

The task set before a research team at Harvard Graduate School of Education in 1979 was to investigate the "Nature and Realization of Human Potential" (Gardner, 1993, p. xi). Howard Gardner was a member of the team; four years later he published the book, Frames of Mind, which was a result of the conclusions he drew from this research endeavor. As a result of Gardner's research, emphasis on and awareness of learning styles have flourished.

It is important to note that Howard Gardner does not consider intelligence to be the same construct as a learning style. In a recent article published in 1996, Gardner stated,

> The concept of style designates a general approach that an individual can apply equally to every conceivable content. In contrast, an intelligence is a capacity, with its component processes, that is geared to a specific content in the world (like musical sounds or spatial patterns). (p. 11-12)

However, the existence of multiple intelligences is categorized many times in the literature along with learning styles, perhaps because there seems to exist a relationship among intelligences and learning style preferences.

Gardner defines intelligence as "the ability to solve problems, or to fashion products, that are valued in one or more cultural or community settings" (Gardner, 1993, p. 7). He believes that we should get away from tests and not try to calculate correlation between tests and learning achievement levels. Consider instead how people develop skills that are necessary to survive in their part of the world. Suppose an African native, who is a leader in his/her community and respected by the tribe, and a Japanese honor student were to take the Stanford-Binet Intelligence Quotient (IQ) test. All would surely agree that the honor student would score higher. But would the honor student necessarily be more intelligent than the native? According to Gardner (1993), s/he would not. The native may have the same intelligence level as a Japanese honor student; however, the Japanese honor student has just been exposed to more of the topics of consideration on the IQ test. Thus, within his/her culture, the native displays a high degree of intelligence. This illustration enables Gardner to apply his definition of multiple intelligence. "Problem solving skill allows one to approach a situation in which a goal is to be obtained and to locate the appropriate route to that goal" (Gardner, 1993, p. 15).

In another illustration of his definition of multiple intelligence, Gardner (1993) discusses a scenario that is common in the public school system. Two children entering middle school are given an IQ test. One student scores well above his/her age equivalent. The other scores at grade level. S/he is considered an "average" child. However, if one continues to examine this pair, many times the "average" student excels in life and the "above average" is frustrated in the work environment. IQ tests measure only logical or linguistic capabilities and, therefore, define intelligence as the "general ability that is found in varying degrees in all individuals" (Gardner, 1993, p. 14).

Gardner (1993) has identified seven intelligences:

- Musical Intelligence. Areas that are located in the right hemisphere of the brain play an important role in discernment and construction of music. There appears to be a biological link to musical intelligence.

- Bodily Kinesthetic Intelligence. Each hemisphere of the brain directs bodily movement from the cerebral cortex. Damage to this area results in an inability to perform coordination movements, which suggests that bodily kinesthetic knowledge indicates a form of intelligence.

- Logical-Mathematical Intelligence. Scientific thinking is one label for this intelligence. This process is usually very quick for the highly intelligent. This intelligence is also nonverbal; for example, a solution can be formulated mentally before it is spoken aloud or written down. This intelligence is consistent with the notion of traditional IQ.

- Linguistic Intelligence. A specific area of the brain is responsible for grammatical construction. If damage occurs here, sentences are difficult to communicate. Understanding is not impaired, just the ability to actually put the words together. This intelligence is consistent with the notion of traditional IQ.

- Spatial Intelligence. The right side of the brain is responsible for spatial processing. This intelligence includes the ability to solve a problem visually, such as navigational procedures. When damage occurs to this area of the brain, the learner will try to compensate for the loss by reasoning aloud or making up answers. These attempts are usually unsuccessful.

- Interpersonal Intelligence. This intelligence involves the ability to read people, to discern their moods, motivations, and intentions. The frontal lobe of the brain plays a major role in the development of this intelligence. Damage to this area may cause extreme personality changes.

- Intrapersonal Intelligence. This intelligence involves the ability to read one's self. It includes the ability to understand one's own behavior. The frontal lobe also plays a major role in this development. Damage to the lower area of the frontal lobe may cause a person to be irritable or exhilarated, while damage to the upper portion may cause one to be apathetic, indifferent, or insensitive. Figure 2.7 shows each intelligence with its characteristics according to Gardner.

FIGURE 2.7
GARDNER MULTIPLE INTELLIGENCE SUMMARY

Multiple Intelligence	Description
Musical/Rhythmic	Structure of music; "schemas" for hearing music; sensitivity to sound; creating melody/rhythm; sensing qualities of a tone.
Body/Kinesthetic	Control of voluntary movements; control of "pre-programmed" movements; expanding awareness through the body; mind/body connection/ mimetic abilities; improved body functions.
Logical/Mathematical	Abstract pattern recognition; inductive reasoning; deductive reasoning; discerning relationships and connections; performing complex calculations; scientific reasoning.
Verbal/Linguistic	Understanding the order and meaning of words; convincing someone of a course of action; explaining, teaching, and learning; humor; memory and recall; "meta-linguistic" analysis.
Visual/Spatial	Accurate perception from different angles; recognizing relationships of objects in space; graphic representation; image manipulation; finding your way in space; forming mental images; active imagination.
Interpersonal	Creating and maintaining synergy; discerning underlying intentions, behavior, and perspectives; "passing over" into the perspective of another; working cooperatively in a group; sensitivity to others' moods, motives, and feelings; verbal/non-verbal communications.
Intrapersonal	Concentration of the mind; mindfulness; metacognition; awareness and expression of different feelings; transpersonal sense of the self; higher order thinking/reasoning.
Naturalist	Recognizes plants collectively and animals collectively, makes other consequential distinctions in the natural world; uses this ability productively.

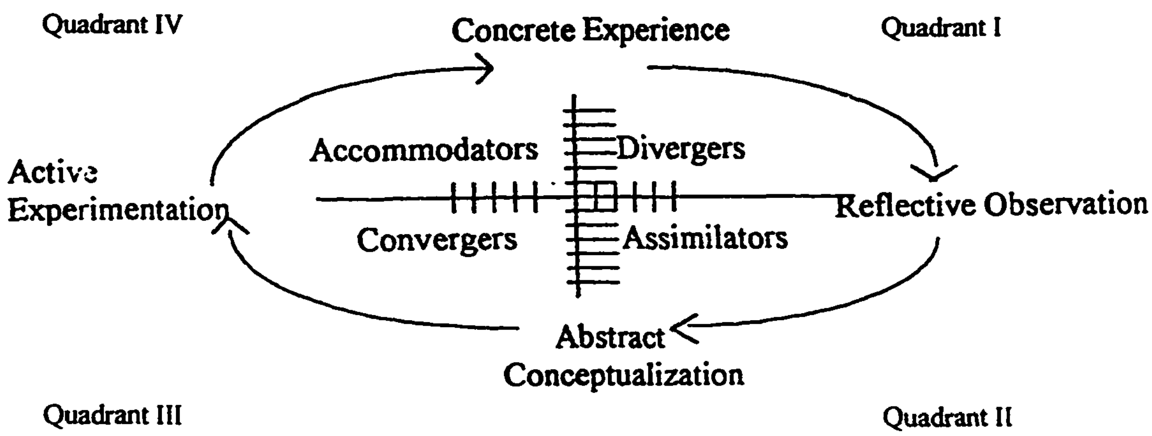
One of the myths Gardner (1996) discusses is the existence of exactly seven intelligences. He suggests possibly adding the intelligence of the "naturalist" to the current list. This intelligence involves the ability to recognize "flora and fauna, to make other consequential distinctions in the natural world, and to use this ability productively (in hunting, in farming, in biological science)" (p. 15). This intelligence is not represented in the existing seven.

According to Gardner (1993), these intelligences are independent of one another. It is entirely possible to have a highly developed intelligence in mathematics (logical-mathematical) with an underdeveloped intelligence in dancing (bodily-kinesthetic dexterity). Each person should be considered as a collection of intelligences instead of singular in ability. Diversity within the classroom is created through the development or underdevelopment of these intelligences.

Kolb's Learning Style Model

Kolb believes that there are two ways that learners comprehend materials: Concrete experience and abstract conceptualization. He also asserts that learners process information in two ways: Through reflective observation and active experimentation (Higgs *et al.*, 1995; McCarthy, 1991). This assertion renders a matrix similar to the coordinate plane. The x-axis represents information processing methods; the y-axis represents comprehension methods. The illustration in Figure 2.8 gives a visual representation of this concept.

FIGURE 2.8
KOLB LEARNING STYLE MODEL



Kolb classifies each quadrant on the coordinate plane as representing divergers, convergers, accommodators, and assimilators (Higgs *et al.*, 1995). Divergers prefer to comprehend information by concrete experience and process that information using reflective observation. Assimilators tend to comprehend information through abstract conceptualization and process that information using reflective observation. Convergers tend to comprehend information through abstract conceptualization and process through active experimentation. Finally, the Accommodator prefers to comprehend information through concrete experiences and process that information using active experimentation.

The Diverger is very imaginative and generates ideas easily. This learner functions well in brain-storming situations. Interests include cultural, social science education, liberal arts, and humanities backgrounds. This learner is strongly innovative, people oriented, and enjoys watching others while assimilating information (Ayersman, 1993). The Diverger learns best by listening or sharing. Group discussions, movies, short lectures with discussions, and audio and visual experiences are the most productive methods of instruction (Scott, 1994).

The Assimilator is a thinker and excels when using inductive reasoning. This learner creates theoretical models while thinking things through thoroughly. S/he is less interested in people than is the Diverger and is not too interested in the application of ideas. The fact that s/he creates theoretical models suggests that this learner focuses on the generation of ideas. The person with this type of learning style is often found in research and planning departments (Ayersman, 1993). This learner is analytical and sequential in processing. Continuity is important. S/he desires to know what knowledge is accepted as s/he formulates ideas. Lecture, the traditional method of instruction, is most productive for the Assimilator. Extensive reading assignments are preferred, as are audio tapes (Scott, 1994).

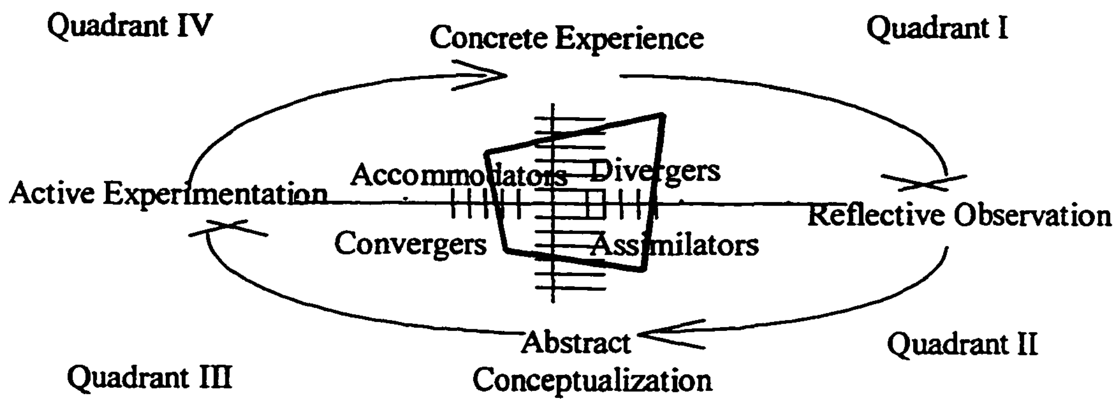
The Converger is a logical thinker who connects cause with effect. Common sense and practical application are strong characteristics of this learner who functions best when there is just one answer to a problem. Many engineers fit this learning style; they enjoy working with things rather than people and score high on intelligence tests. Interests are narrow, and the learner is basically unemotional. Hands-on experiences are used to collect data (Ayersman, 1993). The Converger blends theory with practice. Ideas are tested using experimentation and common sense. This learner desires to know exactly why things work as they do. Workbooks, manuals, demonstrations, and hands-on activities are the preferred methods of instruction for this learner (Scott, 1994).

The Accommodator is a risk-taker. If a particular theory does not seem to fit the facts, this learner may abandon the theory to explore other possibilities. Problem-solving strategies involve intuition and trial and error. This learner is action oriented and has an ability to get things accomplished, but patience is not a virtue for this person and s/he may even seem pushy at times. Change is viewed as exciting for this self-discoverer (Ayersman, 1993). The Accommodator is a dynamic learner who combines experiences with application. Games and simulations are appealing methods of instruction. This learner prefers independent study, contact activity assignments, and special reading assignments (Scott, 1994).

If one refers to the model, learning at the concrete experience level forms a basis for observational reflection. Then new implications are formed from concepts assimilated. These implications in the form of abstractions serve as prescriptions in creating new active experiences (Perry, 1994). A successful learner is not expected to progress through all four processes. Decisions we make in the learning process cause us to develop a preference for a mode of consuming and processing new information. The young learner begins to develop these preferences based on the choices s/he makes and the successes incurred in the learning process. Research indicates that learning styles appear to be fairly stable by adulthood (Ayersman, 1993).

Consider an example of a learning style diagnosis using Kolb's Learning Style Inventory. The score on the assessment is derived by the emphasis the learner places on abstractness over concreteness and action over reflection. Quadrant One would represent the learner who processes information in a reflective manner and comprehends information on a concrete level. S/he is highly imaginative and creative. A graphic illustration of this learning process is shown in Figure 2.9 (Perry, 1994).

FIGURE 2.9
KOLB LEARNING STYLE MODEL ASSESSMENT



This learner comprehends new material most easily on the concrete level and processes that material reflectively. If the concepts are delivered in a traditional lecture fashion, the learner may not grasp them. Divergers learn best by sharing and listening to others. They need to be personally involved. Therefore, if the material is also presented in cooperative group discussions, perhaps this learner will be reached.

In a study of learning styles of high school students, Titus, Bergandi & Shryock, (1990) used the Kolb Learning Style Inventory. The study compared males to females, freshmen to seniors, and slow learners with accelerated learners. The results indicated that the younger participant tended to learn more on a concrete level than the older participant. Females were more concrete oriented than males and were also more homogeneous as a group in their learning styles. Males were more diverse with respect to learning styles when comparing age and aptitude. Slow-track students were more reflective and less abstract than the accelerated learners. A possible contributing factor to consider is that most advanced students have the opportunity to experience abstract concepts in the course selection whereas students in a slower track may not. Slow track students tend to be more involved in the learning process when hands-on activities are integrated into their concrete experiences.

A study by Toth & Baker (1990) revealed an interesting dilemma that occurs in education. Oftentimes the more creative student is less likely to achieve success in the traditional classroom due to time constraints imposed upon the school day by the curriculum. The situation is magnified when the teaching strategies are incongruent with the learning style of the student. The result of this combination of creative ability, time constraints, and inappropriate teaching strategies may produce a cycle of persistent underachievement, and academic success may elude this mentally capable student. These students are often classified as developmentally delayed because they have not succeeded in the traditional classroom.

In addition to various learning style models, another key issue in teaching mathematics and understanding developmentally delayed students is the learning theory of left-brain/right-brain (RB/LB) dominance. Student achievement may increase if activities in the classroom are geared to stimulate both sides of the brain.

Hemisphericity

Many students labeled as developmental show a preference for right-brain (RB) thinking style. Most of the instruction in the traditional mathematics classroom corresponds to the left-brain (LB) based education techniques and assessment procedures. Because of the incongruency in the teaching style and the learning style, these students have developed a feeling of learned helplessness, which becomes self-fulfilling in a cycle of failure and creates a hurdle to overcome in their learning processes (Beamish, 1995; Kitchens, Barber, & Barber, 1991).

This cycle of failure can be explained biologically. Research conducted by Beamish (1995), explains the physical development of the brain during the learning process. Beamish also discusses the process of "downshifting" that occurs during stress or anxiety. It appears that the left and right hemispheres shut down their operation during these periods of stress. Processing shifts to the limbic system which normally handles matters of basic needs. During this period, long- and short-term memory are shut off, and the student cannot remember stored data. This accounts for the student who crams for a test, and then becomes anxious during the test, then "goes blank." Beamish states, "downshifting can lead to a self-feeding negative spiral" (p. 25).

The RB/LB learning style model acknowledges that one side of the brain or the other is responsible for processing certain mental tasks. The right hemisphere is responsible for the development of visual, auditory, tactile, holistic, and emotional growth (Ayersman, 1993; Beamish, 1995; Dunn, Sklar *et al.*, 1990; Kitchens *et al.*, 1991; Lavach, 1991). When understanding of information involves the right hemisphere, visual images are necessary. Recognition of patterns and shapes is required in mathematical understanding. Spatial relationships are perceived by this side. Language skills developed in this hemisphere are tone of voice, body language, gestures, and facial expressions. The thinking processes characteristic of this side are divergent, intuitive, and exclusive. Development of spatial relations and visualization of three-dimensional geometric shapes occurs in this hemisphere. Using the right hemisphere in problem-solving allows the learner to combine parts of a problem into a whole, such as in geometric proofs (Creswell, Gifford, & Huffman, 1988).

Right-brain dominant learners tend to be extroverted people, and research indicates that hemisphericity contributes significantly to the decisions a person makes concerning a lifelong occupation. The determination of hemisphericity was done using brain wave patterns recorded on an EEG test. This test compared people classified as normal, introverted, and extroverted (Lavach, 1991). In research results by Ayersman (1993), musicians, artists, farmers, and architects appear to be more right-brain dominant than people in other occupations.

The left hemisphere is responsible for the development of logical thinking skills. Processing of an analytical, linear, and informational nature is conducted in the left hemisphere (Ayersman, 1993; Beamish, 1995; Dunn, Sklar *et al.*, 1990; Kitchens *et al.*, 1991; Lavach, 1991; McCarthy; 1991). The left side determines significance of issues making use of logic rather than emotion. The occupations that seem to be best suited for left-brain dominant people are philosophers, salespersons, and theoreticians.

Some learners process information using both sides of the brain. Others process information predominantly out of one side or the other. Gender differences reveal that males are often left-brain dominant and females are right-brain dominant (Ayersman, 1993). Most people function using both sides of the brain, but contributions to the learning process are not equal (Lavach, 1991; McCarthy, 1991; Beamish, 1995). The differential is very seldom more than a 60%-40% spread favoring one or the other. About 80% of the general population in the United States appears to be left-brain dominant (Creswell *et al.*, 1988; Beamish, 1995).

Understanding information for the left-brain dominant learner involves abstract models. Development of mathematical skills includes numeration, basic facts, and computations. Development of language skills includes reading, speaking, and writing. The thinking process is sequential and convergent (Creswell *et al.*, 1988).

Some researchers believe that student achievement will increase if activities are provided to stimulate both sides of the brain. Public school education emphasizes language skills and verbal processing, which are left-brain activities. Many right-brain dominant learners are not stimulated by left-brain dominant instructional strategies used by the traditional classroom teacher. In the evolution of the learner, very few young children use both sides of the brain. Using Piaget's developmental stages, for a child in the preoperational stage the right hemisphere is active and the left hemisphere is developing. In the concrete operational stage, the right and left hemispheres are active. However, during this stage most mathematical activities are structured, systematic, and left-brain dominant stimulators. Concrete manipulatives aid in the development of the right hemisphere. However, most classrooms at the middle school level use activities that will be duplicated at the high school level. Generally, these are lecture in format and geared to stimulating the left hemisphere. Activities should be developed across the curriculum throughout the educational process which will aid in the development of processing using both sides of the brain (Beamish, 1995; Creswell *et al.,* 1988).

Students at all levels should be taught how to use both sides of the brain in retaining and processing information. At the college level, students who have traditionally been successful in courses up to and including algebra tend to have difficulty with visualizations that are necessary in higher levels of mathematics. These students have been encouraged by their own success in the left-brain activities but have not developed the right-brain processing skills. The right-brain dominant students, on the other hand, may have been discouraged at the algebraic level with the sequential processes that are taught using left-brain dominant activities. These students may never get to the level of mathematics that is more suitable for their processing skills. Without teaching students about how they process information, they could be lost in the educational system. The left-brain dominant student becomes discouraged at the calculus level, and the right-brain dominant student never reaches it (Beamish, 1995; Kitchens *et al.*, 1991). Instruction should be altered to mentally stimulate these students. This may involve integration of hands-on activities and the use of manipulatives at all levels of mathematics instruction.

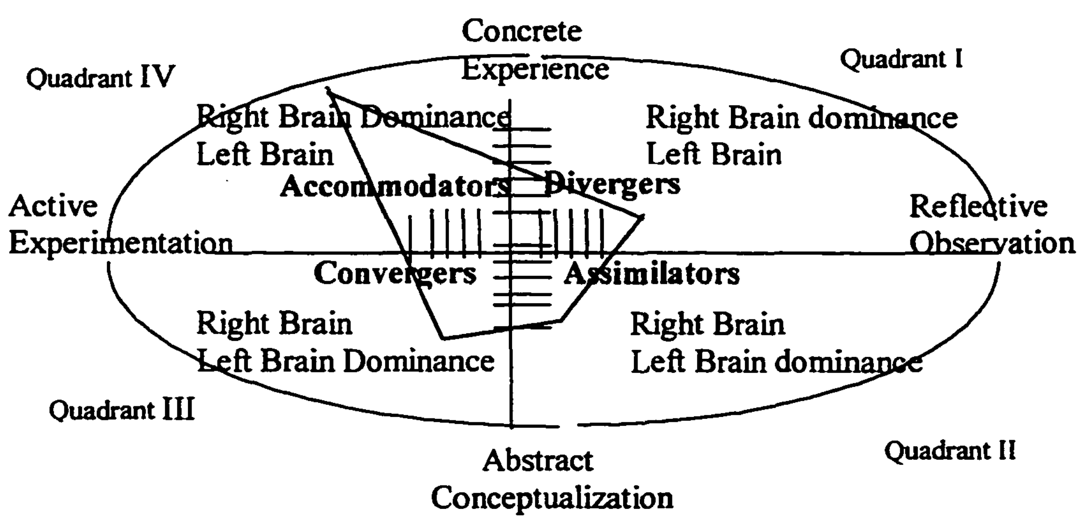
In a study by Dunn, Sklar *et al.*, (1990) hemispheric preferences of minority developmental college students were evaluated. The Differential Hemispheric Activation Test, the Semantic Differential Instrument, and the Productivity Environmental Preference Survey were administered to approximately 800 minority college students in New York City. The students who participated in this study performed significantly better when they were taught using techniques that were congruent with their learning styles and significantly poorer when they were taught in styles that were incongruent with their styles. It made no difference in their attitudes whether they were taught in styles congruent or not congruent with their learning styles. These researchers suggested that remedial programs should involve teaching students about their learning styles and then using those techniques to teach their courses. The implication is that perhaps developmental students failed in the past because they were taught using methods that were incongruent with their learning styles.

Students with different learning modalities tackle learning in different ways and have preferred ways of processing and organizing information. One system of instruction, known as the 4MAT System, develops teaching techniques which activate the right and left hemispheres of the brain and address the preferred ways of processing and organizing information through reflection or experimentation.

The 4MAT System

The 4MAT learning style model is based on Kolb's learning style model and the concept of brain hemisphericity. It is an eight-step model derived from applying the concept of right-brain/left-brain dominance to the four quadrants of Kolb's learning style model. It was developed by Bernice McCarthy in 1972 (McCarthy, 1991). She hypothesized that both sides of the brain should be stimulated during instruction since learning in both hemispheres is equally important. She also formulated that the full cycle of Kolb's model would be experienced during the ideal lesson. A visual representation of McCarthy's 4MAT model is provided in Figure 2.10.

FIGURE 2.10
4MAT LEARNING STYLE MODEL



According to McCarthy (1991), concrete experience learners tend to process information using the right hemisphere, while abstract conceptualization learners tend to process using the left. The complete cycle is important for all learners. No section is more important than the whole cycle. Teaching techniques can be developed which alternate dominant patterns so that students are both comfortable within their modes and challenged outside their modes. These techniques can be developed so that they alternate the processing needs of a diverse set of learners. Progressing through the cycle begins with experience involving senses. The learner then reflects, thinks, develops theories, and experiments. Finally, the learner evaluates and combines pieces of information into a whole. This enables the learner to apply new information to the next adventure.

Within the model structure, the Quadrant One right brain dominant segment is the first step in the instruction process. The instruction is designed as a lesson that personally connects the learners and the concept. This involves evaluating of prior knowledge and prior experience possessed by the learners, then integrating this knowledge into a common experience for the student populace. The primary task of the instructor is to involve the students in an activity that will connect all students to the same experience that will be used later in the cycle. This is sometimes accomplished through field trips, movie clips, or other creative activities. The second step of the 4MAT model progressing through the second segment of Quadrant One addresses the needs of the left brain dominant learners. In this segment, the learners will analyze what happened in the activities they experienced. They will reflect upon their own opinions and beliefs in relation to their experience in the class activity (McCarthy & Germain, 1996). For example, if a classroom teacher is teaching a lesson on determining the difference between fact and opinion, the first step in the 4MAT model might be to show a video clip of different advertisements and the claims made by the corresponding companies. It is important that everyone in the classroom experience the same activities in this model. In the second step, the students would analyze the advertisements, answering questions such as "which would you buy, and why." Students are encouraged to share their perceptions, beliefs, and reflections on the advertisements viewed.

