AN ANALYSIS OF KINESTHETIC LEARNERS' RESPONSES:
TEACHING MATHEMATICS THROUGH DANCE

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To Guy–

in the hope that we could always clearly see

where we are

what is next

and

the realistic alternatives for future action

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ABSTRACT

This study was designed to look at the learning process of students with kinesthetic learning as their dominant learning style. To achieve this, kinesthetic learners (KLs) were observed as they studied geometry concepts in a mathematics classroom.

The need for understanding KLs' learning process in the context of learning mathematics arises from existing studies showing that: a) KLs are able to demonstrate increased academic achievement when instruction incorporates dance activities; and b) when dance activities are not incorporated into KLs' instruction, their performance on mathematics tests drops below grade level average.

The need for this study is also supported by the constructivist theory of knowledge. This perspective advocates that mathematical-thinking develops through mathematical exploration that is tightly connected with real and meaningful experiences. That is, learners need to explore mathematics in situations that make sense to them.

This researcher's position is that KLs currently fail mathematics tests because they are not given the opportunity to explore mathematics through situations that most make

sense to them–kinesthetic situations, i.e., dance. Instead, most mathematics teaching (at the elementary level) requires learners to have strong and proficient auditory, visual and tactile processes. These learning modes, however, are not compatible with KLs' learning strengths. Because KLs' dominant learning mode is kinesthetic sense, teaching that relies on other modes prevents them from achieving their highest academic potential.

A qualitative case study was designed, conducted and analyzed to answer the study's question. This study produced the following:

1. A clear definition of KLs' characteristic behavioral responses in the academic environment.
2. A kinesthetic-teaching strategy designed to assist teachers to teach academic curriculum, specifically mathematics, to kinesthetic learners by using dance activities.
3. An explanation of the ways in which teaching kinesthetically assists KLs to achieve their highest academic potential, and improve their auditory, visual and communication processing.

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CHAPTER I

INTRODUCTION

Context of the Study

The Curriculum and Evaluation Standards for School Mathematics (1989) and the Professional Standards for Teaching Mathematics (1991),[1] designed by the National Council of Teachers of Mathematics (NCTM), reflect the mathematics education community's[2] consensus that students need to learn more mathematics and that mathematics instruction must be significantly revised (NCTM, 1989, p. 1). The standards reflect an attempt to revise mathematics education in grades K through 12 by creating a framework that suggests new teaching philosophies, goals, and strategies to be applied in the mathematics classroom (NCTM, 1989). Because of the lack of research examining kinesthetic learners' learning processes[3] as it is reflected in their learning of mathematics, the standards could not examine this issue nor could recommendations be made on ways to accommodate kinesthetic learners.

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[1]The two documents will be referred to as the standards.

[2]The mathematics education community includes among others the National Commission on Excellence in Education; The National Science Board Commission on Pre-college Education in Mathematics; and the Mathematical Science Education Board.

[3]Learning process is defined as students' verbal, social and physical manifestations relating to understanding the curriculum taught in this study.

The notion that teaching strategies in general, and mathematics teaching strategies in particular should take into consideration different types of learning, and therefore include a wide range of activities, has been raised by researchers such as Ernst Von Glasersfeld, the Mathematics National Reform Movement, Howard Gardner and Rita Dunn. While many ways of learning are currently acknowledged,[4] kinesthetic learners are not viewed as a unique set of students with different needs.

Students who are primarily kinesthetic learners and who experience difficulties with mathematics at the fourth-grade level are of great concern to dance educators Diane Hohl and Carla Smith (1996). These researchers examined the effectiveness of dance activities[5] as a teaching strategy for geometrical concepts. Their data showed that about seventeen percent of fourth-grade students who fail mathematics tests when taught through traditional teaching techniques[6] are kinesthetic learners who could dramatically increase their mathematics performance if taught through kinesthetic activities, in this case dance (Hohl & Smith, 1996).

Kinesthetic learning is manifested through the stimulation of Kinesthetic Intelligence as identified and defined by Howard Gardner in his book <u>Multiple</u>

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[4]The following learning types–learning styles and intelligences, are acknowledged by school systems, teachers and curriculum. Learning styles include auditory, visual and tactile (Dunn, 1983a); intelligences include Mathematical-Logical, Linguistic and Musical Intelligences (Gardner, 1983).

[5]See Definition of Terms section for a complete definition.

[6]Traditional teaching techniques include oral lectures and pencil and paper drill exercises.

Intelligences: The Theory in Practice. Gardner defines Kinesthetic Intelligence as the "ability to solve problems or to fashion products using one's whole body, or parts of the body" (Gardner, 1993, p. 9). Gardner describes eight other intelligences—Mathematical-Logical, Musical, Linguistic, Spatial, Intrapersonal, Interpersonal, Naturalistic and Spiritual intelligences (Gardner, 1997), and he argues that because of the variety of intelligences, teachers should identify students' dominant intelligences to determine which teaching strategies and learning activities will facilitate the desired understanding (Gardner, 1993.)

The NCTM's attempt to revise mathematics instruction to enable students to understand mathematics reflects an awareness of Gardner's Linguistic and Mathematical Intelligences as well as auditory, visual and tactile learning styles.[7] This is evident in recommendations made to use geoboards, beads, pattern blocks, tiles, rulers, calculators and social interaction as teaching