The third step of the 4MAT model begins in Quadrant Two with right brain dominant activities. Validation and analysis of opinions occur in this segment of instruction, which is usually conducted using a medium other than reading or writing and often involves a personal experience activity (McCarthy & Germain, 1996). In the example given above, instruction may involve actual sampling of products to test for validity of the advertisement. This activity establishes the fact that some of the opinions expressed in the advertisements and by participants are subjective and, therefore, different for each individual.

The next step in Quadrant Two is to involve the left brain dominant learner. Instruction should be designed to present information in a systematic method with emphasis on analysis of confirmed facts and concepts. Attention should be drawn to important details (McCarthy & Germain, 1996). In the example, students would define the concepts of opinion and fact based on their experiences in the activities. They would classify then claims made by the advertising companies as opinion or fact. They may even be expected to give examples of each.

Step five of the 4MAT model is also designed for the left-brain dominant learners. It "emphasizes a shift from acquisition and assimilation to testing and adaptation" (McCarthy & Germain, 1996, p. 28) of knowledge acquired. In Quadrant Three, learners demonstrate the ability to apply concepts that have been introduced. Precise answers are important in this segment because of left-brain dominance (McCarthy & Germain, 1996). In the example, students may find advertisements in newspapers or magazines to support their concepts of opinion versus fact. This is the time in the learning process when worksheets may be used to reinforce instruction. Mastery of learning assessment is prominent in determining if reteaching is necessary. Generally, in the educational process in the traditional classroom, instruction oscillates back and forth between Quadrant Two left-brain dominant and Quadrant Three left-brain dominant. Unfortunately, instruction very seldom involves right-brain activities of Quadrant Two and Quadrant Three. A concept is introduced using classification and examples, then learners perform activities to support the instruction given. Assessment is done to determine whether the material has been mastered or reteaching should be done.

The sixth step in the instruction process using the 4MAT model is for right-brain dominant learners. In Quadrant Three, the emphasis is on teaching the learner to apply what has been taught. For a right-brain dominant activity, learners will demonstrate what they have learned by creating personal applications and are encouraged to "tinker" with ideas and relationships, making connections between experience and concept (McCarthy & Germain, 1996). In the example used previously, students might design their own open-ended explorations of the concept. A project could be required in which learners develop advertisements about themselves that include two facts and two opinions. Choices would be provided within the project so that a partner could determine which item is fact and which is opinion.

In Quadrant Four the learners integrate newly learned skills into their own world. It is here that their work is refined and edited. They analyze and transform any contradictions that arise between new knowledge and prior knowledge. The instructor acts as a guide as students refine their knowledge base. The seventh step of the model is in Quadrant Four. The left-brain dominant instruction is in a facilitator design. The instructor helps students analyze their application of the knowledge learned. Refining may be necessary when mistakes are viewed as learning opportunities (McCarthy & Germain, 1996). In the example, learners will share their project with a partner, who will then choose whether the item in question is fact or opinion. Learners will evaluate each other's work and refine their own as necessary.

The final step in the learning model is a right-brain dominant activity. This segment provides celebration and closure for all the learning acquired in this unit of study. Learners are given the opportunity to demonstrate concepts learned. There is a "what if" attitude evident in the classroom atmosphere (McCarthy & Germain, 1996). In the example, the learners will share their projects with the class, which provides a demonstration and validation of the concepts learned. This should be an enjoyable time of sharing and a profitable experience for all participants. This celebration can also be a bridge to the next unit of study. In many plans of instruction, Quadrant Four is not an element, possibly due to time constraints and lack of training. This quadrant is very important for the students who are active, concrete learners who are always asking "what if." It is also in this quadrant that closure is drawn for the unit of study.

A few studies have compared the 4MAT to the traditional textbook method of teaching (Scott, 1994). One study cited by Scott (1994) used both methods to teach science to elementary school children. There was a significant difference in favor of 4MAT on the objective test covering the content of the unit. The objective test was given again to the same group of children thirty-five days later, and the results concerning retention were even more positive in favor of the 4MAT.

McCarthy (1991) found that when 4MAT is used in staff development programs, several things happened. Teachers became more open to the concept of diversity of learning that exists in the classroom. Their techniques in presenting lessons became more interactive and less authoritative, and they also accepted part of the responsibility for motivation. McCarthy also found that the teachers who were involved in implementation of 4MAT developed a deep sense of camaraderie and professionalism.

Focus of the Present Study

Many types of diversity exist in the classroom. Through education and research, educators have become aware of many of these differences. Cultural awareness programs have been implemented, gender differences have been discussed, and ethnic variances have been reviewed. Diversity also exists in the cognitive developmental stages of students within the classroom and in the way students receive and process information. An awareness of the existence of different stages of development and different learning styles in the classroom may make a profound impression on the classroom teacher and on the techniques used to transmit information. Also, informing students of their present stage of development and their particular learning style may help them understand how they learn. This should make students feel more comfortable in the classroom setting and enhance the learning process (Davidson, 1990).

The practice of teaching mathematics is complex. It requires "knowledge of mathematics, of diverse learners, of how students learn mathematics, and of the contexts of classroom, school, and society" (NCTM, 1991, p. 22). Practical implications that arise from the research on learning styles and cognitive development address instruction and course design. Concrete components of subject matter match the learning styles of the adolescent and the young female student, whereas abstract components of subject matter might better serve the bright male adolescent student. Slower students need activities to supplement direct instruction. Females process information more efficiently when teaching models are more concrete and less flexible. Adolescent males need diversity of teaching models (Titus *et al.*, 1990).

The purpose of the present study is threefold. First, the relationship between learning style preferences and the level of cognitive development of preservice elementary teachers who are currently enrolled in a content course in mathematics will be investigated. Many of these preservice teachers may be learning mathematics conceptually for the first time, and many of these students are in their first or second year of higher education. According to research, many of them may be in lower stages of cognitive development. One way to promote success in the mathematics training of preservice elementary teachers is to help students go beyond the developmental levels of Piaget. Analysis of stage development using Perry's model may enable students to understand themselves and better understand the way in which they learn mathematics. Awareness of the cognitive stage of development and a preferred learning style should enable the learner to go beyond the rote method of learning mathematics and progress to a meaningful level of understanding.

Second, the effect of using a learning style model for structuring instruction of teaching preservice teachers who are enrolled in a content mathematics course will be investigated. It is hypothesized that a result of using this instructional model will be a higher achievement level for those students in the traditional group when compared to those who are taught in a traditional higher education format such as lecture. The use of a learning style model will address each of the four basic learning types, including right- and left-brain dominance, which exist in the classroom. This should make the content more meaningful and applicable to the learners, therefore raising the achievement scores on the content presented. In many cases the use of a learning style model engages the students in an active learning process as opposed to the passive participation that so often occurs in the traditional college classroom. This should enable the students to identify and overcome some of their misconceptions about mathematics.

Finally, a further investigation involving teaching strategies will attempt to determine whether the retention rate of material presented is higher for the students in the traditional group compared to those taught in the traditional lecture method. If it is discovered that students retain material better when methods are used that vary from the traditional lecture method of instruction, educators in higher education institutions may be able to plan their instruction for better retention rates of their students. In the next chapter, a research design is developed which will allow the researcher to investigate the possible relationship between cognitive development and learning styles. Instructional techniques will be designed to determine if the use of a particular strategy impacts gains in achievement and rates of retention of mathematical content.

CHAPTER III

METHOD

Present Study

In the previous chapter, a review of literature was presented supporting the use of Perry's model to measure the level of cognitive development of preservice elementary teachers enrolled in a required mathematics content course. Also, a review of literature was presented discussing a variety of learning style models. The 4MAT learning style model was determined to be the most appropriate instructional strategy for this research project. The question posed for this research is: How do changes in instructional strategies that focus on diversity of students' learning styles impact the level of cognitive development, achievement, and retention of those students enrolled in a mathematics content course for preservice elementary teachers?

This study was conducted on the campus of a regional university in the Southwest, where student enrollment is approximately 5000 students per semester. The university is one of eight regional universities in the state. The university is committed to excellence in training teachers, as evidenced by its certification by the National Council of Accreditation of Teacher Education (NCATE). The university offers elementary, secondary, and master's degree programs in education, along with superintendent certification. A pharmacy degree program through the doctorate level, nursing bachelor's degree program, and physical therapy bachelor's degree program are also offered along with other applied degrees.

The mathematics content requirement for elementary education majors consists of twelve semester hours. Structural Concepts in Arithmetic is the first course required; it covers topics such as problem-solving techniques, logic, set theory, number theory, and rational numbers. The second course, Structural Concepts in Mathematics, covers topics such as probability, statistics, and geometry. Two other required courses are Algebra for Elementary Teachers and Geometry for Elementary Teachers. The course that was used in this study was the second required course, Structural Concepts in Mathematics. The rationale for using this course was that it contains topics such as probability and statistics that are new concepts for most elementary education majors. Thus, the focus of this study was on the topics of probability and statistics.

Participants

The students who enroll in Structural Concepts in Mathematics are generally in their first or second year of their higher education experience. Some have been admitted to Teacher Education and some have not since it is not a requirement for admission. However, all have committed to the elementary education program. The only prerequisite for enrolling in the course is completion of Structural Concepts in Arithmetic. Both of these courses together satisfy the mathematics General Education requirement for elementary education majors. No substitution for this course has been approved by the Mathematics Department. Therefore, the course is required for all elementary education majors. The only exception would be an equivalent course taken elsewhere by a transfer student. Generally, the male enrollment is low in comparison to the female enrollment because of the gender differential in the elementary education program.

This study involved students from two sections of Structural Concepts in Mathematics. One section was taught using traditional methods. The other was taught first using traditional methods and then using teaching strategies developed from the 4MAT Learning Style Model. All students signed a consent form for the research project, and a copy was returned to all.

One section had six students enrolled. Fifty percent were freshmen, 34% were sophomores, and 17% were juniors. There were no seniors in this section. Seventeen percent of the students in this section were males. No high school data was available for one student. All remaining students (83%) had at least three years of high school mathematics courses including Algebra I, Algebra II, and Geometry. Sixty-seven percent of those students completed a fourth year of high school mathematics. All students had completed the prerequisite course, Structural Concepts in Arithmetic. The mean overall cumulative university grade point average for this section of students was 3.36 on a 4.00 scale.

The other section had fourteen students enrolled. Fourteen percent were freshmen, 57% were sophomores, and 29% were juniors. There were no seniors in this section. Fourteen percent of the students in this section were males. High school data was available for all students. Seventy-nine percent of the students completed at least three years of high school mathematics including Algebra I, Algebra II, and Geometry. Twenty-nine percent of the students completed a fourth year of high school mathematics. All students except one completed the prerequisite course. The mean overall cumulative university grade point average for this section of students was 2.64 on a 4.00 scale.

Design

Demographic information was obtained from the students and from the registrar's office. Based on this demographic information, the following observations were made. All participants, except one, were elementary education majors. All participants were from rural settings, implying fairly conservative cultural backgrounds, and were from similar socioeconomic backgrounds. All participants, except one, had at least taken Algebra I, Algebra II, and Geometry in high school. All participatns' ages, except one, fell within the interval of 20 – 27 years of age. Therefore, variances were assumed to be homogeneous from group to group, within the bounds of random variation. ACT scores, high school GPAs, and previous mathematics course exposure were analyzed to further understand the comparability of the groups. This analysis and the evaluation of a Knowledge Inventory Test were used to identify which group would receive treatment. The $MAT instructional strategies would be used as treatment on the selected group.

Each student chose a four-digit number to use in place of his/her name. The code that identifies the proper number with the student was kept in a locked file in the researcher's office. Before the treatment was administered, students in both groups were given the SID-IV (see Appendix E). Each student wrote a short diagnostic essay entitled: "The Best Class I Ever Had and the Worst Class I Ever Had." Responses to several questions on the Data Sheet were used to analyze the student's concepts of the qualities of a good course, an inadequate course, a good instructor, and method(s) of teaching that aid in the learning process. Samples of student responses are included as Appendix F.

The same professor taught both courses. One course was offered on Monday, Wednesday, and Friday at 9:00 a.m. The other course was offered on Monday, Tuesday, and Thursday at 1:00 p.m. Both sections were given the same instruments for this study, the same homework assignments, and the same out-of-class assignments. Both sections used the same textbook, *A Problem Solving Approach to Mathematics for Elementary School Teachers*, sixth edition, by Billstein, Libeskind, & Lott (Addison Wesley Longman, Inc., 1997). Topics covered in both courses were Introductory Geometry; Congruency, Symmetry, and Similarity; Measurement; Algebra and Coordinate Geometry; Probability; and Statistics. The methods of instruction were the same for all chapters except probability and statistics. See Appendix Q for a schedule of activities for this research as they occurred during the Spring 1998 semester.

For the chapters on probability and statistics, the 4MAT Learning Style Model was used to introduce new material to the treatment group. The researcher attended a three-day national conference in November 1997 on the 4MAT Learning Style Model, administration and analyses of instruments, and planning of instruction. Activities for all four quadrants and both brain-dominant preferences were developed and used within each chapter (see Appendix I). The traditional group received the same content, but the instructional strategies for this group remained constant throughout the semester. See Appendix G for copies of the lesson plans used during the experiment. At the end of the chapter on probability an exam was given to both classes. The same procedure was followed for the statistics chapter. Both exams are included as Appendix O.

Sample lesson plans for both instructional strategies are included to provide a precise illustration of the nature of instruction for each group. Content validity of the textbook lesson plans was ascertained by having a colleague within the mathematics department view the lesson plans and compare them with the textbook to verify that the lessons represented the content in the text. This verification form is provided in Appendix H. The 4MAT lesson plans in the treatment group were reviewed and approved by a 4MAT consultant as accurately representing the 4MAT System (see Appendix J).

Instruments

Demographic Information and Knowledge Inventory Test

Each student read and signed a consent form for the research project (see Appendix A). Each student filled out a data sheet for demographic information (see Appendix B), while other essential information was obtained from the registrar's office (see Appendix C). A Knowledge Inventory Test was given, which consisted of sixteen open-ended questions taken from the content of the course (see Appendix D). The achievement scores on this test as well as the analyzed demographic information were used to determine which group would receive the treatment. Based on the analyses of the Knowledge Inventory Test and the size of the groups, the larger group was chosen as the treatment group. This class will hereafter be referred to as the 4MAT group, while the smaller class will be referred to as the traditional group.

Cognitive Development Scale

The Scale of Intellectual Development – IV (SID-IV) is an experimental instrument objectively scored to measure cognitive development. The SID-IV is published by Developmental Analytics in Harrison, VA. The following information was extracted from a manual published by this company. The SID-I was originally developed based on Perry's scheme of intellectual and ethical development and Robert's Scales of Ethical and Intellectual Develop (SEID). The SID-IV is the fourth version of the instrument developed for improved reliability of measuring cognitive development. The SID-I was administered to 3300 freshmen at a southwestern university. Factor analysis was performed on the 119-item instrument. Nine positions, or nine factors, were not supported; consequently, four factors were chosen, accounting for 70% of the variance. These became sub-scales for the SID-I. Figure 3.1 describes the sub-scales and their reliability coefficients.

FIGURE 3.1
CRONBACH'S RELIABILITY COEFFICIENTS FOR THE SID-I

Sub-scale	Measurement	Cronbach's alpha coefficient For internal consistency
Dualism	Sees issues in clear-cut terms. Authority gives right answer.	r = .81
Relativism	Discovers that alternative viewpoints and differences exist; still believes outside powers determine future.	r = .70

Table 3.1 - *Continued*

Commitment	Denotes to what degree a student has become committed to a personal standpoint, even while recognizing differences in others.	r = .76
Empathy	Denotes degree to which the student feels responsible to society for their actions.	r = .73

Revisions were conducted to improve reliability. The SID-II consisted of 101-items, while the SID-IV consists of 115-items. In the SID-IV additional items were added under each of the existing sub-scales. A fifth sub-scale, referred to as "Faking," was added. The purpose of the fifth scale is to determine whether a student is responding to the instrument items to give a fake favorable or unfavorable appearance. A score of 19 or greater on the fake sub-scale would indicate a need to regard the scores on the other four sub-scales as invalid. The Developmental Analytics manual provides factor analysis coefficients for each test item. The SID-IV has been used in several studies published in journals, unpublished master's theses, and unpublished doctoral dissertations since 1988.

The SID-IV was given to both groups before any changes in teaching strategies were implemented (SID-IV-A), and at the end of the experimental period (SID-IV-B). A copy of the instrument is provided in Appendix E.

Personal Interviews

Personal interviews were conducted with each respondent. The interviews were used to verify the level of cognitive development according to Perry's model through questions dealing with the meaning of knowledge, the responsibility of learning, exchange of conflicting opinions, tolerance of difficult instructional situations, attitudes toward problem solving, and attitudes about commitment. The interviews were also used to verify the data collected from the 4MAT Learning Type Measure. Sample questions and responses are included as Appendix K. Respondents answered a Self-Analysis Survey to verify the findings of the 4MAT Learning Type Measure. Sample questions and responses are included as Appendix L.

Learning Type Measure

Bernice McCarthy at Excel, Inc., developed the Learning Type Measure (LTM®) and the Hemispheric Mode Indicator (HMI). The LTM® is an instrument that assesses the preferred learning style of the participant as described in the literature review based on the 4MAT Learning Style Model. LTM® Part A contains 15 items with four stems each (see Appendix M). Respondents are asked to rank each stem from 4 to 1, where 4 indicates "most like you" and 1 indicates "least like you." The stems are indexed to each learning type. The stems represent the descriptions of the four types of learners found in several books and articles by Dr. Bernice McCarthy and her associates (McCarthy, 1996). Part B contains eleven items with two choices each. The choices are "Doers" and "Watchers" (see Appendix N). The Hemispheric Mode Indicator (HMI) evaluates left- and right-brain approaches to learning. Participants respond to thirty-two phrases to analyze. There are four choices for each phrase to measure preference.

To demonstrate construct validity, McCarthy (1996) responds to two questions. First, is there one learning type that is distinguishable from the rest? To answer this question, 380 respondents were given the LTM®. They were asked to score it in the indicated manner. Their scores were tallied and categorized according to the measure.

Figure 3.2 shows the results of that study. Of 380 respondents, only 10 show "No Single Type" indicated by a tie in two or more types.

FIGURE 3.2
FREQUENCY DISTRIBUTION OF LEARNING TYPES

Type	Count	Percent
Ones	167	42.8
Twos	55	14.1
Threes	78	20.0
Fours	80	20.5
No Single Type	10	2.6
Total	390	100.0

The next question applies to the concern with construct validity: "Do people have sharply peaked profiles or are the sums across the four types nearly the same?" (McCarthy, 1996, p. 134). There are 15 items with a high point value of 4 and a low point value of 1 per item on the LTM®. Therefore, a maximum sum is 60 and the minimum sum is 15. McCarthy and her associates calculated the differences between the maximum sum and the next highest sum of individual respondents. This is designed to test the peakness within each respondent's score. Figure 3.3 renders the results of that analysis.

FIGURE 3.3
DIFFERENCE BETWEEN THE MAXIMUM AND THE NEXT HIGHEST SUM

Difference	Count	Percent	Difference	Count	Percent	Difference	Count	Percent
0	10	2.6	9	24	6.2	18	5	1.3
1	35	9.0	10	18	4.6	19	9	2.3
2	22	5.6	11	10	2.6	20	11	2.8
3	25	6.4	12	20	5.1	21	4	1.0
4	23	5.9	13	16	4.1	22	5	1.3

Figure 3.3 – *Continued.*

Difference	Count	Percent	Difference	Count	Percent	Differen ce	Count	Percent
5	27	6.9	14	11	2.8	23	5	1.3
6	26	6.7	15	14	3.6	25	3	0.8
7	30	7.7	16	13	3.3			
8	13	3.3	17	11	2.8			
						Total	390	100.0

The table shows that 70% of the respondents had differences of 5 or more between their maximum sum and their next highest sum; 50% had differences of 7 or more. The 10 respondents who had at least two identical sums had differences of 0.

For reliability, two forms were presented. Internal consistency was measured by the Cronbach alpha statistic. A high alpha represents items that measure the underlying dimension represented by the total score. A low alpha represents items that measure several different dimensions (McCarthy, 1996). Figure 3.4 shows the alpha values for the four sets of items configuring the four learning type sums. Part A records the learning type, and Part B records the "do" versus "watch" items.

FIGURE 3.4
INTERNAL CONSISTENCY OF ITEMS SCALE

	Scale	Cronbach Alpha
Part A	Learning Type One	0.853
	Learning Type Two	0.835
	Learning Type Three	0.767
	Learning Type Four	0.885
Part B	Do versus Watch	0.863

Another test for reliability is the test-retest. Referred to as the coefficient of stability, this statistic is calculated by finding the correlation between the administration of the same measure given to the same respondents on two different occasions. The test-retest coefficient is .71. This statistic is considered an indicator of a high level of stability.

The Learning Type Measure has also been compared with the Learning Style Inventory (LSI), recording a 61% agreement. The Myers Briggs Type Indicator (MBTI) comparison with the Learning Type Measure showed a correlation between learning types.

Retention Equivalent Forms Exam

Equivalent forms exams will be used to determine the relationship between retention and instructional strategies. Approximately thirty days after the exam on the probability chapter, an equivalent forms exam was given to both groups. Since the semester ended with instruction on statistics, the final exam content was a comprehensive exam with content specific to probability and statistics. Due to time limitations of the study, the relationships among subject matter complexities, students' level of understanding, and retention will not be examined. Both retest exams are included as Appendix P.

Data Analysis

The Student t-test was selected as the statistic for analyzing some of the results of this experiment. A one-tailed t-test was used to determine whether the mean of the 4MAT group was significantly greater than the mean of the traditional group at the 95% confidence level. The t-test makes adjustments for the fact that the distribution of scores for small samples becomes increasingly different from a normal distribution as sample sizes become increasingly smaller. Also, according to Kerlinger (1986), the t-test is robust enough that it operates well under violations of assumptions such as normality and homogeneity of variance, provided violations are not gross and multiple. The population distributions of the parameters represented in this research involving elementary education majors were assumed to be normal. Also, as discussed earlier in the chapter, homogeneity of the groups was established based on the demographic data. For the data analysis, each question was addressed separately.

Question 1a: What is the relationship between learning style preference and level of cognitive development?

Descriptive statistics were used to illustrate a comparison between demographic data collected and the corresponding position of cognitive development. These charts were developed using the data collected before and after the 4MAT instructional strategies had been administered in order to compare classification with growth of cognitive level within the groups. Each student was assigned a number from two to eight to correspond to the cognitive development position determined by the SID-IV. A numerical value of two was assigned to the student who tested in the *dualistic* stage. Four was assigned to one who tested at the *relativism* stage. Six was assigned to one who tested at the *commitment* stage, and eight was assigned to one who tested at the *empathy* stage.

After the administration and analysis of the LTM® and the HMI, each participant was assigned a number from one to eight corresponding to the preferred learning style ascertained by the instruments. The 4MAT Learning Style Model is divided into four quadrants, and each quadrant is then subdivided according to left- or right-brain dominance. Number assignments of one through eight follow the design of the 4MAT model as indicated below:

1 - Quadrant I – right
2 – Quadrant I – left
3 – Quadrant II – right
4 – Quadrant II – left
5 – Quadrant III – left
6 – Quadrant III – right
7 – Quadrant IV – left
8 – Quadrant IV – right

After a week of instruction on learning styles, the LTM® and the HMI were administered to all students. Explanations of the assessments were also given to all participants. A written survey was administered to all students to determine the reliability and validity of the interpretation of the instruments. This survey consisted of six questions addressing the most favored quadrant, the least favored quadrant, and the student's self-analysis of the assessment. Students were asked to support or deny the analysis of the assessment. The desire was that all participants be in agreement with the findings of the instruments. They were also asked to consider how this instruction and analysis on learning style preferences influenced them, and how this instruction could be useful to them as a potential classroom teacher.

Correlation was calculated using data collected from Perry's model instrument as the independent variable and data derived from the 4MAT Learning Cycle instrument as described above to determine if a relationship exists between the cognitive development level and a preferred learning style.

Question 1b: Does the use of a teaching style model designed to accommodate different learning styles of students bring about a transition in the level of cognitive development?

Changes that occur in cognitive development within the groups were analyzed using a test to compare the differences of the means of the cognitive level of development based on the SID-IV test given before treatment and the SID-IV given after treatment. Since each participant was paired with a score before instruction (T1) began and a score toward the end of the semester (T2), these are considered dependent samples. A t-distribution was used to determine whether the teaching technique was effective. If it is, we expect the scores of the 4MAT group to be significantly higher on the second set of data. Since this is a comparison within groups, differences across groups is irrelevant.

To determine the effectiveness of the teaching technique, a one-tailed t-test was used at the 95% confidence level. $\overline{X}_{T1}$ represents the sample mean of the cognitive level of development of the 4MAT group before treatment. $\overline{X}_{T2}$ represents the sample mean of the cognitive level of development of the 4MAT group after treatment. Likewise, s_{T1} and s_{T2} denote the standard deviations.

The following method was used to determine if the mean cognitive development level increased within the 4MAT group. The value of $t_{1-\alpha}$ for $(n_{T1} + n_{T2} - 2)$ degrees of freedom was selected from a t-distribution table. The following computations were then made:

$$s_T = \sqrt{\frac{(n_{T1}-1)s_{T1}^2 + (n_{T2}-1)s_{T2}^2}{n_{T1}+n_{T2}-2}} \qquad \text{and} \qquad u_T = t_{1-\alpha}(s_T)\sqrt{\frac{n_{T1}+n_{T2}}{(n_{T1})(n_{T2})}}$$

If $(\overline{X_{T2}} - \overline{X_{T1}}) > u_T$, then the average of T2 exceeds the average of T1. Otherwise, there is no reason to believe that the average of T2 exceeds the average of T1. If the groups are not considered equal then use $|\overline{X_{T2}} - \overline{X_{T1}}|$.

The same procedures were followed to evaluate any potential change in the cognitive development of the traditional group.

Question 2: Does the use of a learning style model for teaching impact the achievement of those students enrolled in a mathematics content course for preservice elementary school teachers? If so, is the degree of impact specific to any particular learning style type?

The t-test was used to determine whether the probability examination score sample means or the statistics examination score sample means were significantly different for the two groups. To determine if the traditional group (T) improved in achievement more than the 4MAT group (M), the means of test scores and the associated standard deviations for each class were determined. Since the variances of each class were unknown and cannot be assumed equal, the following method was used.

Compute the estimated variance of the traditional group (V_T) and the 4MAT group (V_M) in the following manner:

$$V_T = \frac{s_T^2}{n_T} \qquad \text{and} \qquad V_M = \frac{s_M^2}{n_M}.$$

Compute the effective number of degrees of freedom (f) in the following manner:

$$f = \frac{(V_T + V_M)^2}{\dfrac{(V_T)^2}{n_T + 1} + \dfrac{(V_M)^2}{n_M + 1}} - 2.$$

From the t-distribution, select $t_{1-\alpha}$ for f' degrees of freedom, where f' is the nearest integer to f, and $t'_{1-\alpha}$ represents the t value from the table using f' degrees of freedom. Compute:

$$u = t'_{1-\alpha}\sqrt{V_T + V_M}.$$

If $(\overline{X}_T - \overline{X}_M) > u$, then the average score of the traditional group exceeds the average score of the 4MAT group for achievement on statistics and probability units of study. Otherwise, there is no reason to believe that the average score of the traditional group exceeds the average score of the 4MAT group. If the groups are not considered equal, then use $|\overline{X}_T - \overline{X}_M|$.

If $(\overline{X}_T - \overline{X}_M) \leq u$, then the same procedure would be used to analyze the data based on learning styles. Likewise, if the groups are not considered equal, use $|\overline{X}_T - \overline{X}_M|$.

Question 3: Does the use of a learning style model for teaching impact the retention of material presented to those students enrolled in a mathematics content course for preservice elementary school teachers? If so, is the degree of retention specific to any particular learning style type?

An equivalent exam on probability was given to both classes approximately thirty days after the instruction and assessment of that chapter. The semester ended with instruction on statistics, therefore, the final exam was also developed content specific for probability and statistics. Since the comparisons were made within the groups, they are considered dependent variables. Again, if the teaching technique affects retention, we expect the scores of the 4MAT group to be significantly higher on the equivalent forms test and the final exam. We expect the scores to remain the same on the equivalent forms test and the final exam for the traditional group. A t-distribution was used as described in Question Two.

CHAPTER IV

DATA ANALYSIS

Present Study

In the previous chapter, a design for the present study was developed using Perry's model to measure the level of cognitive development of preservice elementary teachers enrolled in a required mathematics content course. The design also included the use of the 4MAT Learning Style Model to determine the most appropriate instructional strategies for preservice elementary teachers. A review of literature was presented discussing the application of Perry's model to measure the level of cognitive development. Also, the literature review included discussion of a variety of learning style models. The question posed for this research is: How do changes in instructional strategies that focus on diversity of students' learning styles impact the level of cognitive development, achievement, and retention of those students enrolled in a mathematics content course for preservice elementary teachers?

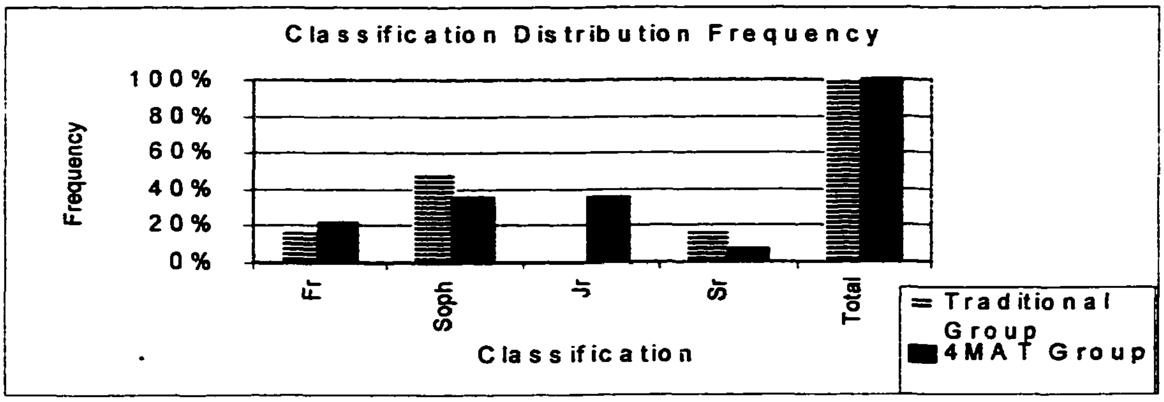
This chapter includes the relationships found among the cognitive development level, learning style preferences, achievement, and retention of students enrolled in the content course Structural Concepts in Mathematics as depicted by the qualitative and quantitative data collected. The chapter also includes validation of the data collected.

Demographic Information

Structural Concepts in Mathematics in the Spring of 1998 consisted of two sections, with six enrolled in the traditional group and 17 enrolled in the 4MAT. The traditional group consisted of five females and one male. The 4MAT consisted of 15 females and two males. Three female students withdrew from the 4MAT group before the research began, leaving 14 in that section. All participants, except one, were elementary education majors. All participants were from rural settings, implying fairly conservative cultural backgrounds, and were from similar socioeconomic backgrounds. All participants, except one, had at least taken Algebra I, Algebra II, and Geometry in high school. All participants' ages, except one, fell within the interval of 20-27 years of age. Therefore, variances were assumed to be homogeneous from group to group, within the bounds of random variation. ACT scores, high school GPAs, and previous mathematics course exposure were analyzed to further understand the comparability of the groups. This analysis and the evaluation of a Knowledge Inventory Test were used to identify which group would receive treatment. The 4MAT instructional strategies would be used as treatment on the selected group. Figure 4.1 illustrates the enrollment and classification of each section. The lower-achieving group was chosen as the treatment group since there would be greater potential to observe achievement gains and cognitive growth. Students in the smaller group are hereafter referred to as the traditional group. Students in the larger group are hereafter referred to as the 4MAT group.

Univariate analysis was performed to find the means and standard deviations of the Math ACT scores (ACT-M), Composite ACT scores (ACT-C), high school grade

FIGURE 4.1
CLASSIFICATION FREQUENCY TABLE



point averages (GPA-HS), higher education grade point averages (GPA-HE), and the mean of the grades made in the prerequisite course, Structural Concepts in Arithmetic (SCAM). The ACT test was taken more than one time by several of the students; in these cases, the first ACT score was used in the analysis. The high school GPA was not available for only one student in traditional group. This score was treated as missing data. ACT scores were available for all students in both groups. Only one student in the 4MAT group had not taken the prerequisite course, Structural Concepts in Arithmetic. This score was also treated as missing data. A mean for each group was calculated using the grades earned in the prerequisite course using an assignment of four points for an A, three points for a B, two points for a C, one point for a D, and zero points for an F. The results are located in table 4.1. Note that as expected, the spread of scores was less in the traditional group compared to the spread of scores in the 4MAT group. The means were greater in all the areas for the traditional group as compared to the 4MAT group. This might suggest that students in the traditional group had better math scores and richer previous experiences than those in the 4MAT group. It also may indicate a lack of variance due to the small number in the group. Based on this, the group chosen for treatment was the 4MAT group.

TABLE 4.1
DEMOGRAPHIC GROUP MEANS

	Traditional Group			4MAT Group		
	Mean	S.D.	N	Mean	S.D.	N
ACT-M	20.17	1.17	6	17.14	3.36	14
ACT-C	20.00	2.45	6	18.21	3.68	14
GPA-HS	3.60	0.27	5	3.14	0.51	14
GPA-HE	3.38	0.50	6	2.64	0.64	14
SCAM	2.83	0.75	6	2.62	1.10	13

Knowledge Inventory Test

The Knowledge Inventory Test was given at the beginning of the semester to all students in both groups. The results are located in table 4.2. The lowest score in the traditional group was 75. There were seven students in the 4MAT group who scored below 75. Also, the highest score of the 4MAT group was 91. There were two students in the traditional group who scored at or above that score. Therefore, the 4MAT group appeared to perform lower than the traditional group on this test.

TABLE 4.2
KNOWLEDGE INVENTORY SCORES

Traditional Group		4MAT Group			
Code	Score	Code	Score	Code	Score
0720	76	0614	54	3827	62
4236	75	1701	85	4783	68
5687	85	1797	86	6772	91
7777	91	1976	83	6896	47
9204	100	3112	85	7304	84
9865	89	3473	64	7773	73
		3496	34	9612	84

Univariant analysis was performed to find the mean and the standard deviation of each set of scores. The results are located in table 4.3. The mean was higher for the traditional

TABLE 4.3
KNOWLEDGE INVENTORY STATISTICS

	Traditional Group	4MAT Group
Count	6	14
Mean	86.00	71.43
Standard Deviation	9.51	17.26

group than the mean of the 4MAT group. The standard deviation was smaller for the traditional group as well. An analysis of these statistics suggest that the traditional group performed better than the 4MAT group on the Knowledge Inventory Test. This is consistent with the data collected on the demographic information.

Cognitive Development Scale

The SID-IV was administered before any changes in teaching strategies were implemented and again at the end of the experimental period. According to the Scale of Intellectual Development Manual that was distributed with the test material, all raw scores were converted to SID-IV standardization of scores using the following formulas:

SS = AX + B where SS = standard score.

A = 10/Raw standard deviation.

B = 50 – A times the Raw mean.

The standardized scores for the traditional group are located in table 4.4. According to

TABLE 4.4
SID-IV STANDARDIZATION OF SCORES – TRADITIONAL GROUP

SID-IV-A					SID-IV-B				
Code	Dualism	Relativism	Commitment	Empathy	Code	Dualism	Relativism	Commitment	Empathy
0720	35	34	66	53	0720	45	36	65	51
4236	55	57	47	53	4236	48	64	55	58
5687	61	55	39	32	5687	48	52	39	33
7777	63	66	42	45	7777	58	86	32	62
9204	47	58	49	53	9204	67	48	43	51
9865	51	46	49	58	9865	42	48	·48	58

the manual assignment of stage development is based on the highest score of the four levels obtained by the test taker. No other analysis of this data should be done except to determine the stage of development based on the highest score. The manual also clearly states that it is a very rare situation for a student to score highest at the *empathy* stage of development. Therefore, any student who scored the highest in this stage of development was recorded as the next highest on the scale. For example, student 9865 scored highest at the *empathy* stage of development. However, using the suggestions of the developers of the test, this student was recorded at the *commitment* stage since that is his/her next highest score. SID-IV-A was the first administration of the SID-IV; SID-IV-B was the final administration of the same test.

Table 4.5 denotes the stage of cognitive development for the traditional group for both the SID-IV-A and the SID-IV-B and the students' respective classifications. For coding in the table, "A" indicates the results of the SID-IV-A; "B" indicates the results of the SID-IV-B. The asterisk indicates students who tested at the *empathy* stage but were actually assigned the next highest score as explained previously. As shown in the table, 50% of the students in the traditional group remained at the same level of cognitive development throughout instruction. Fifty percent of the students changed from one level of development to another. One freshman who tested at the *relativism* stage, one sophomore who tested at the *commitment* stage, and one junior who tested at the *relativism* stage had no change in position from one test to another. On the SID-IV-A, one sophomore tested at the *relativism* stage, and one tested at the *commitment* stage. The sophomore who tested at the *relativism* stage on the first test actually regressed from that stage to dualism. This situation is discussed in the literature review as *retreat*. On the SID-IV-B, all the freshman students tested at the *relativism* stage on SID-IV-B, indicating a change in position for two of these students.

TABLE 4.5
COGNITIVE LEVEL – TRADITIONAL GROUP

	Classification	Dualism	Relativism	Commitment	Empathy
5687	Freshman	A	B		
7777	Freshman		A,B		
9865	Freshman	A*	B*		
0702	Sophomore			A,B	
9204	Sophomore	B	A		
4236	Junior		A,B		

* Student scored highest at the *empathy* stage requiring stage assignment to be adjusted.

The raw scores for the 4MAT group were converted to SID-IV standardized scores using the procedure described above. These scores are located in table 4.6. In this group 67% (four of six students) scored at the *empathy* stage of development. Again, following the published test evaluation manual, assignment of stage development was done based on the next highest score of the four possible stages attained by the test taker. The other data are discounted with regard to data analysis. In the table, SID-IV-A indicates the scores attained on the first administration of the test. SID-IV-B indicates the scores attained on the last.

A summary of the scores appears in table 4.7. Again, for coding in the table, "A" indicates the results of the SID-IV-A; "B" indicates the results of the SID-IV-B. The asterisk indicates students who tested at the *empathy* stage but were actually assigned the

TABLE 4.6
STANDARDIZED SCORES – 4MAT GROUP

SID-IV-A					SID-IV-B				
Code	Dualism	Relativism	Commitment	Empathy	Code	Dualism	Relativism	Commitment	Empathy
0614	64	55	39	35	0614	59	46	43	36
1701	36	39	50	43	1701	35	36	53	37
1797	44	43	32	40	1797	44	36	40	41
1976	46	40	67	52	1976	49	54	54	65
3112	56	40	50	50	3112	53	48	52	48
3473	47	51	55	43	3473	40	57	55	44
3496	64	59	59	62	3496	63	59	62	59
3827	37	48	37	54	3827	46	63	21	38
4783	54	61	39	43	4783	59	59	55	50
6722	39	40	48	59	6722	41	32	53	59
6896	46	67	50	65	6896	40	60	53	58
7304	68	55	60	54	7304	69	49	53	54
7773	47	41	59	36	7773	49	44	52	47
9612	54	62	52	63	9612	54	56	55	65

next highest score as explained previously. More students tested in the *dualism* stage than any other on SID-IV-B. For all students except one or 93%, there was no change in the cognitive stage of development. Only one student changed stages, and that student showed signs of *retreat*. There were more juniors at the *dualism* stage than any other classification. That level of cognitive development may explain why those students delayed their enrollment in the course. One freshman and two sophomores also tested at the *dualism* stage. All who tested at the relativism stage were sophomores. Surprisingly, one freshman tested at the *commitment* stage. Also, two sophomores and one junior tested at that stage.

TABLE 4.7
COGNITIVE LEVEL – 4MAT GROUP

		SID-IV-A		SID-IV-B	
Code	Classification	Dualism	Relativism	Commitment	Empathy
3112	Freshman	A,B			
7773	Freshman			A,B	
1701	Sophomore			A,B	
3473	Sophomore		B	A	
3827	Sophomore		A*,B		
4783	Sophomore		A,B		
6722	Sophomore			A*,B	
6896	Sophomore	A,B			
7304	Sophomore	A,B			
9612	Sophomore		A*,B*		
0614	Junior	A,B			
1797	Junior	A,B			
1976	Junior			A,B*	
3496	Junior	A,B			

* Student scored highest at the *empathy* stage requiring stage assignment to be adjusted.

Personal Interviews

Personal interviews were conducted to verify the cognitive level of development. All students in the traditional group and all students except one in the 4MAT group were interviewed. The missing interview in the 4MAT group existed because of health restrictions of the student. The students were asked questions that investigated their concepts of the meaning of knowledge, responsibility of learning, exchange of conflicting opinions, tolerance of difficult instructional situations, attitudes toward problem solving, and attitudes about commitment. For some of these questions, responses were standard and anticipatory. Validation of cognitive development stages occurred with responses to the questions dealing with tolerance of difficult instructional situations, attitudes toward problem solving, and attitudes toward acquisition of knowledge.

The question posed to the students on tolerance of difficult instructional situations was, "Have you ever taken a class where you had to figure out what the professor wanted from you?" A follow-up question was, "What did you learn from that experience?" Almost all the students who measured at the *dualism* stage blamed the professor for any difficulties that arose during the instructional process. Responses such as "I had a professor who just really didn't explain herself. I guess she just wanted me to be able to do it on my own" and "Like maybe he really didn't care whether I got it or not" are typical of the frustration expressed by this group. Another at the *dualism* stage stated, "I couldn't figure out what they were asking on the questions...I just didn't have the answer." When asked what they learned from the experience, some students responded with:

- It was really hard, I thought...I learned not to take the professor again.
- To keep my mouth shut! Listen and pay attention.
- I guess you should find out what they're like before you take their class.

These responses are typical of a student at the *dualism* stage.

One student who tested at the *relativism* stage responded to the first question with "Yeah, I think college is kind of like that, because, I mean, they change their minds just like any other teacher does, but usually after the first test you kind of know what to look for." Another responded with "I'm taking a psychology class and sometimes her tests are totally off the subject and you just have to figure out what she wants for the answers." Some of the students in this group stated that they had not been in this situation yet. These students are beginning to take responsibility for their learning, which is an attribute of the *relativism* stage.

Some common responses from students who tested at the *commitment* stage were:

- Yes, and no. I think the professors up here have the best interest of the student in mind. They are not up here just for the money or to goof off. They are here for the students.
- Yes, you had to figure out [what the professor wanted] and then realize it was something that you couldn't give.
- I learned that you really have to learn the information front and back.

These students were clearly placing the responsibility of learning on themselves rather than on the instructor. This is a characteristic of the student who is in the *commitment* stage of cognitive development.

Another question that aided in validation of the assignment of the cognitive stage of development was, "Have you ever worked on a problem that has more than one way to arrive at a solution?" with a follow-up question of "How does that make you feel?" Typical responses of the students who scored in the *dualism* stage were:

- Like my answer might not be right.
- Curious, I would like to know the other way, but, it kind of scares me, too.
- That is really frustrating, because I'm really bad, and I don't trust myself enough, because if this is the answer, then the other [way] must be wrong.

Other responses included:

- Yes, I get confused. I try to find a more simple or easiest way for me to do it.
- [I feel] like I'm wrong. If you don't know that there is more than one solution, you think you're wrong, and you just give it up.

- I don't like it at all.

These are very typical responses for students who are at the *dualistic* stage of cognitive development.

Students who tested at the *relativism* stage gave the following responses:

- Confused, because if I worked it different than someone else, then I think that I might have done it wrong. But it makes me feel good because you can get there two different ways.
- Yes, I think it is great as long as you understand.
- Yes, I just want to do it the way it is easiest for me.
- Yeah, I'm glad they're like that though because everybody looks at it different so that they can't be wrong as long as they can get the same answer.

Responses given by students who measured at the *commitment* stage of development were:

- Yeah, those are the questions that I like a lot of times because I'm real big on trial and error. I would much rather just try to work my way through the problem and if one way doesn't work out, then I'll go try something else.
- Yeah, I really had a good teacher in school, and we were working on proofs and you could do them in three pages or you could do them in two.
- I think that it is pretty interesting and makes me feel like I did arrive at something and I did it my own way.

When comparing the responses of students in the three stages of development, increasing maturity in attitude toward problem solving is evident as students progress through each stage.

Essays

Students in both groups were also asked to write an essay on "The Best Class I Have Ever Had and the Worst Class I Have Ever Had." The responses to these questions were not quite as revealing as the personal interviews; however, in some cases, the cognitive level was evident. For example, students who tested at the *dualism* stage responded with statements such as:

- She [referring to the teacher] made the class very enjoyable by getting involved in the teaching of it.
- My teacher has made it a fun class and an informative class.
- I usually don't like science but this teacher makes it fun and interesting.
- The teacher was hard and pretty blunt. I feel she went out of her way to ridicule and humiliate students and their intellect.
- The teacher really never discussed the material that was on the test.

These responses are typical of students at the *dualism* stage. The responsibility for learning is placed on the authority, and assessment of learning is based on testing exactly what was taught.

Students who appeared to be at a transition position between *dualism* and *relativism* responded in the following manner: "I don't really like the subject" and "My teacher was great and I understood, I just don't like working with proofs very much." In these responses more responsibility for learning is assumed by the learner. There is still a bit of immaturity in the responses but not as much frustration in the tone.

Students who were at the *relativism* stage of cognitive development responded to the questions in the essay in the following ways:

- I honestly believe that the worst class I ever had has become the best through what I've learned.
- She [teacher] was extremely knowledgeable, well prepared for class, and straight to the point.
- I have underestimated his [teacher] accomplishments, because looking back I have found that I did learn a lot more than I had believed.

These responses show more emphasis on *how* rather than just on *what* the student learns. More responsibility is taken by the student for the learning process as well.

From students who tested at the *commitment* stage of development, the following responses to the same questions were given:

- She was extremely encouraging and understanding. She taught [subject] in many different teaching styles trying to reach each student.
- He seems down to earth and really cares about the students and how their lives are going on.
- It really isn't the professor.

For these students, the grade may be important, but the learning experience is more consequential. The student begins to assume responsibility for their own learning experience and does not blame others when the perceived situation is not ideal.

Finally, to identify their attitudes toward acquisition of knowledge students were asked, "In order for a learner to acquire knowledge [in the classroom], what is the role of the teacher?" and "What is the role of the student?" Some of the students who tested at the *dualism* stage responded to the question addressing the responsibility of the teacher with:

- To communicate the information to the student in a way that makes it possible for the student to learn.
- [The teacher's] responsibilities are to be available to students if they need help, to be easily contacted, or to grade fairly and give everybody a chance.
- Go over and over the material until the students understand it.
- To make sure the student does the work satisfactory.
- Explaining it step by step, and make sure everybody understands.
- To teach the information to where there is an understanding.

In response to the second question, some of these students stated "The role of the student is to understand that teachers are important, and why they're [teachers] there, and understand that learning isn't going to be easy just because they're [students] there every day, and taking notes, and doing well on tests" and "To listen, to be able to pull it all together and make the information work." Another responded with, "To ask questions and acquire knowledge." For the students at this level, the responsibility appears to rest upon the authority in the classroom, the teacher. Students who tested at a transition stage between *dualism* and *relativism* responded to this question with, "The student has to work at understanding it, they should be in class, ask questions, and do the homework" and "Working, try to figure it out."

Students who tested at the *relativism* stage responded to the first question with

- I think they [teachers] have to be their [students] friend and sometimes their counselor because a lot of times they won't talk to anyone but the teacher.
- To explain, and show us how to do things.
- Encourage them [students].

In response to the second question, some of these students said, "To do the homework" and "They [students] need to try hard in class and try to learn because it affects their future" and "They [students] need to learn it in the classroom, and then go back." Students assume a larger portion of the responsibility for acquiring knowledge, yet they still hold fast to the notion of needing to be "shown how" to acquire this knowledge.

There is an apparent shift in attitudes concerning responsibility of learning for the students who tested at the *commitment* stage, and this is clear in some of their responses to the first question:

- [Responsibilities of the teacher are] Like a guide or an aid. I don't expect the teacher to just give the answer but to guide you in the right direction.
- It is to be sensitive enough to realize how a student learns.
- I think the teacher should be motivated and excited about what they're doing.

In response to the second question, some of the students who tested at this stage responded with, "To want to learn, to act excited, too, even though it may not be something they're completely interested in, try to get involved in it" and "To be in class and arrange your life so that it is easier to obtain knowledge. Make sure that you are mentally in class."

The students were not informed of their presumed level of cognitive development. Also, they were not given any instruction on levels of cognitive development. After the students took the SID-IV test the first time, they were introduced to the concepts of learning style preferences.

Learning Type Measure

At the beginning of the experimental period, three days of instruction were committed to learning style preferences for both groups. Then the Learning Type Measure® (LTM®) and the Hemispheric Mode Indicator (HMI) were administered and evaluated for both groups. Table 4.8 shows the results for the traditional group.

TABLE 4.8
LTM® - TRADITIONAL GROUP

Code	I - Concrete/Reflective	II – Abstract/Reflective	III – Abstract/Active	IV – Concrete/Active	Total	Most Favored Quadrant	Watching/Doing		Hemispheric Mode	Indicator
0720	46	31	34	39	150	I	+51	D	+11	R
4236	46	35	34	35	150	I	+9	D	-5	W-L
5687	44	40	36	30	150	I	+1	D	-3	W-L
7777	42	29	27	52	150	IV	+11	D	+48	R
9204	52	30	25	43	150	I	+9	D	+18	R
9836	44	43	35	28	150	I	-3	W	-11	L

According to the data, five out of six students showed Quadrant I as their preferred quadrant. Quadrant IV was the learning style preference for one student. No students in the traditional group showed Quadrants II or III as preferred quadrants. Five of six students favored "doing" while learning rather than watching. One of those students was very close to neutral with a score of +1. Only one student favored "watching" while learning, and that score was also very close to neutral. The right- or left-brain dominance scores are indicated in the last column of the table. Right- or left-brain dominance is denoted by the appropriate first letter. The numerical score is also given in the column. Notation "W-L" indicates a balance of dominance or "whole" with a slight tendency toward the left. Three students were clearly right-brain dominant, and one of those was extreme. Two tested as balanced with a tendency toward the left. One tested left-brain dominant.

Students in the traditional group completed a Self-Analysis Survey discussing the results of the LTM® and HMI. Students were asked to acknowledge the validity of the highest quadrant which would be most descriptive of them and the lowest quadrant which would be least descriptive of them. One student in this group did not submit the survey. This was treated as missing data. All others in the group agreed with their test results for the most favored quadrant. Only one student disagreed with the results indicating the quadrant least like him/herself. After reviewing right- and left-brain dominant characteristics, students were asked to analyze the results of the HMI. All agreed with the results. However, the student who scored extremely to the right stated, "It is pretty accurate. I believe I should have been a little more left brained in the test."

Students also answered the question "How does this analysis of your learning style preference influence you?" A response such as "I think that this analysis considerably helped to shine some light on this situation. I feel my results are accurate and help me get an idea of how I learn" was typical of almost all the students. Another student stated, "It helped me understand why I think and study the way I do." Another responded, "Sometimes I wonder if I am just weird by thinking the way I do. I now realize that it is okay to think the way I do."

Another question students responded to was, "How do you think this information can be helpful in the elementary classroom?" Some responses were: "I think it will be easier to teach kids if you understand them" and "I will further understand that many children prefer or require different learning techniques. Therefore, I will switch up my classroom to involve everyone equally, and give everyone a chance" and "If you know what kind of teacher you are and you know this information, then you can better understand how you and your students will best learn together." All students viewed this experience as beneficial to them in their learning experience and in their future teaching experience.

Students in the 4MAT group were given the same instruments at the same time as the traditional group. They were given the same instruction on learning styles and right- and left-brain dominance. The results of their tests are located in table 4.9. Students who had tie scores for the most favored quadrant or the least favored quadrant are indicated with an asterisk in the table. In each case, the student analyzed the characteristics of each quadrant and chose his/her preferred learning style. Eight of 14 students tested in Quadrant I. Two students tested in Quadrant II. One student tested in quadrant III. Three students tested in Quadrant IV. Six students favored "doing" while learning rather than watching while learning. Eight students favored "watching" while learning rather than being active during the learning process. Four students were right-brain dominant, and five students were left-brain dominant. Five students were balanced or "whole" brain dominant with four of those showing tendencies toward the right, and one toward the left. These scores are denoted with "W-R" or "W-L," respectively.

TABLE 4.9
LTM® - 4MAT GROUP

Code	I-Concrete/Reflective	II – Abstract/Reflective	III – Abstract/Active	IV – Concrete/Active	Total	Most Favored Quadrant	Watching/Doing		Hemispheric Mode	Indicator
0614	50	25	35	40	150	I	+11	D	+19	R
1701	50	28	26	46	150	I	+7	D	-20	L
1797	45	33	39	33	150	I	+3	D	+23	R
1976	53	29	37	41	150	I	-7	W	+4	W-R
3112	51	27	35	37	150	I	+11	D	+25	R
3473	44	44	41	21	150	II*	-1	W	-13	L
3496	38	36	41	35	150	III	-1	W	+5	W-R
3827	36	34	40	40	150	IV*	-5	W	-4	W-L
4783	35	40	39	36	150	II	-11	W	-21	L
6722	41	32	33	44	150	IV	-7	W	+26	R
6896	42	29	41	38	150	I	-1	W	+23	L
7304	44	37	42	27	150	I	-9	W	-11	L
7773	31	39	39	41	150	IV	+9	D	+4	W-R
9612	49	37	34	30	150	I	+7	D	+2	W-R

*Duplicate scores occurred in more than one quadrant.

Another question that was posed to the students in the personal interviews was, "Have you noticed any different teaching techniques in our class from the beginning to the end?' This question was developed to ascertain whether the students noticed when the instructional strategies of the 4MAT Learning Cycle were implemented and then ended. The period of this treatment was approximately eight weeks. Although students in the traditional group did not receive 4MAT instructions, they also were asked this question. Some of their responses were:

- I think we take more time at the end of class to work the problems.
- I didn't notice any difference.
- Yes, the way you present the material, we did a lot more on our own.

Three other students not quoted responded with "No."

Each student in the 4MAT group was asked the same question. Surprisingly, almost all of them responded with "No." Some responses other than negations included:

- Yeah, a little bit more with the overhead lately. And since we've gotten away from constructions...it's different...cause we're not doing as much on paper, I guess.
- It seems like we've done more games...I mean like that ball thing...I mean, we haven't done a lot of games...but it seems like its more interaction and not just lecture.
- No. Everything has been consistent. You've taken everything step-by-step as much as you could.
- I like the hands-on learning, even though we are a college class, that helps me understand.
- I think that you did more grouping and things on the board the second half than you did the first.

Students in the 4MAT group completed a Self-Analysis Survey discussing the results of the LTM® and HMI. All students in the 4MAT group responded to the survey. Two students disagreed with the results of the most favored quadrant. These two disagreed with only a few of the descriptors. Three students disagreed with the results for the least favored quadrant. Each of these students listed characteristics of the quadrant that they felt did not fit them. All but one student agreed with the results of the right- and left-brain dominant analysis. This student was adamant about possessing the left-brain dominant characteristics. The score actually placed this student there as well. The student had incorrectly read the score as right-brain dominant rather than left.

Students also answered the question, "How does this analysis of your learning style preference influence you?" All students responded positively. A few were already aware of their learning style preference. However, for many students this was their first exposure to the concept of learning style preferences. Some of the responses were:

- It has helped me realize what type of classroom setting I would best learn in. If I am ever in a situation that's not good for my learning I now know how to study, review, whatever to best suit my learning abilities.
- For one thing, I don't feel as bad now that I am not as interested in or can't [get] into some of my lecture classes. I better know how to go into those classes.
- This can help me to gain confidence in learning new things.
- It is interesting. I have become aware of my weak points and what I should work on to be a good teacher.

The last question on the survey to which the students responded was, "How do you think this information can be helpful in the elementary classroom?" All had positive feedback concerning this question. Some of the responses were:

- It has shown me that there are many different learning styles. What one child finds easy another might find hard.
- By learning the styles, I can adapt to my students instead of them adapting to me. I can try to avoid all the uncomfortable situations.
- By knowing that every child is an individual and learns differently.
- Helps keep an open mind about how a child might learn and is influenced by the teacher's style and how each student could be reached.
- I think this information will help a lot because now I will be more versatile in my understanding of learning.

For the data analysis, each question will be addressed separately.

Data Analysis

The Student t-test was selected as the statistic for analyzing some of the results of this experiment. A one-tailed 5-test was used to determine whether the mean of the 4MAT group was significantly greater than the mean of the traditional group at the 95%

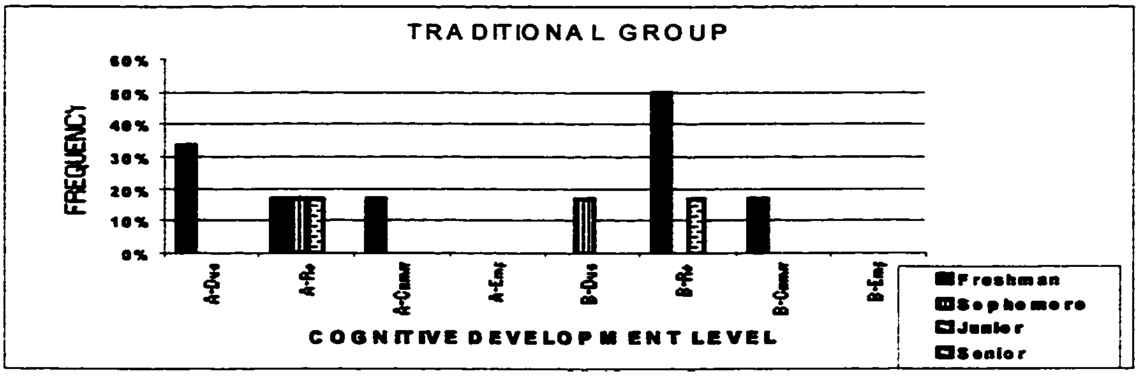
confidence level. The t-test makes adjustments for the fact that the distribution of scores for small samples becomes increasingly different from a normal distribution as sample sizes become increasingly smaller. Also, according to Kerlinger (1986), the t-test is robust enough that it operates well under violations of assumptions such as normality and homogeneity of variance, provided violations are not gross and multiple. The population distributions of the parameters represented in this research involving elementary education majors were assumed to be normal. Also, as discussed earlier in the chapter, homogeneity of the groups was established based on the demographic data.

In basing decisions on the outcomes of statistical tests, one runs the risk of making either a Type I error or a Type II error. If one rejects the null hypothesis when it is true, then a Type I error occurs. If one fails to reject the null hypothesis when it is false, then a Type II error occurs. Although we do not know in a given case whether errors have been made, we can know the probability of making either error. For this study, a conservative significance level of $\alpha = .05$ was chosen which would result in a high probability of not rejecting the null hypothesis. For the data analysis, each question was addressed separately.

Question 1a: What is the relationship between learning style preference and level of cognitive development?

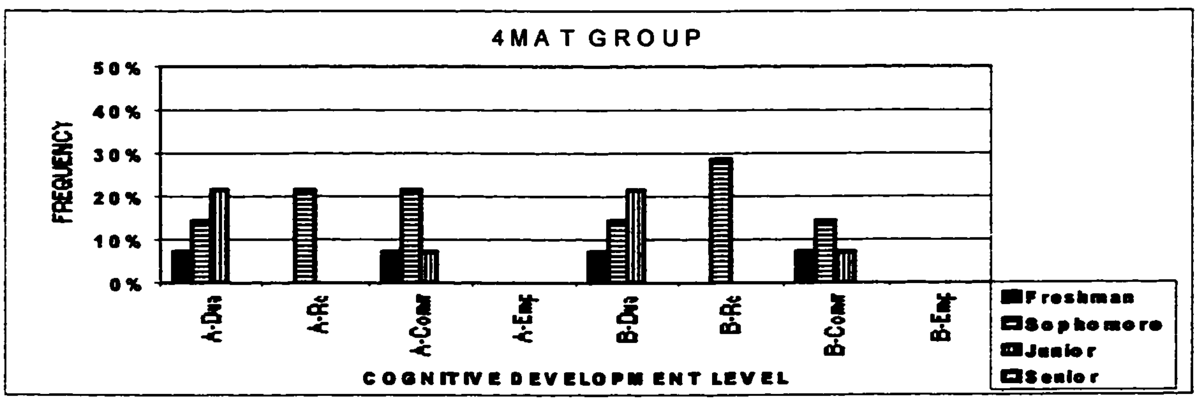
The following descriptive statistics illustrate a comparison between demographic data collected and the corresponding position of cognitive development. These charts were developed using data collected before and after the treatment was administered. Figure 4.2 shows the data for the traditional group. According to the data, 33% (or two of six) freshmen tested at the *dualism* stage on the first test, denoted by A-Dual. Those two freshmen advanced to another level, while 17% (or one of six) sophomores tested at the dualism stage on the second test, denoted by B-Dual. Clearly 17% (or one of six) sophomores regressed in stage development since there were no sophomores who tested at the *dualism* stage on the first test, and one sophomore who tested at that stage on the second test. Eighty-three percent (five of six) of the students in the traditional group either stayed in the same cognitive development level or advanced.

FIGURE 4.2
COGNITIVE DEVELOPMENT LEVEL AND CLASSIFICATION



For the 4MAT group, depicted in figure 4.3, 93% (13 of 14) remained at the same cognitive development level. The student, a sophomore, who changed positions actually regressed from the *commitment* stage on the first test to the *relativism* stage on the second test.

FIGURE 4.3
COGNITIVE DEVELOPMENT LEVEL AND CLASSIFICATION



To determine if a correlation exists between the cognitive development level and the learning style preference, numerical values were given for each stage of development. The numerical values provided the basis for the analysis and testing of data. The following assignment was made:

2=Dualism
4=Relativism
6=Commitment
8=Empathy

If a student tested at different levels on SID-IV-A and SID-IV-B, then an average of the assigned value was calculated. Table 4.10 shows the values assigned to each student with regard to the SID-IV assessment.

After the administration of the LTM® and the HMI, numerical values were assigned for each score. The 4MAT Learning Style Model has four distinct quadrants and each quadrant is divided again for right- and left-brain dominance. Therefore, there are eight sectors of the cycle. Numerical values were assigned according to the following scale from the 4MAT model:

1 - Quadrant I – right
2 – Quadrant I – left
3 – Quadrant II – right
4 – Quadrant II – left
5 – Quadrant III – left
6 – Quadrant III – right
7 – Quadrant IV – left
8 – Quadrant IV – right

Table 4.10 shows the value assigned to each student with regard to the LTM® and the HMI assessment.

TABLE 4.10
COGNITIVE LEVEL, LTM®, HMI

Traditional Group					4MAT Group				
Code	SID-IV	LT M®	H MI	Assigned Value LTM/HMI	Code	SID-IV	LT M®	H MI	Assigned Value LTM/HMI
0720	6	1	R	1	0614	2	1	R	1
4236	4	1	W/L	2	1701	6	1	L	2
5687	3	1	W/L	2	1797	2	1	R	1
7777	4	4	R	8	1976	6	1	W/R	1
9204	3	1	R	1	3112	2	1	R	1
9865	3	1	L	2	3473	5	2	L	4
					3496	2	3	W/R	6
					3827	4	4	W/L	7
					4783	4	2	L	4
					6722	6	4	R	8
					6896	4	1	R	1
					7304	2	1	L	2
					7773	6	4	W/R	8
					9612	4	1	W/R	1

As discussed earlier, explanations of the assessments were given to all participants to determine the reliability and validity of the LTM® and the HMI instruments. All students in the traditional group agreed with the assessment. Eighty-seven percent of the students in the 4MAT group agreed with the assessment.

In order to determine if a correlation exists between the cognitive development level and a preferred learning style, correlation coefficient *r*, was calculated using the data from Perry's model as the independent variable and data from the 4MAT Learning Cycle. The correlation coefficient was determined using both groups of data and resulted in the calculated *r* is 0.2964. So, no correlation exists between the cognitive development level and the learning style preference for either group in this study, and there appears to be no relationship between the two.

Question 1b: Does the use of a teaching style model designed to accommodate different learning styles of students bring about a transition in the level of cognitive development?

Changes that occur in cognitive development within the groups were analyzed using a test to compare two means as described in Chapter 3. Table 4.11 shows the numerical values assigned for each assessment using the values described in the previous question.

TABLE 4.11
COGNITIVE LEVEL, LTM®, HMI (Numerical Values)

Traditional Group					4MAT Group				
Code	SID-IV-A	SID-IV-B	LT M®	Assigned Value LTM/HMI	Code	SID-IV-A	SID-IV-B	LT M®	Assigned Value LTM/HMI
0720	6	6	1	1	0614	2	2	1	1
4236	4	4	1	2	1701	6	6	1	2
5687	2	4	1	2	1797	2	2	1	1
7777	4	4	4	8	1976	6	6	1	1
9204	4	2	1	1	3112	2	2	1	1
9865	2	4	1	2	3473	6	4	2	4
					3496	2	2	3	6
					3827	4	4	4	7
					4783	4	4	2	4
					6722	6	6	4	8
					6896	4	4	1	1
					7304	2	2	1	2
					7773	6	6	4	8
					9612	4	4	1	1
Mean	3.7	4.0		2.7		4.0	3.9		3.4
S.D.	1.5	1.3		2.7		2.2	2.0		1.2

A one-tailed t-distribution was used for significance at a 95% confidence level. Table 4.12 shows a collection of the statistics. Subscripts for the mean and standard deviation denote which SID-IV test that statistic describes.

TABLE 4.12
LEARNING STYLE AND COGNITIVE DEVELOPMENT STATISTIC

	n	$\bar{X}_{T1}$	$\bar{X}_{T2}$	s_1	s_2	d.f.	$t_{.95}$	s_T	u_T	$\bar{X}_{T2}$-$\bar{X}_{T1}$
Traditional Group	6	3.7	4.0	1.5	1.3	10	1.812	1.404	1.468	.3
4MAT Group	14	4.1	3.9	2.2	2.0	26	1.706	2.102	1.355	.2

For the traditional group, since $|(\bar{X}_{T2} - \bar{X}_{T1})| < u_T$, there appears to be no reason to believe any change occurred in the cognitive level of development from the time the SID-IV test was first administered to the last time. Likewise, for the 4MAT group, since $(\bar{X}_{T2} - \bar{X}_{T1}) < u_T$, there appears to be no reason to believe any change occurred in the cognitive level of development from the time the SID-IV test was first administered to the last.

Question 2: Does the use of a learning style model for teaching impact the achievement of those students enrolled in a mathematics content course for preservice elementary school teachers? If so, is the degree of impact specific to any particular learning style type?

Identical exams were given to both groups during the treatment period on Probability, Statistics, and Probability Retest. The t-test was used to determine whether the exam score sample means were significantly different, i.e., whether the 4MAT group improved in achievement more significantly than the traditional group. The means of the test scores for both groups and the associated standard deviations were determined. The variances of each class are unknown and cannot be assumed equal. Table 4.13 shows the exam scores for both groups.

One student in the traditional group and one in the 4MAT group did not take the retest for probability. These scores were treated as missing data. All scores were based on percentages. Both the traditional group and the 4MAT group also took a final examination which consisted of content specific only to probability and statistics. The results of this examination are also included as part of the analysis. All students in both groups took the exam. The exam scores are also based on percentages. The procedures

TABLE 4.13
ACHIEVEMENT DATA

Traditional Group			4MAT Group					
Code	Exam Probability	Exam Statistics	Code	Exam Probability	Exam Statistics	Code	Exam Probability	Exam Statistics
0720	79	76	0614	23	72	3827	67	33
4236	66	97	1701	57	62	4783	60	81
5687	87	80	1797	79	75	6722	97	82
7777	85	99	1976	62	33	6896	43	47
9204	78	98	3112	76	79	7304	72	72
9865	95	96	3473	71	63	7773	79	81
			3496	47	42	9612	58	71
Maximum	95	99		97	82			
Minimum	66	76		23	33			
Mean	81.67	94.0		63.64	63.79			
S.D.	9.83	10.20		18.23	17.81			

outlined in Chapter 3 for this analysis generated the set of statistics shown in table 4.14.

For the Probability test, since the mean difference, $|X_T - X_M|$, is greater than the calculated u, there is reason to believe that the mean difference for the traditional group

TABLE 4.14
ACHIEVEMENT STATISTICS

	n	$\bar{X}$	s	V	d.f.	$t_{.95}$	$\bar{X}_T - \bar{X}_M$	u
Probability test					19	1.729	18.03	10.914
Traditional Group (T)	6	81.67	9.83	16.105				
4MAT Group (M)	14	63.64	18.23	23.738				
Statistics test					19	1.729	30.21	10.934
Traditional Group (T)	6	94.0	10.20	17.34				
4MAT Group (M)	14	63.79	17.81	22.66				

exceeds the mean difference of the 4MAT group. Likewise, for the statistics test, the mean difference, $|\bar{X}_T - \bar{X}_M|$, is greater than the calculated u; therefore, there is reason to believe that the mean difference of the traditional group exceeds the mean difference of the 4MAT group. This is consistent with the fact that it appears that the traditional group entered the course with better mathematics skills and possibly better mathematical experiences. It is also consistent with their higher scores on the Knowledge Inventory Test.

Question 3a: Does the use of a learning style model for teaching impact the retention of material presented to those students enrolled in a mathematics content course for preservice elementary school teachers?

Two retests were given to determine if the teaching technique affects retention of material presented. An equivalent exam on probability was given to both classes approximately thirty days after the instruction and assessment of that chapter. Table 4.15 shows the exam scores for both groups for the retests. The semester ended with instruction on statistics; therefore, the final exam also covered content specific to probability and statistics only. The procedures outlined in Chapter 3 for this analysis generated the set of statistics shown in table 4.16.

For the probability retest, since the difference in the means, $|\bar{X}_T - \bar{X}_M|$, is not greater than the calculated u, there is no reason to believe the average of the traditional

TABLE 4.15
RETENTION DATA

Traditional Group			4MAT Group					
Code	Retest Probability	Retest – Final Exam Statistics/Probability	Code	Retest Probability	Retest – Final Exam Statistics/Probability	Code	Retest Probability	Retest – Final Exam Statistics/Probability
0720	82	75	0614	60	72	3827		48
4236	84	93	1701	82	79	4783	58	92
5687	62	76	1797	82	83	6722	84	95
7777	77	96	1976	43	52	6896	50	42
9204	57	88	3112	100	97	7304	65	81
9865		78	3473	80	65	7773	72	73
			3496	32	60	9612	88	94
Mean	72.40	84.3		68.92	73.79			
S.D.	12.18	9.18		19.66	18.23			

group exceeds the average of the 4MAT group. Likewise, for the final exam, the difference of the means, $|\bar{X}_T - \bar{X}_M|$, is not greater than the calculated u. Therefore, there is no reason to believe the average of the traditional group exceeds the average of the 4MAT group.

TABLE 4.16
RETENTION STATISTICS

	n	$\bar{X}$	s	V	d.f.	$t_{.95}$	$\bar{X}_T - \bar{X}_M$	u
Probability retest					18	1.734	3.48	12.544
Traditional Group (T)	6	72.40	12.18	24.725				
4MAT Group (M)	14	68.92	19.66	27.608				
Final Exam					20	1.725	10.31	10.609
Traditional Group (T)	6	84.30	9.18	14.05				
4MAT Group (M)	14	73.79	18.23	23.74				

Question 3b: If so, is the degree of retention specific to any particular learning style type?

Since it cannot be assumed that the average of the traditional group exceeds the average of the 4MAT group in either of the retests, an analysis of the scores within the particular learning type was performed to determine if the degree of retention was specific to any particular learning style type.

In the traditional group, when the data were organized according to learning style type, five of the six students tested in Quadrant I; one student tested in Quadrant II. Therefore, only Quadrant I could be analyzed to determine if the mean of the traditional group exceeds the mean of the 4MAT group for the probability retest and the final exam retest. Eighty-three percent (i.e., all but one) of the students in the traditional group tested in Quadrant I learning style type. Fifty-seven percent of the students in the 4MAT group also tested in Quadrant I learning style type. Table 4.17 shows the data organized according to learning style preference. One student in the traditional group did not take the probability retest. This score was treated as missing data.

The t-test was used to determine whether the two exam score sample means were significantly different for the probability retest and the final exam for the Quadrant I learning style preference. Table 4.18 shows the statistics generated by the data.

For the probability retest, since $|\bar{X}_T - \bar{X}_M| < u$, it cannot be assumed that the mean of the traditional group exceeded the mean of the 4MAT group. Likewise, for the final exam retest, since $|\bar{X}_T - \bar{X}_M| < u$, it cannot be assumed that the mean of the traditional

TABLE 4.17
RETENTION DATA AND LEARNING STYLE PREFERENCE DATA

Traditional Group (T)			4MAT Group (M)		
Code	Retest Probability	Retest – Final Exam Statistics/ Probability	Code	Retest Probability	Retest Final Exam Statistics/ Probability
0720-I	82	75	0614-I	60	72
4236-I	84	93	1701-I	82	79
5687-I	62	76	1797-I	82	83
9204-I	57	88	1976-I	43	52
9865-I		78	3112-I	100	97
			7304-I	65	81
$Mean_{T-I}$	71.25	82.0	6896-I	50	42
$S.D._{T-I}$	13.74	8.03	9612-I	88	94
			$Mean_{M-I}$	71.25	75.0
			$S.D._{M-I}$	19.83	19.23

Table 4.17 – *Continued.*

Traditional Group (T)			4MAT Group (M)		
Code	Retest Probability	Retest – Final Exam Statistics/ Probability	Code	Retest Probability	Retest Final Exam Statistics/ Probability
7777-IV	77	96	3473-II	80	65
			4783-II	58	92
			$\text{Mean}_{\text{M-II}}$	69.0	78.5
			$\text{S.D.}_{\text{M-II}}$	15.56	19.09
			3496-III	32	60
			3827-IV		48
			6722-IV	84	95
			7773-IV	72	73
			$\text{Mean}_{\text{M-IV}}$	78.0	72.0
			$\text{S.D.}_{\text{M-IV}}$	8.49	23.52

group exceeded the mean of the 4MAT group. Thus, at least for Quadrant I there is no reason to believe there is any difference in the exam scores due to the learning style preference.

TABLE 4.18

RETENTION STATISTICS AND LEARNING STYLE PREFERENCE STATISTICS

Quadrant I	n	$\overline{X}$	s	V	d.f.	$t_{.95}$	$\overline{X}_T - \overline{X}_M$	u
Probability retest					29	1.699	0	16.677
Traditional Group (T)	4	71.25	13.74	47.20				
4MAT Group (M)	8	71.25	19.83	49.15				
Final Exam					11	1.796	7.0	13.808
Traditional Group (T)	5	82.0	8.03	12.89				
4MAT Group (M)	8	75.0	19.23	46.22				

CHAPTER V

SUMMARY AND CONCLUSIONS

In the previous chapters, it was suggested that we, as educators, examine current methods of instructional strategies in higher education. Knowing more about students' cognitive development and exploring a variety of instructional strategies that vary from the traditional lecture format may help resolve some of the academic tensions for our students, particularly preservice elementary education students. Research indicates *how* students learn is directly connected to *what* they learn, and that some of these academic tensions may be released when cognitive development grows and instructional strategies vary. A review of literature was presented supporting the use of Perry's model to measure the level of cognitive development. How one relates to authority, along with fundamental conjectures about the nature of knowledge, characterizes Perry's theory on the progression of cognitive development. A variety of learning style models was presented including the 4MAT model, which was used in this research project. A design was developed using Perry's model to measure the level of cognitive development and the 4MAT Learning Style Model as an instructional strategy for preservice elementary teachers who were taking a required mathematics content course.

This chapter summarizes the research results of the analysis of the relationship among the cognitive development level, learning style preference, achievement, and retention of preservice elementary teachers in a content course in mathematics. It also provides some observations and limitations of the study. Finally, conclusions are constructed based on the study, and recommendations are made for future research.

Results of the Study

Students who enrolled in a content mathematics course in the Spring of 1998 were selected as participants for this study. Analyses of various achievement indicators were used to determine which of the two groups would receive instruction based on the 4MAT Model. This instructional strategy was used as treatment on the lower-achieving group.

To determine whether a relationship between learning style preference and level of cognitive development existed, scores were analyzed using the cognitive development instrument and the learning style instrument. According to the results of the analysis, there appeared to be no correlation between the cognitive development level and the learning style preference for either group. While the cognitive levels varied among the students, the learning style preferences were much less diverse. Concrete experiences appear to be most favored with 85% of all the students indicating preference for learning in this fashion. Fifty-five percent of the students preferred being physically active during the learning process, while the remainder preferred watching.

When comparing the results of the initial cognitive development level scores with the final cognitive development level scores, there appeared to be no change in stage development with either group. At least with this set of university students, instructional strategies appeared to be irrelevant regarding stage advancement. Most of the students remained at the same level of cognitive development throughout the instruction regardless of whether their instructional strategies remained consistent or not. Research on cognitive development supports this finding. Progression through the stages of cognitive development are slow, and many times the progression from one stage to another takes years of lifetime experiences.

Personal interviews were conducted to verify the measured cognitive development level of the students in the study. Using these interviews, it was determined that most of the level assignments were accurate. In order to reduce bias of the researcher during the duration of the study, no data of cognitive levels of development were analyzed until the end of the study. Students filled out surveys and wrote essays to verify the measured learning style preference. Most of these measures were also found to be accurate.

In the achievement gains, the two groups were compared using two separate unit tests. While the means were consistently higher and the standard deviations were consistently smaller for the traditional group, it appeared that the use of a learning style model did not impact achievement gains for the 4MAT group. For this study, the traditional group scored significantly better than the 4MAT group on both the probability test and the statistics test. Due to the number of variables, e.g., class size, length of instruction, student background, level of content, or maturity of the student, it was not possible to determine the exact cause of the test outcomes. Thus, extreme caution should be exercised when interpreting the results.

In order to determine whether the use of a learning style model impacted the retention of material presented to preservice elementary teachers, the groups were compared using two separate tests. One test was an equivalent forms test. The other test was a final exam in which the content was limited to the content used in the study. Unlike the results of the achievement test, the results of the tests taken to measure retention indicate that there is no difference between the two groups. This result occurred on both tests. Therefore, the 4MAT group did not perform significantly better than the traditional group. Again, caution should be practiced when using these results for the reasons provided previously.

To determine whether the degree of retention was specific to any particular learning style, scores were analyzed across the groups among the learning styles. Since the 4MAT group had five of six students in one learning style, only that learning style was evaluated across the groups. According to the study, the analysis of the difference of the means reveals that there was no reason to believe that the degree of retention was due to a particular learning style preference, at least for students whose learning style preference was in Quadrant I.

Limitations of the Study

Some limitations of the study include number of samples, sample sizes, length of application of instructional strategy, and amount of content included. In the present study, there were two samples. More samples would enable a researcher to isolate and evaluate the variables mentioned above. For example, larger sample sizes would provide a stronger basis for drawing inferences from the test data. This would decrease the spread of scores, and the mean of the sample would be closer to the true mean of the population. Increasing the length of application of instructional strategy and the amount of content included in instruction would provide more test data as it relates to cognitive development and learning styles. These statistics might expose relationships which impact cognitive development and learning styles, i.e., life experiences, levels of education, and maturing of the student.

Research indicates that learners progress slowly in the development of or transition between cognitive stages. Therefore, variations in instructional strategies for only two chapters may not be enough material allocated to the study especially when the students didn't notice the change in instructional strategy. Also, a combined time of approximately eight weeks may not be long enough. A longitudinal study of consecutive semesters may enable the researcher to detect changes in levels of cognitive development of the learner.

Recommendations for Future Research

Future research could be done using the same design as this study but involving a larger number of students. Because the classes were so small, it was not possible to fully evaluate each learning style preference and retention exams. In fact, the effectiveness of this teaching approach in college mathematics may be for large lecture classes rather than small relatively homogeneous groups. Also, the duration of the treatment period could be extended to involve two semesters since there are sequential courses which are required for completion of the elementary education program.

Better control of variables may help determine whether changes in retention identified in the study were due specifically to the use of a learning style model. It was obvious from the survey responses that teaching in preferred learning styles was one way to make students feel more comfortable in the classroom; however, whether it improves the retention of material covered in the classroom is yet to be determined. In the exploration of retention, further study should be done to investigate the relationship between retention and understanding of mathematical content. One method of investigation is to conduct an item-analysis of equivalent forms test questions in which items would be examined for complexity of requirements of the students to exhibit understanding of the mathematical content.

For future research a more detailed breakdown of Perry's model might enable researchers to determine if the use of a learning style model brings about a change in cognitive development within each stage. In this study, four stages of development were analyzed. Perry's model actually has nine levels within these four stages. If a transition occurred between levels within a stage it would not appear as a change without this detail. Also, determinations of level changes within stages normally involve much more detailed and frequent personal interviews. Additional researchers, working collaboratively to analyze the cognitive level of development based on interviews and essays, would be necessary to accurately analyze the data. A detailed test design to conduct extensive research on the relationships among learning styles, instructional strategies, subject matter complexities, and cognitive development should be developed. This would be a multiple-phased research project involving several semesters of instruction.

Implications of this research indicate a need for further investigation of the relationship between application of instructional strategies and cognitive growth for other content areas such as the humanities. Also, extensions to the secondary level of education could determine whether the study of content such as literature, hard sciences, or fine arts aid in the advancement of cognitive growth.

Other implications from this research indicate a need to investigate the impact of the 4MAT System of instruction on teaching behaviors and beliefs about mathematics, teaching, and learning.

Finally, another finding from the personal interviews worthy of further research involves the process of a student actually using his/her textbook as a teaching tool rather than a source of problems to be solved. Students in both classes were required to read and take notes on sections before instruction. Toward the end of the semester, many students commented about the usefulness of this activity, and that they did not realize how much that activity would help in understanding the concepts of mathematics until they had actually done it.

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APPENDIX A

Consent Form for Questionnaire Administration
for the dissertation of Sandy Johnson
University of Oklahoma
Norman, OK

The purpose of this study is to examine the impact of a teaching strategy on the cognitive level of development, achievement, and retention of preservice elementary teachers enrolled in a content mathematics course in the Spring 1998 semester at a regional university in the southwest. The duration of the study will be approximately five weeks.

You will be asked to fill out questionnaires during the Spring 1998 semester which relate to cognitive development, demographic information, and learning style preferences. The researcher will review data such as your ACT score and your GPA. There is no risk to you. However, there are some benefits.

1. You will discover your preferred learning style using the Learning Type Measure and the Hemispheric Mode Indicator. You will gain information during the course that will assist you in the classroom when you become a teacher.

2. You will discover your level of cognitive development using the Scale of Intellectual Development-IV.

3. You may be part of new discoveries in teaching strategies for your own classroom.

There is no penalty for non-participation. If you prefer not to be involved in this study, participation in normal classroom activities such as exams and homework will be expected.

You will choose a four-digit code to use on all questionnaires collected for research purposes. A legend for the four-digit codes will be stored in a locked file in my office. Upon completion of the dissertation, the legend connecting code assignment with name will be shredded. In order to provide support for the study, all other data will be retained in a sealed envelope in the researcher's file.

If you have any questions about the research itself or your rights as a research subject, contact Sandy Johnson. My office is located in Campbell Building, room 324G.

Please check the appropriate paragraph.

_____ I choose to complete the questionnaires concerning cognitive development level and learning styles during this research project. I understand that demographic information, GPA, and ACT score will be collected and kept confidential. I understand that my participation is purely voluntary, that my responses will remain confidential. I understand that participation will in no way affect my final grade in this class.

_____ I choose not to participate. I am unwilling to complete the questionnaires and understand that my decision will in no way affect my grade in this course.

I understand that I am free to refuse to participate and to withdraw from the experiment at any time without prejudice to me. I also understand, if I am participating in this experiment to obtain course credit and I decide to withdraw, I might not get credit associated with this experiment.

______________________________ _______________________

Student's Signature Date

A copy of your signed form will be returned to you for your records.

APPENDIX B

Data Sheet **Spring 1998**

Course ________________________________
Classification______________________
Name____ Expected Year of
Graduation_________
Major_____________________________ Minor (if any)__________________
Why did you choose this career field?

____

____

Math courses completed at the College Level:

____

____

Math courses completed at the High School Level:

____

____

High School Attended:______________________________ Grad Year_________
Academic Goals:(up to and including graduation):

____

Career Goals: (what plans do you have for the next 5 years?)

____

____

For you, list the qualities of a "good" course.

____

____

For you, list the qualities of an inadequate course.

____

____

For you, list the qualities of a good instructor.

____

____

What method(s) of teaching help you learn best? Explain.
(Lecture, hands-on, group, inquiry)

____

____

What do you expect to gain from this course?

____

APPENDIX C

DEMOGRAPHIC INFORMATION
TRADITIONAL GROUP

Code #	Major	HS Math	HS GPA	ACT Math (1st)	ACT Math (last)	ACT COMP (1st)	ACT COMP (last)	Classification	College Math	Cumulative GPA	Knowledge Inventory
0720	El Ed	F - Algebra I, A, C	3.44	20	19	18	19	SOPH	Structures/Arith, C	2.58	76
		S - Algebra II, C, B									
		J - Geometry A, B									
		S - Trigonometry, A, B									
4236	El Ed	F - Algebra I, B, B	3.70	20	21	21	22	JR	Col Alg, A	3.39	75
		S - Geometry, B, B							Structures/Arith, C		
		J - Algebra II, A, A									
5687	El Ed	F - Algebra I, A, A	3.63	19	19	18	17	FR	Structures/Arith, B	3.33	85
		S - Geometry, A, B									
		J - Algebra II, A, A									
		S - Algebra III, A, A									
7777	El Ed	F - Algebra I, B, B	3.26	22	19	21	18	FR	Structures/Arith, B	3.15	91
		S - Geometry, A, B									
		J - Algebra II, B, B									
		S - Trig/Analy, B, B									
9204	El Ed	*	*	21	17	24	22	SOPH	Structures/Arith, B	3.81	100
9865	El Ed	F - Algebra I, A, A	3.96	19	23	18	24	FR	Structures/Arith, A	4.00	89
		S - Algebra II, A, B									
		J - Geometry, A, A									
		S - Pre-Calc, A, A									
	Count		5	6	6	6	6			6	6
	Mean		3.60	20.17	19.67	20.00	20.33			3.38	86.00
	Maximum		3.96	22.00	23.00	24.00	24.00			4.00	100.00
	Minimum		3.26	19.00	17.00	18.00	17.00			2.58	75.00
	Range		0.70	3.00	6.00	6.00	7.00			1.42	25.00
	Standard Deviation		0.27	1.17	2.07	2.45	2.73			0.50	9.51

*Information is not available.

DEMOGRAPHIC INFORMATION
4MATGROUP

Code #	Major	HS Math	HS GPA	ACT Math (1st)	ACT Math (last)	ACT COMP (1st)	ACT COMP (last)	Classification	College Math	Cumulative GPA	Knowledge Inventory
0614	HistED	F - Alg I, C, D	2.64	15	17	17	19	JR	Int Alg, S	1.77	54
		S - Geom, C, C							College Alg, F		
		J - Alg II, C, C									
		S - No Math									
1701	El Ed	F - Algebra I, D, D	1.98	20		21		SOPH	College Math, C	2.70	85
		S - Geometry, F, F							Structures/Arith, C		
		J -									
		S - Geometry C, C									
1797	El Ed	F - Alg I, B, A	3.61	17	18	20	18	JR	Intro to Math, B	3.40	86
		S - Alg II, B, B							Structures/Arith, A		
		J - Geom/Trig, B, B									
		S - No Math									
1976	El Ed	F - Alg I, C, B	2.72	13	16	15	18	JR	Int Alg, C	2.08	83
		S - Geom, A, B							Structures/Arith, F		
		J - Alg II, D, D							Structures/Arith, C		
		S - Alg II, B, B							Structures/Math, W		
3112	El Ed	F - H Alg I, A, A	3.92	19	27	21	28	FR	College Alg, A	3.45	85
		S - H Alg II, A, B							Structures/Arith, A		
		J - H. Geom, A, A									
		S - No Math									
3473	El Ed	F - Alg I, B, B	3.14	20		21		SOPH	College Alg, W	1.88	64
		S - Alg II, C, C							Structures/Arith, B		
		J - Geom C, C									
		S - Trig Anly C, D									
3496	El Ed	F - Math, C, C	2.97	8		9		JR	Basic Alg, U	2.30	34
		S - No Math							Basic Alg, S		
		J - No Math							Structures/Arith, D		
		S - No Math									
3827	Undec	F - Alg I, B, A	3.34	20		18		SOPH	College Alg, W	2.19	62
		S - Geom, B, B							Math Concepts, B		
		J - Alg II, A, A							Structures/Arith, C		
		S - No Math									
4783	El Ed	F - Alg II, B, B	3.75	20		25		SOPH	Structures/Arith, B	3.38	68
		S - Geom, B, B									
		J - Trig/Analy, B, B									
		S - No Math									
6772	El Ed	F - Alg I, B, C	3.27	20		19		SOPH	Structures/Arith, C	2.57	91
		S - Alg II, A, A									
		J - PreCal/Geom, A, A,									
		S - Math Anly, C, C									
6896	El Ed	F - Math II, B, C	2.78	15	16	18	19	SOPH	Basic Alg, U	2.56	47
		S - Alg I, D, D							Int Alg, P		
		J - Geom, B, C							Structures/Arith, C		
		S - No Math									
7304	Sp ED	F - Alg I, A, A-	2.98	15		17		SOPH	Structures/Arith, B	3.02	84
		S - Alg II, C, C-									
		J - Geom, D+, C									
		S - B. Math, B+, A									

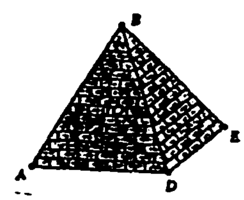
7773	El Ed	F - Alg I, A, A	3.50	17		16		FR	College Alg, D	2.00	73
		S - Alg II, A, A							Structures/Arith, A		
		J - No Math									
		S - Geom, A, A									
9612	El Ed	F - Geom, A, A	3.31	21	23	18	21	SOPH	Structures/Arith, A	3.67	84
		S - Alg II, A, A									
		J - Trig/PreCalc, B, C									
		S - Calc, A, A									
*Information is not available.											
Mean	Count		14	14	6	14	6			14	14
	Mean		3.14	17.14	19.50	18.21	20.50			2.64	71.43
	Maximum		3.92	21.00	27.00	25.00	28.00			3.67	91.00
	Minimum		1.98	8.00	16.00	9.00	18.00			1.77	34.00
	Range		1.94	13.00	11.00	16.00	10.00			1.90	57.00
	Standard Deviation		0.51	3.66	4.51	3.68	3.83			0.64	17.26

APPENDIX D

KNOWLEDGE INVENTORY

Name________________________________ MATH 2143
Chapter 10 - Introduction to Geometry SP 1998

1. For each of the following statements, supply the best answer.
   a. Three undefined terms used in geometry are _____________, _______________, and ____________________.
   b. ______________________________ points are points that lie on the same line.
   c. ______________________________ points are points that lie in the same plane.
   d. ______________________lines are lines in the same plane which do not intersect.
   e. ___________________ lines are lines which do not lie in the same plane and do not intersect.
   f. A(n) _________________________ angle is the angle formed by two planes which intersect in a line.
   g. A(n) ______________________________ is a polygon in which all the angles are congruent and all the sides are congruent.
   h. ______________________________ angles are two angles whose measures sum to 180°.
   i. A network is called ____________________________ if there is a path through the network such that each arc is passed through exactly once.
2. Use the following drawing of one of the Great Pyramids of Egypt to find the following:
   a. The intersection of AD and CE____________
   b. The dihedral angle formed by planes BDE and BDA________
   c. The intersection of planes ABC, ACE, and BCE ____________
   d. The intersection of AD and CA _________
   e. A pair of skew lines ___________
   f. A pair of parallel lines ___________
   g. A plane is not determined by one of the triangular faces or by the base___________



3. Draw an illustration of each of the following:
   a. obtuse triangle
   b. right triangle
   c. adjacent angles
   d. scalene right triangle triangle
   e. isosceles right triangle
   d. right equilateral
4. Draw an illustration of each of the following (mark the characteristics of each figure which places it in this classification):
   a. square
   b. trapezoid
   c. concave hexagon
5. Convert each of the following (in each case, show your work):
   a. 130 in. = _________ yds
   b. 500 yds = _________in.
   c. 150 ft = __________ yds

6. Convert each of the following (in each case, show your work):
   a. 55cm = __________mm

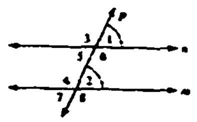
   b. 51.3m = __________cm

   c. 2562cm = __________ km

7. Determine whether the following can or cannot be the lengths of the sides of a triangle. Explain why or why not.
   a. 20cm, 30cm, and 40cm

   b. 5 ft, 7 ft, and 10 ft.

8. Find the measures of the following angles.



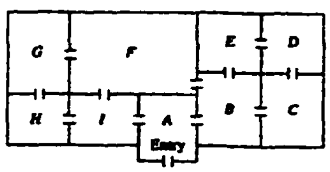
9. Compare and contrast the characteristics of prisms and pyramids. Draw a sketch of each to use in your discussion. Be sure to label your sketches.

10. Compare and contrast the characteristics of cones and cylinders. Draw a sketch of each to use in your discussion. Be sure to label your sketches.

11. How many Platonic solids exist and how are they different from other solids?

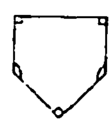
12. What is the sum of the vertex angles of a regular pentagon?
    What is the degree measure of each vertex angle?

13. The following drawing represents the floor plan of an art museum. All tours begin and end at the entry. Is it possible to design a tour route that will allow a person to see every room but not go through any room twice. Explain why or why not using graph theory. Draw a network to illustrate the problem.

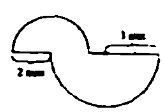


14. Explain mathematically why a three-legged stool is always stable and a four-legged stool sometimes rocks.

Bonus* (5 points each)
a. Home plate on a baseball field has three right angles and two congruent angles. Refer to the following figure and find the measures of each of these two congruent angles:



b. Find the perimeter of the following figure if all arcs shown are semicircles.



(Not bonus)
Was this test what you expected it to be? Explain.

How long did you study for this test? ______________
Explain how you studied for this test.

APPENDIX E

SCALE OF INTELLECTUAL DEVELOPMENT – IV

SID-IV

Instructions:

This questionnaire lists a series of statements about various topics. Read each statement and decide whether you agree or disagree with each statement as follows:

A - Strongly agree
B - Slightly agree
C - Slightly disagree
D - Strongly disagree

Mark the letter for the choice which best describes your opinion in the blank provided to the left of the question. There are no right or wrong answers so do not spend too much time deciding on a correct answer. Sometimes people try to make themselves out to be better than they are. Therefore, the questionnaire includes some items to check on this. The first thing that comes to mind is probably the best response.

Be sure the number on the answer sheet corresponds to the number of the statement to which you are responding. There is no time limit, but work as quickly as possible.

_____ 1. There are some areas in my life where nothing is either right or wrong but rather a matter of my personal preference.
_____ 2. I always put forth my best effort.
_____ 3. I am always trustworthy and truthful.
_____ 4. What happens in my life is usually up to me.
_____ 5. When all members of a group disagree, it usually means everybody is right.
_____ 6. I have often considered how my career will contribute to improving society.
_____ 7. The responsibility for my life is my own.
_____ 8. The safest decision is no decision at all.
_____ 9. I never disagree with other people.
_____ 10. I always think through problems thoroughly.
_____ 11. One thing is certain: Even if there is an absolute truth, men and women will never know about it and, therefore, must learn to choose and venture in uncertainty.
_____ 12. I have had to set priorities on my activities so that I could achieve a goal.
_____ 13. I would not think of marrying a person with religious beliefs different from my own.
_____ 14. I prefer that teachers should simply tell me what is important to know.
_____ 15. In most situations requiring a decision, it is better to listen to someone who knows what they are doing.
_____ 16. I am the person that I am because of the choices I have made.
_____ 17. Personal values should be adapted to fit the situation.
_____ 18. Uncertainty may be the only thing of which a person may be sure about.
_____ 19. I schedule activities in my life according to the long term goals I have set.
_____ 20. No moral principle applies to all situations.
_____ 21. I often wonder if my career dominates too much of my life.
_____ 22. I often consider the potential effects of my behavior on the good of society.
_____ 23. I would never date a person of whom my parents would disapprove.
_____ 24. I worry that I may become too set in my ways.

_____ 25. I never mislead people.
_____ 26. My beliefs about current issues are often influenced more by the opinions of other people than by my own ideas.
_____ 27. A professor's job is to communicate the facts of his or her field to students.
_____ 28. Now that I am fully committed to a career, I plan and think about it often.
_____ 29. I considered several fields before choosing my career (major).
_____ 30. I base many of my moral decisions on what other people do.
_____ 31. When I make a major decision, I often stand back and consider what it is about the choices that appeals to me.
_____ 32. With the amount of knowledge greater now than ever before, one cannot feel confident in choosing a singular point of view.
_____ 33. I have set priorities on what are the most important goals in my life.
_____ 34. The risk of disappointment outweighs commitment to a goal.
_____ 35. Once a person decides on an occupation, his or her professional behavior is mostly set.
_____ 36. There is nothing more annoying than a question that can have more than one answer.
_____ 37. The welfare of other people enters into every decision I make.
_____ 38. I frequently think about how I may someday go about reading my children.
_____ 39. I find myself applying skills learned in one field to another area of study.
_____ 40. There must be correct answers for the majority of philosophical questions such as, "What is truth?"
_____ 41. What other people say is more important than the principle involved.
_____ 42. It is better to simply believe in a religion than to be confused with doubts about it.
_____ 43. My life goals are no more specific this year than they were last year.
_____ 44. Politicians too often consider societal benefits in the decisions they make.
_____ 45. The difficulty of a homework assignment can be judged by the number of pages to be read.
_____ 46. I am beginning to plan how I can balance other aspects of my life with my career.
_____ 47. I have spent a great deal of time thinking about the kind of spouse I would make.
_____ 48. I have been responsible for supervising the work of others.
_____ 49. I have found it is usually better to avoid taking a firm point of view.
_____ 50. The true experts in a particular field generally agree with each other.
_____ 51. The greatest leaders can show emotions and feelings.
_____ 52. A person should not question what the experts believe to be true.
_____ 53. Problems and events can only be understood through the eyes of each individual, a common principle can rarely be determined.
_____ 54. The value of any behavior depends upon the situation in which it occurs.
_____ 55. I have assumed the major responsibilities in most areas of my life.
_____ 56. I enjoy discussing and studying about social issues of our day.
_____ 57. I have formulated a personal code of ethics that is not exactly like that of anyone else.
_____ 58. Most history professors spend too much class time speculating about theory instead of presenting the facts.
_____ 59. It is the job of counselors to guide students into the right occupations.
_____ 60. I do not feel ready to firmly support my beliefs.
_____ 61. I am free to believe whatever I want only when the experts do not agree.
_____ 62. Disagreements regarding important issues should be left to the experts.
_____ 63. I would learn more in the humanities if teachers would stick to the facts.
_____ 64. Defending one's point of view is unwise, other people's opinions are just as important.
_____ 65. People should be made to follow the law exactly and without exception.
_____ 66. I have difficulty balancing the needs of others with the needs of myself.
_____ 67. Right and wrong never change.
_____ 68. The choices I make about my life are always based on my best interests.
_____ 69. I am extremely sensitive to the effects I have on others.
_____ 70. I have yet to decide what I will do after college.
_____ 71. My academic responsibility ends with getting my work done on time.
_____ 72. People should obey the police in all situations.
_____ 73. A person of good character usually does what he or she is told to do.
_____ 74. When I hear an opinion different from mine, I usually ask why the other person believes the

way he or she does.

_____ 75. A strong person rarely discusses or displays how he or she feels about situations.
_____ 76. To a large extent, who I am is defined by the career I have chosen.
_____ 77. Every person's opinion should be weighed with equal consideration.
_____ 78. I have made a major commitment in at least one area in my life.
_____ 79. I need not act upon my beliefs; it is enough that I have them.
_____ 80. It is always better to heed the advice of a more experienced person.
_____ 81. When presented with a new problem, I seldom anticipate how other people might be affected.
_____ 82. I will be able to continually define my job through the ways in which I do my work.
_____ 83. If I was having personal problems, I would want a counselor to tell me what to do.
_____ 84. I often think, "Whatever I do affects other people."
_____ 85. My inner life is very important to me.
_____ 86. Issues are so complex today, a person should adopt a single stance only on rare occasions.
_____ 87. I can't enjoy the company of people who don't share my moral values.
_____ 88. Educators should know by now which is the best teaching method: lecture or small discussion groups.
_____ 89. The style with which I carry out my responsibilities is an important part of my identity.
_____ 90. I have sorted through all my beliefs and decided which ones I will keep and which ones I will discard.
_____ 91. All the skills that I learn could be used in both constructive and destructive ways.
_____ 92. As I grow older, I should guard against becoming too sensitive about other people.
_____ 93. Good teachers never let you leave the classroom with doubts about the subject matter.
_____ 94. The best courses emphasize practical rather than theoretical matters.
_____ 95. Before I do something new, I usually consider what effect it will have on other people.
_____ 96. I have pondered the problems of divorce and considered how I may be able to make my (future) marriage last.
_____ 97. I feel contempt for people who have a life philosophy that differs from my own.
_____ 98. I do not hesitate to change my opinion when another person presents appropriate evidence.
_____ 99. People are not as aware as they should be of their roles.
_____ 100. I have difficulty focusing on a single vocational choice.
_____ 101. My awareness of my inner resources has not grown during the last year.
_____ 102. I frequently have difficulty accepting the consequences of my decisions.
_____ 103. My interpretation of a passage sometimes differs from that of my teachers.
_____ 104. I often wonder if I am on the right track.
_____ 105. I continually question the reasons why I believe what I do.
_____ 106. It is a waste of time to think about how things should be rather than how they are right now.
_____ 107. Money spent for welfare in this country should be spent on something else.
_____ 108. Circumstances or luck usually determine a person's future.
_____ 109. I let others make their own moral decisions instead of telling them what they should do.
_____ 110. I am responsible for all of my choices.
_____ 111. Almost anything can look right when viewed from some perspective.
_____ 112. I enjoy working with complex ideas.
_____ 113. I enjoy problems that do not have a pat answer.
_____ 114. No one can be sure about anything anymore.
_____ 115. In today's world, a person cannot be certain about choosing any of the options available.

Developmental Analytics
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Harrisonburg, VA 22801

APPENDIX F

THE BEST CLASS I EVER HAD AND THE WORST CLASS I EVER HAD

SAMPLE FROM TRADITIONAL GROUP

The Best & Worst Classes
I've ever had!

The best class I've ever had and my favorite would have to be my senior English class. Everything about the class was great. The teacher was nice, she prepared us for what was on her test, and all my friends were in the class. In class she would go over anything that gave someone a problem, and she would give great reviews. Her tests were easy because the material was straight after everything we reviewed and went over in class.

The worst class I've ever had and my least favorite would have to be my junior English class. It was the most miserable hour a person could go through. The teacher hated athletes and really wasn't a very good teacher, in my opinion. In class we would read stories and she would always asign work that was irrelavant to what we were studying. When tests would roll around she would tell us about them the day ahead so we would have to cram that night. We never, my friends and I, knew what to study for. She never gave us a clue.

The difference between the classes grade wise was a low B as a junior and a high A as a senior. The tests all consisted of the same material except my senior teacher made things clear and prepared us all properly.

THE BEST CLASS I EVER HAD AND THE WORST CLASS I EVER HAD

SAMPLE FROM 4MATGROUP

The worst class I have ever taken is Introduction to Music. I took it and World History last summer. I figured music would be very simple and I could easily get an A in it, and then hopefully get a B in World History. I made a 92 on the first test and I was sure I would get an A in music, but each test score got lower. I ended up getting a B in the class. The class was very boring. All we did was listen to classical music and then talk about it. The professor seemed to think we all liked classical music just like him and would tell us where to go buy the CD's he played in class. The thing that made me so mad about music was that I got a B in it and I got an A in World History. If I would have made an A in Music, I could have had a 4.0 for the semester and it would have helped my grade point.

The best class I have ever taken is Child Psychology which I am taking right now. It is the most interesting class I have ever taken. I love learning about kids and thats what this whole class is about. I'm happy I'm finally done with all my general education classes and get to take elementary education classes now. I think I will learn a lot in this class, and it will be stuff I actually need and want to know.

APPENDIX G

LESSON PLANS
TEXTBOOK

Content: Chapter 8 – Probability, pages 411-469.

Text: A Problem Solving Approach to Mathematics for Elementary School Teachers, Sixth Edition. Written by Rick Billstein, Shlomo Libeskind, and Johnny Lott. Published by Addison-Wesley Longman, Inc., 1997.

Wednesday, March 27, 1998
Traditional class – Structural Concepts of Mathematics, 9:00 a.m., MWF
Section 8-1: How Probabilities Are Determined, pages 412-423.

Objectives:
The student will
- **become familiar with terms such as experiment, outcome, sample space, experimental (empirical) probability, theoretical probability, equally likely outcomes, impossible event, certain event, mutually exclusive event, non-mutually exclusive event, complementary events;**
- **calculate theoretical probability of single event using the properties of probability;**
- **determine the fairness (equal probability of winning for each player) of a situation.**

Note: In all my classes, the students are required to read the section before instruction, making notes of highlighted words and properties.

Format of the lesson:

One-on-one check notes on section 8-1.

New Information:

Introduce terminology and concepts.
Use the overhead projector with the following transparencies and appropriate examples.

- ✓ Definition of Probability of an Event with Equally Likely Outcomes
  Example 8-1, page 415
- ✓ Property of Probability of an Event
  Example 8-3, page 416
- ✓ Definition of Mutually Exclusive Events
  Continue Example 8-3
- ✓ Property of Mutually Exclusive Events
  Give samples of mutually exclusive events, such as weather, gender, classification
- ✓ Property of Complementary Events
  Use mutually exclusive events to illustrate examples of complementary events; such as raining, not raining, freshman, not freshman, etc.
- ✓ Properties of Probabilities
  Example 8-5, example 8-6

Homework:
Class exercises (if time permits):
Pages 420-423, #2, #6, #11, #16

Out of Class Assignment:

Pages 420-423, 1-22 all

Friday, March 29, 1998
Traditional class – Structural Concepts of Mathematics 9:00 a.m. MWF
Section 8-2: Multi-Stage Experiments with Tree Diagrams and Geometric Probabilities, pages 424-437. Second of two days of this section.

Objectives:
The student will
- **use a tree diagram as a mathematical model to develop a sample space for a multi-stage event;**
- **use the multiplication rule to calculate the probability of a multi-stage event;**
- **use a geometric** model to calculate the probability of a multi-stage event.

Format of the lesson:
First 20 minutes – discussion of assigned homework problems (pages 434-437, 1-15 all.

New Information
✓ Geometric probability; problem 20, page 436;
✓ Practical application: problem 22, page 436;
✓ Practical application: problem 29, page 436.

Out of Class Assignment
Page 434-437, 16-28 all, 31, 34, 35, 40, 41.

Wednesday, April 1, 1998
Traditional class – Structural Concepts of Mathematics 9:00 a.m., MWF
Section 8-3: Using Simulations in Probability, pages 438-447.

Objectives:
The student will
- **explore empirical data from simulations;**
- **use simulation to estimate the number in a given population.**

Format of the lesson:
One-on-one check notes for section 8-3.

First 20 minutes – discussion of assigned homework problems: pages 434-437, 16-28 all, 31, 34, 35, 40, 41.

New Information:
✓ Discuss the use of the table of random digits provided on page 429.
✓ Discuss Examples 8-9 page 439, 8-10 page 441, 8-11 page 441, and problem 3 page 443.

Homework:
Class exercises (if time permits)
Pages 445-447; #2, #6, #10

Out of Class Assignment:
Page 445-447, 1-10 all, 12, 13-15; 21-23.

Friday, April 3, 1998
Traditional class – Structural Concepts of Mathematics 9:00 a.m. MWF
Section 8-4: Odds and Expected Value, pages 448-454.

Objectives:
The student will
- **compute odds in favor and odds against when given probability;**
- **compute probability when given odds in favor and odds against;**
- **calculate the expected value of an experiment.**

Format of the lesson:
One-on-one check notes for section 8-4.

First 20 minutes – discussion of assigned homework problems: pages 445-447, 1-10 all, 12, 13-15; 21-23.

New Information:
- ✓ Use the overhead projector with the following transparencies and appropriate examples.
- ✓ Definitions of Odds, Example 8-12;
- ✓ Definitions of Expected Value, Example 8-14;
- ✓ Practical problem; Problem 4, page 452.

Homework:
Class exercises (if time permits)
Page 453-454; #4, #10, #12

Out of Class Assignment:
Page 453-454; 1-17 odd, 18, 23-25.

Monday, April 6, 1998
Traditional class – Structural Concepts of Mathematics 9:00 a.m. MWF
Section 8-5: Methods of Counting pages 445-463.

Objectives:
The student will
- **compute the number of possibilities using permutations;**
- **compute the number of possibilities using combinations;**
- **compute probabilities using permutations and combinations.**

Format of the lesson:
One-on-one check notes for section 8-5.

First 20 minutes – discussion of assigned homework problems: pages 453-454; 1-17 odd, 18, 23-25.

New Information:
- ✓ Introduce terminology such as factorial, permutations, combinations;
- ✓ Introduce notation such as nPr and nCr;
- ✓ Calculate permutations using club officers {Al, Betty, Carl, Dan};
- ✓ Transparency for Permutations Involving Like Objects; Example 8-16;
- ✓ Calculate combinations using club officers {Al, Betty, Carl, Dan};
- ✓ Calculate probabilities using permutations and combinations.

Homework:
Class exercises (if time permits)
Pages 463-464; #2, #12, #18

Out of Class Assignment:
Pages 463-464; 1-15 26, 28, 30-32

Wednesday, April 8, 1998
Traditional class – Structural Concepts of Mathematics 9:00 a.m., MWF
Review for Test

First 20 minutes – discussion of assigned homework problems: pages 463-464; 1-15, 26, 28, 30-32.

- ✓ Review terminology introduced in the chapter. Chapter Outline, page 467.
- ✓ Review the chapter with selected problems from Chapter Review, pages 467-469 as time permits.

Homework after the test: students are reminded to read and take notes on Chapter 9, section 1 due before class discussion of that section.

Friday, April 10, 1998
Traditional class – Structural Concepts of Mathematics 9:00 a.m., MWF

Chapter 8 – Probability Test

Content: Chapter 9 – Statistics: An Introduction

Text: A Problem Solving Approach to Mathematics for Elementary School Teachers, Sixth Edition. Written by Rick Billstein, Shlomo Libeskind, and Johnny Lott. Published by Addison-Wesley Longman, Inc., 1997.

Monday, April 13, 1998
Traditional class – Structural Concepts of Mathematics, 9:00 a.m. MWF
9-1: Statistical Graphs, pages 472-491

Note: Students are required to read the section before instruction, making notes of highlighted words and properties.

Objectives:
The student will
- analyze graphical representations of data;
- create a frequency table or grouped frequency table from data provided;
- create graphical representations of data (pictograph, line plot, histogram, stem-and-leaf plot, bar graph, circle graph, line graph)

Format of the lesson:
One-on-one check notes on section 9-1.

New Information:
Introduce terminology and concepts.
- ✓ pictographs
  use problem 1, page 488
- ✓ line plots
  use problem 3, page 488
- ✓ stem-and-leaf plots
  use problem 19, page 490
- ✓ frequency tables
  continue with problem 19, 490
- ✓ histograms and bar graphs
  continue with problem 19, 490
- ✓ double bar graphs
  use figure 9-12, page 481
- ✓ line graphs and frequency polygons
  continue with problem 19, 490
- ✓ grouped data
  use table 9-7, page 486
- ✓ circle graphs (pie charts)
  use figure 9-18, page 487

In Class Assignment:
Discuss 21-24, page 491

Out of Class Assignment:
Page 488-491; 1-20 all

Wednesday, April 15, 1998

Traditional class – Structural Concepts of Mathematics, 9:00 a.m. MWF

9-2: Measures of Central Tendency and Variation, pages 492-509. This section will use two class sessions.

Objectives:
The student will
- calculate the mean, the median, and the mode for given data sets;
- use of the mean, median, and mode in application of real world problems;
- calculate the range for given data sets;
- apply the use of the range in application of real world problems.

Format of the lesson:
One-on-one check for notes on section 9-2.

First 15-20 minutes – answer questions on homework. Take up Out of Class Assignment.

New Information:
✓ define arithmetic mean, median, and mode
✓ compute arithmetic mean, median, and mode
  use data given on page 493
✓ discuss the mean as a balance point
  use data in figure 9-21, page 493 and 9-22, page 494
✓ discuss the most appropriate average (mean, mode, median)
  use examples such as salaries and quantities of supplies

In Class Assignment:
Page 506; 10, 12, 16

Out of Class Assignment:
Page 506-507; 1-17 all

Friday, April 17, 1998
Traditional class – Structural Concepts of Mathematics, 9:00 a.m. MWF
9-2: Measures of Central Tendency and Variation, pages 492-509. This section will use two class sessions.

Objectives:
The student will
- calculate variance;
- calculate standard deviation;
- draw box plot;
- recognize outliers;
- compare sets of data.

Format of the lesson:

First 15-20 minutes – answer questions on homework. Take up Out of Class Assignment.

New Information:

✓ Using data provided in table 9-10, page 497, compute the range, variance, standard deviation.
✓ Use example 9-8, page 499 to illustrate the importance of the standard deviation.
✓ Use data provided in Example 9-10, page 503 to draw a box plot and illustrate outliers.
✓ Use data provided in Table 9-14 to compare sets of data.

In Class Assignment:
Page 507-508; 19, 33, 35

Out of Class Assignment:
Page 507-508; 20-34, 41, 42, 43

Monday, April 20, 1998
Traditional class – Structural Concepts of Mathematics, 9:00 a.m. MWF
9-3: Normal Distributions, pages 511-521

Objectives:
The student will
- compute the z-score;
- relate the z-score, the raw score, and the normal curve;
- analyze relationships using a scattergram.

Format of the lesson:
One-on-one check for notes on section 9-3.

First 15 minutes – answer questions on homework. Take up Out of Class Assignment.

New Information:
- ✓ Define the normal curve.
  Use Example 9-11, page 512 to show the use of the normal curve.
  Use Example 9-12 to show the use of the z-score.
  Use Example 9-13 and Example 9-14 to illustrate application of the normal curve.
- ✓ Discuss correlations and trend lines using illustrations on page 518.

In Class Assignment:
Page 520; 1, 7, 12

Out of Class Assignment:
1-16; 23-27

Wednesday, April 22, 1998
Traditional class – Structural Concepts of Mathematics, 9:00 a.m. MWF
9-4: Abuses of Statistics, pages 522-530

Objectives:
The student will
- analyze data to determine whether facts have been abused;
- investigate facts using graphics;
- investigate facts using measures of central tendency.

Format of the Lesson:
One-on-one check notes for section 9-4.

First 15-20 minutes – answer questions on homework. Take up Out of Class Assignment.

New Information:
- ✓ discuss claims which may be misleading due to graphics;
- ✓ discuss claims which may be misleading due to measures of central tendency.

In Class Assignment:
Page 528; 1-10, 15, 18, 19

Out of Class Assignment:
Prepare for Exam

Friday, April 24, 1998
Traditional class – Structural Concepts of Mathematics, 9:00 a.m. MWF
Exam – Traditional group

APPENDIX H

VERIFICATION FOR TEXTBOOK APPROACH

April 20, 1998

RE: For the purpose of documentation for the dissertation of Sandy Johnson.

The text, A Problem Solving Approach to Mathematics for Elementary Teachers, Sixth Edition by Billstein, Libeskind, and Lott was used to compare the lesson plans prepared by the researcher to the suggestions in the respective textbook unit. All five lessons for Chapter 8, Probability, and all four lessons for Chapter 9, Statistics: An Introduction, were reviewed. In my opinion, these lessons constitute a textbook approach.

Probability was reviewed and approved on March 20, 1998

Statistics: An Introduction was reviewed and approved on April 4, 1998.

Dr. Gerry Church

Dr. Gerry Church
Associate Professor

APPENDIX I

LESSON PLANS
4 MAT SYSTEM

Content: **Chapter 8 – Probability, pages 411-469.**

Text: **A Problem Solving Approach to Mathemtics for Elementary School Teachers, Sixth Edition.** Written by Rick Billstein, Shlomo Libeskind, and Johnny Lott. Published by Addison – Wesley Longman, Inc. 1997.

Tuesday, March 24, 1998
4MAT class – Structural Concepts on Mathematics, 1:00 p.m. MTR
Section 8-1: How Probabilities Are Determined, pages 412-423.

Objectives:
The student will
- become familiar with terms such as experiment, outcome, sample space, experimental (empirical) probability, theoretical probability, equally likely outcomes, impossible event, certain event, mutually exclusive event, non-mutually exclusive event, complementary events;
- calculate experimental probability of a single event;
- calculate theoretical probability of a single event using the properties of probability;
- determine the fairness (equal probability of winning for each player) of a situation.

Note: In all my classes, the students are required to read the section before instruction, making notes of highlighted words and properties.

Format of the lesson:
One-on-one check notes on section 8-1.

New Information:
Quadrant 1, L & R
First 15 minutes, students will play game drawing one ball at a time out of a bag, replace, and draw again to determine makeup of contents of the bag. Each group will explain how they arrived at their guess of the combination of balls in their bags.

Introduce terminology and concepts.
Use the overhead projector with the following transparencies and appropriate examples.

✓ Definition of Probability of an Event with Equally Likely Outcomes
Example 8-2, Page 415
✓ Property of Probability of an Event
Example 8-3, Page 416
✓ Definition of Mutually Exclusive Events
Continue Example 3
✓ Property of Mutually Exclusive Events
Give samples of mutually exclusive events, such as weather, gender, classification
✓ Property of Complementary Events
Use mutually exclusive events to illustrate examples of complementary events; such as raining, not raining; freshman, not freshman, etc.
✓ Properties of Probabilities
Example 8-5, example 8-6

Homework:
Class exercises (if time permits):
Pages 420-423, #2, #6, #11, #16

Out of Class Assignment:
Pages 420-423, 1-22 all

Thursday, March 26, 1998
4MAT class – Structural Concepts of Mathematics, 1:00 p.m. MTR
Section 8-2: Multi-Stage Experiments with Tree Diagrams and Geometric Probabilities, pages 424-437. This section will use two class sessions.

Objectives:
The student will
- use a tree diagram as a mathematical model to develop a sample space for a multi-stage event;
- use the multiplication rule to calculate the probability of a multi-stage event;
- use a geometric model to calculate the probability of a multi-stage event.

Note: In all my classes, the students are required to read the section before instruction, making notes of highlighted words and properties.

Format of the lesson:
One-on-one check notes for section 8-2.

First 15-20 minutes – answer questions on homework: Pages 420-423, 1-22 all.

New Information
Quadrant II, L; Quadrant III, L
✓ Discuss the difference in a one-stage event and a multi-stage event using a bag with three colors of balls. The class will participate during the demonstration. This is not a group activity but rather a demonstration using Example 8-8, page 425 as a guide.
✓ Discuss terms such as random selection, without replacement, with replacement.
✓ Illustrate tree diagrams, using Example 8-10, page 426.
✓ Illustrate the Multiplication Rule for Probabilities, using Example 8-10, page 426.
✓ Discuss the game modeled in Example 8-17 with two possible ways to work the problem.

Homework:
Class exercises (if time permits)
Pages 423-437, #2, #6, #12

Out of Class Assignment:
Pages 434-437, 1-15 all

Monday, March 30, 1998
4MAT class – Structural Concepts of Mathematics, 1:00 p.m. MTR
Section 8-2: Multi-Stage Experiments with Tree Diagrams and Geometric Probabilities, pages 424-437. Second of two days on this section.

Objectives:
The student will
- use a tree diagram as a mathematical model to develop a sample space for a multi-stage event;

- use the multiplication rule to calculate the probability of a multi-stage event;
- use a geometric model to calculate the probability of a multi-stage event.

Format of the lesson:
Quadrant II, L; Quadrant III, L
First 20 minutes – discussion of assigned homework problems: Pages 434-437, 1-15 all.

New Information:
✓ Geometric probability: problem 20, page 436.
✓ Practical application: problem 22, page 436.
✓ Practical application: problem 29, page 436.

Out of Class Assignment:
Page 434-437, 16-28 all, 31, 34, 35, 40, 41

Tuesday, March 31, 1998
4MAT class – Structural Concepts of Mathematics, 1:00 p.m. MTR
Section 8-3: Using Simulations in Probability, pages 438-447.

Objectives
The student will
- explore empirical data from simulations;
- use simulation to estimate the number in a given population.

Format of the lesson:
One-on-one check notes for section 8-3.

First 20 minutes – discussion of assigned homework problems: Pages 434-437, 16-28 all, 31, 34, 35, 40, 41.

New Information:
Quadrant II, R
Next 15 minutes, play game using simulation, tossing a fair coin twice. Players decide if game is fair and explain reasoning.

✓ Discuss the use of the table of random digits provided on page 439.
✓ Discuss Examples 8-9 page 439, 8-10 page 441, and problem 3 page 443.

Homework
Class exercises (if time permits)
Pages 445-447; #2, #6, #10

Out of Class Assignment:
Page 445-447, 1-10 all, 12, 13-15, 21-23.

Thursday, April 2, 1998
4MAT class – Structural Concepts of Mathematics, 1:00 p.m. MTR
Section 8-4: Odds and Expected Value, pages 448-454.

Objectives:
The student will
- compute odds in favor and odds against when given probability;
- compute probability when given odds in favor and odds against;

- calculate the expected value of an experiment.

Format of the lesson:
One-on-one check notes for section 8-4.

New Information:
Quadrant II, L; Quadrant III, L
First 20 minutes – discussion of assigned homework problems: Pages 445-447, 1-10 all, 12, 13-15, 21-23.

✓ Use the overhead projector with the following transparencies and appropriate examples;
✓ Definitions of Odds, Example 8-12;
✓ Definitions of Expected Value, Example 8-14;
✓ Practical problem; Problem 4, page 452.

Homework:
Class exercises (if time permits)
Page 453-454; #4, #10, #12

Out of Class Assignment:
Page 453-454; 1-17 odd, 18, 23-25.

Monday, April 6, 1998
4MAT class – Structural Concepts of Mathematics, 1:00 p.m. MTR
Section 8-5: Methods of Counting, pages 445-463

Objectives:
The student will
- compute the number of possibilities using permutations;
- compute the number of possibilities using combinations;
- compute probabilities using permutations and combinations.

Format of the lesson:
One-on-one check notes for section 8-5.

First 20 minutes – discussion of assigned homework problems: Pages 453-454; 1-17 odd, 18, 23-25.

Quadrant III, R
Next 15-20 minutes, students (in pairs) will create a game that involves either cards, dice, or spinners.

New Information:
✓ Introduce terminology such as factorial, permutations, combinations;
✓ Introduce notation such as nPr and nCr;
✓ Calculate permutations using club officers {Al, Betty, Carl, Dan};
✓ Transparency for Permutations Involving Like Objects; example 8-16;
✓ Calculate combinations using club officers {Al, Betty, Carl, Dan};
✓ Calculate probabilities using permutations and combinations.

Homework:
Class exercises (if time permits)
Page 463-464; #2, #12, #18

Out of Class Assignment:
Pages 463-464; 1-15, 26, 28, 30-32.

Tuesday, April 7, 1998
4MAT class – Structural Concepts of Mathematics, 1:00 p.m. MTR
Review for Test

First 20 minutes – discussion of assigned homework problems: Pages 463-464; 1-15, 26, 28, 30-32.

- ✓ Review terminology introduced in the chapter, Chapter Outline, page 467.
- ✓ Review the chapter with selected problems from Chapter Review, pages 467-469 as time permits.

Quadrant IV, L
Last 20 minutes, students exchange the created game with another (groups of two). Compare their analyses of the game regarding fairness.

Quadrant IV, R
Students will share games with the class. Time for reinforcing concepts learned in unit (good review for test).

Homework after the test: students are reminded to read and take notes on Chapter 9, section 1 due before class discussion of that section.

Thursday, April 9, 1998
4MAT class – Structural Concepts of Mathematics, 1:0 0 p.m. MTR

Chapter 8 – Probability Test

Content: **Chapter 9 – Statistics: An Introduction**

Text: **A Problem Solving Approach to Mathematics for Elementary School Teachers, Sixth Edition.** Written by Rick Billstein, Shlomo Libeskind, and Johnny Lott. Published by Addison-Wesley Longman, Inc., 1997.

Monday, April 13, 1998
4MAT class – Structural Concepts of mathematics, 1:00 p.m., MTR
9-1: Statistical Graphs, pages 472-491

Note: Students are required to read the section before instruction, making notes of highlighted words and properties.

Objectives:
The student will
- analyze graphical representations of data;
- create a frequency table or grouped frequency table from data provided;
- create graphical representations of data (pictograph, line plot, histogram, stem-and-leaf plot, bar graph, circle graph, line graph).

Format of the lesson:
One-on-one check notes on section 9-1.

Quadrant 1, L & R:
Use the first 15 minutes to clip charts and statistical data from USA Today, Newsweek, Time magazine. Students will explain how they perceive the use of statistics based on their exploration.

Quadrant 2, R:
Using six examples of data representations, decide if representations are appropriate or possibly misleading. Explain your reasoning.

Quadrant 2, L & Quadrant 3, L:
New Information:
Introduce terminology and concepts.
- ✓ pictographs
  use problem 1, page 488
- ✓ line plots
  use problem 3, page 488
- ✓ stem-and-leaf plots
  use problem 19, page 490
- ✓ frequency tables
  continue with problem 19, 490
- ✓ histograms and bar graphs
  continue with problem 19, 490
- ✓ double bar graphs
  use figure 9-12, page 481
- ✓ line graphs and frequency polygons
  continue with problem 19, 490
- ✓ grouped data
  use table 9-7, page 486
- ✓ circle graphs (pie charts)
  use figure 9-18, page 487

In Class Assignment:

Discuss 21-24, page 491
Out of Class Assignment:
Page 488-491; 1-20 all

Tuesday, April 14, 1998
4MAT class – Structural Concepts of mathematics, 1:00 p.m., MTR
9-2: Measures of Central Tendency and Variation, pages 492-509. This section will use two class sessions.

Objectives:
The student will
- calculate the mean, the median, and the mode for given data sets;
- use of the mean, median, and mode in application of real world problems;
- calculate the range for given data sets;
- apply the use of the range in application of real world problems.

Format of the lesson:
One-on-one check for notes on section 9-2.

First 15-20 minutes – answer questions on homework. Take up Out of Class Assignment.

Quadrant 2 L, Quadrant 3 L:
New Information:
✓ Define arithmetic mean, median, and mode.
✓ Compute arithmetic mean, median, and mode.
✓ Use data given on page 493.
✓ Discuss the mean as a balance point.
✓ Use data in figure 9-21, page 493 and 9-22, page 494.
✓ Discuss the most appropriate average (mean, mode, median.
✓ Use examples such as salaries and quantities of supplies.

In Class Assignment:
Page 506; 10, 12, 16

Out of Class Assignment:
Page 506-507; 1-17 all

Thursday April 16, 1998
4MAT class – Structural Concepts of mathematics, 1:00 p.m., MTR
9-2: Measures of Central Tendency and Variation, pages 492-509. This section will use two class sessions.

Objectives:
The student will
- calculate variance;
- calculate standard deviation;
- draw box plot;
- recognize outliers;
- compare sets of data.

Format of the lesson:

First 15-20 minutes – answer questions on homework. Take up Out of Class Assignment.

Quadrant 2L and Quadrant 3L:

New Information:
✓ Using data provided in table 9-10, page 497, compute the range, variance, standard deviation.
✓ Use example 9-8, page 499 to illustrate the importance of the standard deviation.
✓ Use data provided in Example 9-10, page 503 to draw a box plot and illustrate outliers.
✓ Use data provided in Table 9-14 to compare sets of data.

Quadrant 3 R:
Students (in pairs) will collect data on a survey of SWOSU students. Students will decide collectively in the class, what questions to include in the survey. Collect the data for the meeting on April 21, Tuesday.

In Class Assignment:
Page 507-508; 19, 33, 35

Out of Class Assignment:
Page 507-508; 20-34, 41, 42, 43

Monday, April 20, 1998
4MAT class – Structural Concepts of mathematics, 1:00 p.m., MTR
9-3: Normal Distributions, pages 511-521

Objectives:
The student will
- compute the z-score;
- relate the z-score, the raw score, and the normal curve;
- analyze relationships using a scattergram.

Format of the lesson:
One-on-one check for notes on section 9-3.

First 15 minutes – answer questions on homework. Take up Out of Class Assignment.

Quadrant 2, L and Quadrant 3, L
New Information:
✓ Define the normal curve.
✓ Use example 9-11, page 512 to show the use of the normal curve.
✓ Use Example 9-12 to show the use of the z-score.
✓ Use Example 9-13 and Example 9-14 to illustrate application of the normal curve.
✓ Discuss correlations and trend lines using illustrations on page 518.

In Class Assignment:
Page 520; 1, 7, 12

Out of Class Assignment:
1-16; 23-27

Tuesday April 21, 1998
4MAT class – Structural Concepts of mathematics, 1:00 p.m., MTR

9-4: Abuses of Statistics, pages 522-530

Objectives:
The student will
- analyze data to determine whether facts have been abused;
- investigate facts using graphics;
- investigate facts using measures of central tendency.

Format of the Lesson:
One-on-one check notes for section 9-4.

First 15-20 minutes – answer questions on homework. Take up Out of Class Assignment.

New Information:
✓ Discuss claims which may be misleading due to graphics.
✓ Discuss claims which may be misleading due to measures of central tendency.

In Class Assignment: (15 – 20 minutes)
Quadrant 4, L & R:
Students will compare information with another pair of students on data collected on survey.
Students will decide if the data collected represents the population of students at SWOSU.
Students will draw a graphical representation of their collected data and share it with the class.
Discussion should follow on abuse of statistics.

Out of Class Assignment:
Prepare for Exam

Thursday April 23, 1998
4MAT class – Structural Concepts of mathematics, 1:00 p.m., MTR
Exam – Chapter 9: Statistics – An Introduction

APPENDIX J

VERIFICATION FOR 4MAT SYSTEM

Education Service Center region IX

April 20, 1998

RE: For the purpose of documentation for the dissertation of Sandy Johnson.

The text, A Problem of Solving Approach to Mathematics for Elementary Teachers, Sixth Edition by Billstein, Libeskind, and Lott was used to prepare lessons using the 4MAT System. All five lessons for Chapter 8, Probability, and all four lessons for Chapter 9, Statistics: An Inroduction, were reviewed. In my opinion, these lessons constitute a fine example of the 4MAT lesson plan model.

"Probability" was reviewed and approved on March 20, 1998.

"Statistics: An Introduction" was reviewed and approved on April 4, 1998.

Cindy Seward

Cindy Seward
Education Specialist
Certified 4MAT Trainer

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APPENDIX K

SAMPLE INTERVIEW – TRADITIONAL GROUP

Interview Transcription # 9204

Tell me your code number...
9204
And your classification...
Sophomore
Okay. And your major...
Elementary Education
And...when did you decide on the major?
Freshman Year
And what influenced you the most in this decision?
My fiancé is a secondary teacher at Eakly and he got me interested in it.
Have you ever thought of anything else?
I feel very strongly about it.
Okay. What are your basic feelings about mathematics?
I like Algebra, but the Geometry and things that make me think, I don't like.
Have you learned anything this semester about how to study mathematics?
I didn't really study it differently than usual, but we didn't have to read the sections before we went to class. It really helped a lot.
How do you think math came into being?
Maybe somebody needed to know distances and things like that.
Do you think it was discovered or invented?
I think we discovered it.
When we did the exercise in class where you drew the balls out of the bag in probability and you didn't know how many balls were in the bag (of each type) and you had to make a guess based on your tally...what did you learn from that exercise?
didn't do
Okay...we created games and you determined whether they were fair or not...what did you learn from that?
didn't do
When we looked at the statistics of the TIMSS report...what did you learn from that?
didn't do
This is kind of a different thought...when someone expresses an opinion that is different from yours, how does that make you feel?
I guess I realize that everyone has his or her own opinion, and you can learn from other people's opinions.
If someone tells you your opinion is wrong, how does that make you feel?
If I don't think it is, then I'm upset. But I will look at it from both sides first and if they are right then they are right.
How wrong can somebody be in their opinion for you to deal with it?
I think I am pretty tolerant with it. If it wasn't something that was unacceptable then I can live with it.
Do you think people can reasonably disagree? And how is the disagreement resolved?
Yes, you learn to listen.
Kind of a different idea now...What is knowledge?
Ideas and facts.
In order for a learner to acquire knowledge (in the classroom), what is the role of the teacher?
To explain, and show us how to do things.
And the role of the student?
To do the homework.
And the role of instructional materials...

To cover the information well.

And reading...we've been doing a lot of reading this semester...what's the role of that?

To inform the student

And has that helped you at all?

not asked

For a learner to acquire knowledge...what is the role of problem solving?

To make us think.

What advice would you give someone coming to Southwestern about knowledge?

Keep up on everything and don't fall behind.

Have you ever taken a class where you had to figure out what the professor wanted from you?

I don't think so.

What did you learn from that experience?

Have you ever been in a class where you had to alter the way you expressed yourself in order to please your professor?

No.

What advice would you give a prospective student concerning the educational process?

I don't know.

Okay...how do you learn the material presented in our class?

Do the homework and work all the problems even though it's repetition. It helps when it's repetition.

Have you ever worked on a problem that has more than one way to arrive at a solution?

Yes.

How does that make you feel?

Confused. Because if I worked it different than someone else then I think that I might have done it wrong. But it makes me feel good because you can get there two different ways.

Have you ever worked on a problem that doesn't have a definite solution?

confused, because if it doesn't have a solution then why am I working it anyway...(laugh).

And what does that teach you?

That something just don't have an answer to it and that's the solution, there isn't one...

Have you ever experienced working really hard on something and then not doing so well on a test or on an exercise?

Yes.

And how did that make you feel?

Depressed, because you put all of this time into preparation and then you get up there and you can't recall any of that information. I know that I need to relax and take my time.

Do you ever think about how you learn rather than what you learn?

Yes.

Have you ever done anything like the learning styles inventory like we did...on yourself?

No.

Did you feel like you matched what the inventory revealed about you?

not asked

How did that help you...

I found out that learning in groups really helps me. I get more from other people, it seems like, than I do from myself. (laugh)

What advice would you give to somebody coming in about learning?

They need to find out their learning styles. I wish I knew my learning styles when I started school.

Have you noticed any different teaching strategies in our classroom from the beginning to now in the way I present material?

No .

If you were teaching the class, would you do anything differently?

I don't think so.

What's a commitment?

Something that you dedicate yourself to doing, you make a promise to yourself or someone else to be there or not give up.

Do you remember the first commitment you ever made?

Going to college.

Can you remember a recent commitment?

not asked
Did you have any trouble following through with your commitment?
Yes it was difficult .
And what did you learn from the experience...I mean...as far as making a commitment and following through with it?
I learned to not give up.
How did that make you feel about future commitments?
not asked
What advice would you give to a prospective student concerning making commitments?
Don't just make one. There may be other things that you need to commit yourself to.
Any questions for me?
No.
That's it.

SAMPLE INTERVIEW – 4MATGROUP

Interview Transcription #3112

Tell me your code number...
3112
And your classification...
Freshman.
Okay. And your major...
Elementary Ed
And...when did you decide on the major?
When I was in high school..
And what influenced you the most in this decision?
I've always wanted to do it since I was a little girl..
Have you ever thought of anything else?
I thought of physical therapy but then I wasn't very good in science...so I decided on elementary education.
Okay. What are your basic feelings about mathematics?
I didn't use to like it at all, but I've taken about three classes now and I can understand more now and I've gotten more into it.
Have you learned anything this semester about how to study mathematics?
A little bit...I didn't used to study at all because I used to think you couldn't study for a math test...you either knew it or you didn't. But now I just work through the review...and that's about all I do.
How do you think math came into being?
I don't have any idea!
(both laugh) Everybody gives me that expression...I don't think anybody thinks about how it started.
I guess they had little problems to solve and worked out formulas to help solve the problems.
When we did the exercise in class where you drew the balls out of the bag in probability and you didn't know how many balls were in the bag (of each type) and you had to make a guess based on your tally...what did you learn from that exercise?
Um...One nice thing we learned from that exercise was that it helped us understand probability because you can see by experiment that or project or whatever that it does apply to real life so you can understand it better.
Okay...we created games and you determined whether they were fair or not...what did you learn from that?
That it still applied to your life and anything you do pretty much has probability...the games you play (?)
When we looked at the statistics of the TIMSS report...what did you learn from that?
I saw that we are not as strong as we think we are and that we spend a lot of time on it but they still learn it better. We're not doing very good internationally.
This is kind of a different thought...when someone expresses an opinion that is different from yours, how does that make you feel?
At first I listen to them and I try to think about it for a while and try to see where they are coming from.
If someone tells you your opinion is wrong, how does that make you feel?
It hurts my feelings, but...then I think about their opinion too and I might change mine after I think about it.
How wrong can somebody be in their opinion for you to deal with it?
That I would tell them about it...or? If it is really off from what I think then I would probably say something about it but I probably wouldn't say anything if it's not too far off.
Do you think people can reasonably disagree? And how is the disagreement resolved?
It may not be resolved...(?)

Kind of a different idea now...What is knowledge?

Um...maybe a basic understanding...maybe not basic...but an understanding of what goes on in the world.

In order for a learner to acquire knowledge (in the classroom), what is the role of the teacher?

Go over and over the material until the students understand it.

And the role of the student?

To try to understand what they're telling you, to work with them. It's kind of your responsibility (?) to get it done.

And the role of instructional materials...

To go over everything...(?)

And reading...we've been doing a lot of reading this semester...what's the role of that?

To get a basic understanding of the material.

And has that helped you at all?

When I take time to read all of it...it does a little bit...but when I just kind of get the main ideas and stuff...that's what you go over later.

For a learner to acquire knowledge...what is the role of problem solving?

It makes you think about it more...instead of having the numbers just stuck in there...you have to figure out where they go...what the numbers are and where they go.

What advice would you give someone coming to Southwestern about knowledge?

You may not know a lot when you get here. But once you get here, if you'll pay attention, you'll learn a lot. After just two semesters, I feel a lot smarter...

Have you ever taken a class where you had to figure out what the professor wanted from you?

Yes...I had a geography class and I would study for a week...like every night I would study and I still made a B. And I know that a B is not a bad grade, but I think it's bad for me. And I couldn't figure out what they were asking on the questions...I just didn't have the answer.

What did you learn from that experience?

I didn't learn anything...because I was too preoccupied trying to figure out what he was talking about. And when I'd study I'd try to switch it around so I could get it this time. I was too worried if I was going to get it right...I spent too much time trying to figure him out instead of learning what I should.

Have you ever been in a class where you had to alter the way you expressed yourself in order to please your professor?

My literature class. I had to learn to keep it short and to the point and don't put flowery words in there. And now I'm in another literature class and she wants the flowery stuff and I have to start writing neat stuff.

(laugh) Just the opposite of what you learned before...what did you learn from that experience?

I guess you should find out what they're like before you take their class.

What advice would you give a prospective student concerning the educational process?

How they can learn better?...Kind of ask around and see what they're like...and get to know what their class is like cause if they do something and you don't know how to study...(?)

Okay...how do you learn the material presented in our class?

I'll work one or two (problems) then I'll look back and see how they worked it...it's kind of encouraging and I have to keep it in my mind...if I look at it and I don't know what I did then I have to sit and think for five or ten minutes and then I can go on and finish...

Have you ever worked on a problem that has more than one way to arrive at a solution?

I think so...

How does that make you feel?

Like I'm wrong...if you don't know that there is more than one solution...you think you're wrong...and you just give it up.

Have you ever worked on a problem that doesn't have a definite solution?

It's about the same...you still think you're wrong...because you think there should be something...

And what does that teach you?

That you can't figure everything out...

Have you ever experienced working really hard on something and then not doing so well on a test or on an exercise?

Yeah...

And how did you deal with that?

I get mad at myself…that last test…it's the first test I've studied for this year and I still did bad…I just dealt with it because, you know…

Do you ever think about how you learn rather than what you learn?

I haven't thought about it much except for this class…I knew before that I had to see it before I could understand it…

Have you ever done anything like the learning styles inventory like we did…on yourself?

In my home ec (economics) class we might have done just a little…but it wasn't this extensive.

Did you feel like you matched what the inventory revealed about you?

I'm a little bit of both but then it pointed out what I really need to learn.

How did that help you…

The main part was seeing what teachers you can kind of relate to and what teachers you (?)…so now I relate better to kids when I teach but also how to do better with the teacher I have so I can figure out what they need.

What advice would you give to somebody coming in about learning?

You can't get it all at once…it takes time. Like with math…when I had Algebra (College Algebra) I couldn't figure it out…

You couldn't figure it out?

I couldn't do it…

That is so surprising to me (She made an A in College Algebra)

I didn't think I knew it at all…I guess you just gotta give it time…because I was helping one of my friends with Algebra and…I guess…it takes time and don't give up. I hated math because I didn't think I could do it. But now that I've been through Algebra and Geometry…it's good.

Have you noticed any different teaching strategies in our classroom from the beginning to now in the way I present material?

It seems like we've done more games…I mean like that ball thing…I mean, we haven't done a lot of games…but it seems like it's more interaction and not just lecture.

If you were teaching the class, would you do anything differently?

I think that I would have more activities…not that…I mean…there's not many that you can have with math…because I learn that way and (?)…and it's not boring…

Okay…(pause) What's a commitment?

When you decide that you're going to do something and work through it even if it's difficult…

Do you remember the first commitment you ever made?

No…

Can you remember a recent commitment?

When I committed to be involved with our church college group for six weeks on Wednesday night for the college kids.

Did you have any trouble following through with your commitment?

Yeah…some evenings I didn't want to be there…but I made the commitment.

And what did you learn from the experience…I mean…as far as making a commitment and following through with it?

Um…I learned that it wasn't that bad. And once you get done with it you think "WOW, I spent six weeks helping the youth…"

How did that make you feel about future commitments?

You think you can reach them now that you have done a short term one.

What advice would you give to a prospective student concerning making commitments?

Don't be too hard on yourself, if you don't make it. But, if you make a commitment, then stick with it but if you don't make it, don't give up.

Any questions for me?

No…

That's it.

APPENDIX L

SELF-ANALYSIS SURVEY
TRADITIONAL GROUP SAMPLE

SELF-ANALYSIS OF THE LEARNING TYPE MEASURE (LTM®)

CODE ID 0720 Date March 23, 1998

My Learning Type Measure (LTM®) indicates that my preferences in decending order are: 1,4,3,2. I have reviewed the characteristics of all four quadrants before making the following analysis.

I agree/disagree with the instrument for assignment of my highest preference in Quadrant 1 because

I am lead by my heart. I like to be involved in important issues and to bring harmony. I enjoy discussions + groupwork, as well as thriving to take time to develope good ideas. I completely agree with this analysis because it is correct on the positive aspects as well as the uncomfortable or negative aspects. I dislike timed tests, no interaction, feeling pressured, and taped discussions.

I agree/disagree with the instrument for assignment of my lowest preference in Quadrant 2 because

I dislike tackling problems with rationality + logic, lead by principles + procedures, and by exercising authority w/assertive persuasion, by knowing facts. These group is too structured + has too many rules. The things they are uncomfortable with, I am most comfortable with. I enjoy teachers who don't stay on task, multiple work stations, Noise, + group grades.

One the Hemispheric Mode Indicator, I scored +51 which means that my preference in brain hemisphericity is Right. Do you feel comfortable with the analysis? Is it fairly accurate? Explain your reasoning.

Yes, there are characteristics of me in both but I'm primarily right brained. I am open-minded and spontaneous. I solve problems w/ hunches or trial + error. I'm free with my feelings and open with others. Some of my left characteristics are I'm planned + somewhat structured, and I like to talk, talk, talk.

In your highest preference quadrant, review the characteristics of THE UNCOMFORTABLE LEARNING ENVIRONMENT. Discuss if these characteristics best describe situations which make you uncomfortable. Is there another quadrant characteristics of the UNCOMFORTABLE LEARNING ENVIRONMENT which fits you better? Explain.

These situations fit me very well. I'm not comfortable with timed tests, No interaction, colorless environment, and taped discussions to name a few. I best learn by listening or sharing. I enjoy class discussions & interaction. But I dislike sarcasm or embarrassing situations, so many times I choose not to say anything.

How does this analysis of your learning style preference influence you. Discuss anything it has revealed to you as far as the way you learn.

I think that this analyses considerably helped to shine some light on this situation. I feel my results are accurate and help me get an idea of how I learn. All of my results were similar as far as the learning Type Measurement Test + the Hemispheric Mode Indicator Test. They describe my learning style + the situations I'm comfortable in.

How do you think this information can be helpful in the elementary classroom?

I think this can be helpful in elementary classrooms because you can determine early what type of learner they are and cater to their needs. Also they will just be establishing a learning style.

SELF-ANALYSIS SURVEY
4MATGROUP SAMPLE

SELF-ANALYSIS OF THE LEARNING TYPE MEASURE (LTM®)

CODE ID 6728 Date 3/23/98

My Learning Type Measure (LTM®) indicates that my preferences in decending order are: 4-1-3-2. I have reviewed the characteristics of all four quadrants before making the following analysis.

I agree/disagree with the instrument for assignment of my highest preference in Quadrant 4 because

I agree with the results of my LTM placing me in quadrad 4, although I feel it I probably fit into quadrant 1, also. I think that quadrant 4 fits because of my relationships with friends, I notice that I am very adaptive, but somehow remain impatient, pushy. However, I think I'm more likely to solve a problem by creativity combined with trial & error. I enjoy the arts and humanities, but don't feel I have the skill to participate in these activities, I suppose that's the technical part of me.

I agree/disagree with the instrument for assignment of my lowest preference in Quadrant 2 because

I agree that I do not fit in quadrant 2, because I am the most unorganized, random person ever. I may set goals, but rarely complete them if it doesn't seem relevant to me anymore.

On the Hemispheric Mode Indicator, I scored +26 which means that my preference in brain hemisphericity is Right. Do you feel comfortable with the analysis? Is it fairly accurate? Explain your reasoning.

I feel this is a pretty accurate description of how I think. I am intuitive about how others are feeling. and I need someone to actually show me what to do, In the end if I am going to do something, it has to be my own decision, my own motivation, also I love to find patterns in people, behavior, assignments, tests, etc.

In your highest preference quadrant, review the characteristics of THE UNCOMFORTABLE LEARNING ENVIRONMENT. Discuss if these characteristics best describe situations which make you uncomfortable. Is there another quadrant characteristic of the UNCOMFORTABLE LEARNING ENVIRONMENT which fits you better? Explain.

I agree with the characteristics of the uncomfortable learning environment of quadrant 4. I can't stand long lectures, I'd go to sleep in 5 minutes. Repitition is annoying & boring to me. I prefer the application of a lesson, what it's used for?, what can be done with this?, Relevance? On the whole I would struggle with Type 2 teachers, because I feel they seem to focus on straight knowledge, with out focussing on the individuals character.

How does this analysis of your learning style preference influence you. Discuss anything it has revealed to you as far as the way you learn.

It wasn't a really big surprise to see that I learn by finding my own way doing things, and I know I'm not organized, it's kind of a relief that I don't see that as a negative characteristic anymore. It has helped me to realize that I do learn by relying on past experiences & combining with current problems.

How do you think this information can be helpful in the elementary classroom?

It makes me want to find out how my future students learn, what kind of activities will maximize their ability?, What can I do to help them broaden their ways & manners of learning?

APPENDIX M

LEARNING TYPE MEASURE

The Learning Type Measure (LTM®)

Part A:

Instructions: The following questions are designed to indicate your preferences in attending to and acting on what you learn. When learning, which descriptor is most like you? Using 4, 3, 2, and 1, place a "4" in the blank corresponding to the descriptor MOST LIKE YOU and a "1" in the blank for the descriptor which is LEAST LIKE YOU. Then fill in your "2" and "3" responses. You must use all four numbers. Do not make ties.

FOR RESEARCH ONLY

Name or Student Number________________________________

Date____________________

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1. **I EXCEL AT:**
   ____making realistic decisions ____reaching accurate conclusions ____uncovering hidden connections ____respecting people's feelings

2. **FOR ME, IT IS PARTICULARLY IMPORTANT FOR LEARNING ENVIRONMENTS TO EMPHASIZE:**
   ____original thinking and creativity ____logical reasoning and order ____discussion and collaboration ____problem-solving and experiments

3. **I LEARN BEST BY:**
   ____testing how things work ____working in groups ____self-discovery ____reflecting and thinking

4. **PEOPLE WOULD IDENTIFY ME AS:**
   ____productive ____creative ____responsive ____logical

5. **ONE OF MY STRENGTHS IS:**
   ____reflective thinking ____enthusiasm ____practicality ____listening skills

6. **WHEN LEARNING I ENJOY:**
   ____exploring hidden possibilities ____organizing ideas ____making personal connections ____producing results

7. **I STRIVE FOR:**
   ____consensus ____objectivity ____efficiency ____originality

8. **GENERALLY I AM:**
   ____nurturing ____dependable ____decisive ____intuitive

9. **I TEND TO BE:**

____too impulsive	____too impressionable	____too eager for closure	____too critical

10. **GENERALLY I AM:**

____cooperative	____methodical	____straightforward	____free-spirited

11. **LEARNING ENVIRONMENTS SHOULD EMPHASIZE:**

____real problem-solving	____clarity of reasoning	____connections to personal meaning	____adaptability to change

12. **I AM MOST COMFORTABLE WITH PEOPLE WHO ARE:**

____supportive	____unique	____productive	____informed

13. **I HAVE PARTICULAR DIFFICULTY WITH TEACHERS WHO ARE:**

____rule-bound	____disorganized	____emotional	____impersonal

14. **GENERALLY, I AM:**

____studious	____caring	____down-to-earth	____innovative

15. **I WOULD PREFER TO:**

____make the world a happier place	____acquire knowledge	____solve practical problems	____create new ways of doing things

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Part B

Instructions: For each numbered item, circle the one descriptor which best describes you.

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1. WHEN LEARNING, I PREFER:

a quiet environment	an active environment

2. WHEN LEARNING, I PREFER TO:

reflect before I act	act and then reflect

3. I TEND TO:

keep a lot inside	talk out my ideas

4. I AM:

public	private

5. I PREFER TO:

initiate	evaluate

6. GENERALLY, I AM:

action-oriented	reflective

7. WHEN SOLVING PROBLEMS, I:
ponder experiment

8. GENERALLY, I AM:
reserved energetic

9. GENERALLY, I AM:
talkative quiet

10. I TEND TO BE MORE:
extroverted introverted

11. I PREFER LEARNING TASKS THAT ARE:
individual group

The 4MAT Learning Type Measure was co-developed by Dr. Bernice McCarthy and Dr. Clif St. Germain. Technical manual by Dr. Marcus Lieberman, 4MAT and Learning Type Measure (LTM) are registered trademarks of Excel, Inc.

APPENDIX N

HEMISPHERIC MODE INDICATOR (HMI)

HEMISPHERIC MODE INDICATOR (HMI)

INSTRUCTIONS

For each numbered item there are four possible choices. Either choose "a lot" or "somewhat" from the column A side, or "a lot" or "somewhat" from the column B side. For example: I prefer dogs "a lot" or "somewhat" — or — I prefer cats "a lot" or "somewhat". Choose one answer for each numbered item. Place an O in the appropriate blank.

Example:

COLUMN A	A lot	Somewhat	Somewhat	A lot	COLUMN B
Prefer dogs	O				Prefer cats

COLUMN A	A lot	Somewhat	Somewhat	A lot	COLUMN B
1. bases decisions on facts					bases decisions on feelings
2. prefers organized structure in a work setting					prefers open-ended work setting
3. carefree, spontaneous					careful, deliberate
4. understands how the pieces fit together					understands from experience
5. tries hunches					approaches problems logically
6. like an athlete or artist					like an accountant or chemist
7. like a tax lawyer					like a criminal lawyer
8. neat					sloppy
9. process oriented					product oriented
10. improvising new ideas					thoughtful, both feet on the ground
11. prefers change and the unusual					prefers order and stability
12. recalls information, names					recalls faces, dress, actions
13. precise in language					free, sweeping terms
14. focus on words said and the message					takes in body language, emotional tone
15. holistic, intuitive					orderly, sequential
16. words and numbers					space and form
17. synthesizing					analyzing
18. abstract					concrete
19. emotional					rational
20. objective					subjective
21. waking					dreaming
22. timebound					timeless
23. realistic					idealistic
24. lead by the heart					lead by the mind
25. specific					ambiguous
26. community					agency
27. outlook					insight
28. cause and effect					resemblances
29. lumper					splitter
30. intellectual rigor					imagination
31. soft					sharp
32. persist					encompass

APPENDIX O

PROBABILITY AND STATISTICS EXAMS

Name____ **MATH 2143**
Chapter 8 - Probability **April 10, 1998**

Be sure to show your work if full credit is expected.

1. Complete each of the following statements with the best possible solution. [10]
   a. A ______________________________ is the set of all possible outcomes of an experiment.
   b. A(n) ____________________ event is an event with a probability of 0. This event can never occur.
   c. A(n) ____________________ event is an event with a probability of 1. This event is certain to happen.
   d. When a probability is determined by observing outcomes of experiments, it is said to be ________________ probability.
   e. When one outcome is just as likely to occur as another, as in coin tossing, the outcomes are ________________ likely.
   f. If a number is chosen __________________, then it has an equal chance of being chosen.
   g. The probability of an event occurring and the probability of an event not occurring are called ___________________________ of each other.
   h. Another name for a mathematical expectation is called a(n) __________________________.
   i. An arrangement of things in a definite order with no repetitions is a(n)__________________.
   j. An arrangement of things where order is unimportant is a(n)__________________________.

Problems 2-12 are worth 8 points each.

2. Suppose the names of the months of the year are placed in a box and one name is drawn at random.
   a. List the sample space for this experiment.
   b. List the event consisting of outcomes that the month drawn starts with the letter J.
   c. What is the probability of drawing a month that starts with J?

3. A box contains four red balls, five black balls, and 1 white ball. Suppose one ball is drawn at random. Find the probability of each of the following events:
   a. A black ball is drawn.
   b. A black or a white ball is drawn.
   c. A red ball is not drawn.
   d. A black or white or red ball is drawn.

4. Consider the following two boxes. If a letter is drawn from box 1 and placed in box 2 and then a letter is drawn from box 2, what is the probability that the letter is an A? **Explain your work in words or with a diagram.**

MATH		ART

5. A die is rolled once. What are the odds against rolling a prime number? **Explain your answer**.

6. A total of 3000 tickets have been sold for a drawing. If one ticket is drawn for a single prize of \$1000, is \$1.00 a fair price for a ticket? Explain your reasoning.

7. Five women live together in an apartment. Two have brown eyes. If two of the women are chosen at random, what is the probability that they both have brown eyes?

8. Amy has a quiz on which she is to answer any three of the five questions. If she is equally well versed on all questions and chooses three questions at random, what is the probability that question 1 is not chosen? **Explain.**

9. How could each of the following be simulated by using a random-digit table?

   a. Tossing a fair die.
   b. Picking two days at random from the seven days of the week.
   c. Spinning a spinner that is equally divided into four parts.

10. Draw a spinner with two sections, red and blue, such that the probability of getting (blue, blue) on two spins is 25/36. **Explain your reasoning.**

11. A student is not sure when to add and when to multiply probabilities. Provide an explanation which is suitable for this problem.

12. A student wonders why probabilities cannot be negative. Provide an explanation that is suitable for this problem.

13. An experiment consists of tossing a coin twice. The student reasons that there are three possible outcomes: two heads, one head and one tail, or two tails. Thus P(HH) = 1/3. Provide an explanation for this problem.

Bonus (each problem is worth 4 points).

A. Use the slope to determine if there is a single line through the points with coordinates (4,2), (0, -1), and (7, -5). Explain your reasoning.

B. If a pyramid has an octagon for a base, how many lateral faces does it have? Illustrate this with a drawing.

C. A calculus class is composed of 20 business majors and 30 math majors. Ten of the students are double majors of business and math. Explain your reasoning on each of the following questions. If a single student is chosen at random, what is the probability that the student is the following:

   1. Only a business major
   2. Only a math major
   3. A female math major
   4. How many students are in the class?

Name____ **MATH 2143**
Statistics: An Introduction **April 24, 1998**

Be sure to show your work if full credit is expected. If some of your calculations are done on the calculator, be sure to show on paper the process you used to solve the problem. Point values for the problems are given in [ ].

1. Complete each of the following statements with the best possible solution. [10]
   a. A(n) ______________________________ used in statistics, is a picture that displays data.
   b. b.A(n) ______________________________ is a data point whose value is significantly larger or smaller than other values in the data.
   c. The ordered ____ plot arranges numbers in ascending or descending order.
   d. A(n) __________________________________ shows how many times a certain piece of data occurs.
   e. ______________________________ graphs can be used to make comparisons in data.
   f. A(n) ____ is formed by the line graph that connects the set of data points (x, y) where x is the midpoint of an interval and y is the frequency of the interval.
   g. A(n) ______________________________ graph shows how parts are related to the whole.
   h. One way of thinking of the mean is to think of it as a(n)________________ point of the data.
   i. The value exactly in the middle of an ordered set of numbers is the__________________.
   j. The interquartile range (IQR) is used when we determine if a(n) __________________ exists.

2. HKM Company employs 30 people of the following ages: [15]

34	58	21	63	48	52	24	52	37	12
23	34	45	46	23	26	21	18	41	27
41	32	26	41	25	18	23	34	29	26

   a. Draw a stem-and-leaf plot for the data.
   b. What percent of the people are 50 years or older?
   c. What percent of the people are in the interquartile range?
   d. Draw a histogram using interval width of 10. For example, one interval would be 30-39.

3. Find the mean, mode, and median of the following set of data. [5]
   10, 40, 40, 50, 30, 10, 10

4. Find the range, variance, and standard deviation for the data in Problem #3. [5]

5. Following are box plots comparing the ticket prices of two performing arts theaters: (be sure to label your answers specifically) [10]

a. What is the median ticket price for each theater?

b. Which theater has the greatest range of prices? Explain.

c. What is the highest ticket price at either theater?

d. Compare and contrast the ticket prices of the two theaters based on the box and whisker plots.

6. On a certain exam, the mean is 72 and the standard deviation is 9. Explain the following in words or pictures. [10]

   a. If a grade of A is given to any student who scores at least two standard deviations above the mean, what is the lowest score that a person could receive and still get an A?

   b. If a failing grade is given to any student who scores at least two standard deviations below the mean, what is the lowest score a person could receive and still pass the exam?

   c. What percentage of the students failed the exam?

7. The weights of newborn babies are distributed normally with a mean of approximately 105 oz and a standard deviation of 20 oz. If a newborn is selected at random, what is the probability that the baby weighs less than 125 oz? [10]

8. A standardized mathematics test was given to 10,000 students, and the scores were normally distributed. The mean was 500, and the standard deviation was 60. If a student scored below 440 points, the student was considered deficient in mathematics. About how many students were rated deficient? Explain. [10]

9. A school administrator reports to you, a school board member, that the "average" number of students in a class in a school is 32. What other information might you need in order to predict whether any single classroom was overcrowded? [10]

10. The following scattergram was obtained from data collected relating quiz scores and hours of study. [10]

    a. What kind of correlation exists between the scores and hours of study?

    b. Explain in words what the scattergram reveals about the data.

    c. What is the mode of the hours studied?

    d. What is the range of the quiz scores?

11. A professor tells you that s/he grades on the "Bell" curve. Describe the grading process and give an illustration of the negative aspects of this grading system. [5]

Bonus (5 points each)

a. Consider the following two boxes. If a letter is drawn from box 1 and placed into box 2 and then a letter is drawn from box 2, what is the probability that the letter is an L? (Be sure to show your work)

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b. A game consists of rolling two dice. Rolling double ones pays \$7.20. Rolling double sixes pays \$3.60. Any other roll pays nothing. What is the expected value for this game?

c. A survey was conducted for ice cream favorites. Ten people liked chocolate ice cream and 15 people liked strawberry. Three people liked both.

1. How many people participated in the survey?

2. How many people liked only chocolate?

3. How many people liked only strawberry?

4. If a person were chosen at random, what is the probability that s/he liked both chocolate and strawberry?

APPENDIX P

PROBABILITY RETEST AND FINAL EXAM

Name____ Math 2143
Chapter 8 – Probability – Retest April 28, 1998

1. Complete each of the following statements with the best possible solution. [10]
   a. Another name for a mathematical expectation is called a(n) ________________________.
   b. When one outcome is just as likely to occur as another, as in coin tossing, the outcomes are __________________ likely.
   c. A ____________________________ is the set of all possible outcomes of an experiment.
   d. A(n) ____________________________ event is an event with a probability of 0. This event can never occur.
   e. When a probability is determined by observing outcomes of experiments, it is said to be ____________________________ probability.
   f. An arrangement of things where order is unimportant is a(n) ________________________.
   g. If a number is chosen ____________________, then it has an equal chance of being chosen.
   h. The probability of an event occurring and the probability of an event not occurring are called ______________________ of each other.
   i. A(n) ____________________________ event is an event with a probability of 1. This event is certain to happen.
   j. An arrangement of things in a definite order with no repetitions is a(n) __________________.

Problems 2-12 are worth 8 points each. Be sure to show your work if full credit is expected.

2. Suppose the days of the week are placed in a box and one name is drawn at random.
   a. List the sample space for this experiment.
   b. List the event consisting of outcomes that the day drawn starts with the letter S.
   c. What is the probability of drawing a day that starts with S?

3. A classroom has seven boys, eight girls, and two teachers. Suppose one person is chosen at random. Find the probability of each of the following events:
   a. A boy is chosen.
   b. A boy or a girl is chosen.
   c. A teacher is not chosen.
   d. A boy or girl or teacher is chosen.

4. Consider the following two boxes. If a letter is drawn from box 1 and placed in box 2 and then a letter is drawn from box 2, what is the probability that the letter is an R? Explain your work in words or with a diagram.

   CHARLIE   BROWN

5. A spinner is equally divided into ten sections numbered 0 – 9. What are the odds against rolling a prime number? Explain your answer.

6. A total of 100 tickets have been sold for a drawing. If one ticket is drawn for a single prize of $50, is $1.00 a fair price for a ticket? Explain your reasoning.

7. Five women live together in an apartment. Two are education majors. Two of the women are chosen at random, first one and then the other. What is the probability that they are both education majors?

8. How could each of the following be simulated by using a random-digit table?

   a. A true-false test.
   b. Picking two months at random from the twelve months of the year.
   c. Spinning a spinner that is equally divided into five parts.

9. Draw a spinner with two sections, red and blue, such that the probability of getting (blue, blue) on two spins is 16/36. Explain your reasoning.

10. A student is not sure when to add and when to multiply probabilities. Provide an explanation that is a suitable response.

11. A student wonders why probabilities cannot be greater than one. Provide an explanation that is suitable for this problem.

12. An experiment in your classroom consists of answering two true-false questions. The student reasons that there are three possible outcomes: two trues, one true and one false, or two false. If the answers to both questions are "true," the student reasons that s/he has a 1/3 probability of getting both right by guessing. Thus P(TT) = 1/3. Provide an explanation for this problem.

Bonus (each problem is worth 4 points)

A. If a building is in the shape of a pentagonal prism, how many edges would it have? Explain in words or a picture.

B. A math and science conference has 25 people teaching sessions in mathematics and 15 people teaching sessions in science. There are 5 people who are teaching sessions for both math and science. Explain the following questions in words or pictures.

   1. How many people are enrolled to teach at this conference?
   2. If a person is chosen at random, what is the probability that person will teach only a math session?
   3. If a person is chosen at random, what is the probability that person will teach only a science session?
   4. If a person is chosen at random, what is the probability that person is a male science presenter?

C. If mathematics were a weather element, it would be a(n) ______________________________ because

Name____________________________________ MATH 2143
Final Exam - Probability & Statistics Spring 98

Be sure to show your work if full credit is expected. If some of your calculations are done on the calculator, be sure to show on paper the process you used to solve the problem. Point values for the problems are given in [ ].

1. Complete each of the following statements with the best possible solution. [20]
   a. Probabilities can be determined ____________________________________ or ______________________________.
   b. A sample space is the set of all possible outcomes of a(n) ________________.
   c. A(n) ____________________________________ is a subset of a sample space.
   d. Outcomes are __________________________________ if each outcome is as likely to occur as another.
   e. A(n) ______________________________ event is an event with a probability of zero.
   f. A(n) _______________________________ event is an event with probability of 1.
   g. Two events are ___________________________________ if, and only if, exactly one of the events can occur at any given time.
   h. The probability of an event occurring and the probability of an event not occurring are called _____________________________________ of each other.
   i. An arrangement of things where order is unimportant is a(n) ________________.
   j. An arrangement of things in a definite order with no repetitions is a(n) ____________________________.
   k. ____________________________ focus attention on the median, the quartiles, and the extremes and invite comparisons among them.
   l. The ____________________________ of n given numbers is the sum of the numbers divided by n.
   m. The ____________________________ of a set of numbers is the middle number if the numbers are arranged in numerical order.
   n. The ____________________________ of a set of numbers is the number of numbers that occur most frequently in the set.
   o. The ____________________________ is the difference between the greatest and least numbers in the set.
   p. One way of thinking of the mean is to think of it as a(n) ______________________ point of the data.
   q. A(n) ______________________________ is a data point whose value is significantly larger or smaller than other values in the data.
   r. In a ________________________________, approximately 68% of the values are within one standard deviation of the mean, 95% are within two standard deviations of the mean, and 99.8% are within three standard deviations of the mean.
   s. A ________________ gives the position of a score in relation to the remainder of the distribution, using the standard deviation as the unit of measure.
   t. A(n) ____________________________ graph shows how parts are related to the whole.

2. One card is selected at random from an ordinary set of 52 cards. Find the probability of each of the following events: [4]
   a. A club is drawn________________
   b. A spade and a 5 are drawn___________________
   c. A heart or a face card is drawn_________________
   d. A jack is not drawn______________________

3. Use the following boxes for a two-stage experiment. First select a box at random and then select a letter at random from the box. What is the probability that the letter is an L? Explain your work in words or with a diagram. [6]

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4. What are the odds in favor of drawing a face card when one card is drawn from an ordinary deck of playing cards? [5]

5. How many four-digit numbers can be formed if the first digit cannot be zero and the last digit must be 2? [10]

6. A club consists of ten members. In how many different ways can a group of three people be selected to go on a European trip? [10]

7. Draw a spinner that has three sections, red, white, and blue, such that the probability of drawing a blue and then a red is 6/36 and the number of blue sections is greater than the number of red or white. Describe the spinner.
   Explain. [10]

8. At Bug's Bar-B-Q restaurant, the average weekly wage for full-time workers is $150. There are ten part-time employees whose average weekly salary is $50 and the total weekly payroll is $3950. How many full time employees are there? [5]

9. Find the mean, mode, median, variance and standard deviation for the following numbers: 10, 30, 40, 50, 60, 70, 90. [10]

10. The mass, in kilograms, of each child in Ms. Rider's class follows: [10]

40	49	43	48	46	42	49	39	47	49
42	41	42	19	41	40	45	43	44	42

   a. Make a line plot for the data.
   b. Make an ordered stem-and-leaf plot for the data.
   c. Make a frequency table for the data.
   d. Make a bar graph of the data.
   e. Make a box and whisker plot of the data.

11. Suppose the class takes a test and the following averages are obtained:
mean = 80, median = 90, mode = 70. Tom, who scored 80, would like to know how he scored in relation to the class. Discuss his score in relation to each of the measures of central tendencies for the class. [10]

12. A tire company tested a particular model of tire and found the tires to be normally distributed with respect to wear. The mean was 28,000 mi, and the standard deviation was 2500 mi. If 2000 tires were tested, about how many are likely to wear out before 23,000? [10]

13. Of the freshmen who entered Loren College last year, 12% made A's in English, 8% made A's in history and 4% made A's in both English and history. What percentage made A's in English or history? [10]

14. The accompanying bar graph shows changes in population for four largest cities in the United States. [10]

   a. Which city increased in population between 1970 and 1984?

   b. In which city did the population decrease the most?

   c. What was the city with the second largest population in 1984?

15. If a triangle and a parallelogram have equal areas and equal bases, what can be said about their altitudes? [10]
Area of triangle = ½ base * height, Area of parallelogram = base * height

16. Consider two cubes that are similar (the ratio of their corresponding sides are proportional), with sides 6 and 8. What is the ratio of their surface area? What is the ratio of their volume? [10]
If s = length of the side, Surface area of a cube = $6s^2$ and Volume of a cube = s^3.

Bonus* (10 points)
As a preservice elementary teacher, explain (in a paragraph) the critical aspects of teaching mathematics to children.

APPENDIX Q

TIME-LINE FOR RESEARCH PROJECT

SPRING 1998 Week of:	Scheduled Activity
January 12	Data Sheet
January 26	Knowledge Inventory – Introduction to Geometry
February 16	Essay: The Best Class I Have Ever Had; Essay: The Worst Class I Have Ever Had
March 16	SID-IV; Instruction on Learning Styles; LTM & HMI Self-Analysis Survey
March 23	Began instruction using 4MATmodel in a 4MAT class; Probability, Chapter 8 Personal Interviews began
April 6	Exam – Probability, Chapter 8 Personal interviews continued
April 13	Continued instruction using 4MAT model in a 4MAT class; Statistics: An Introduction, Chapter 9 Personal interviews continued
April 27	Exam – Statistics: An Introduction, Chapter 9; Retention Exam – Equivalent Forms - Probability, Chapter 8 SID-IV
May 1	Final Exam – Probability and Statistics Retest

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6"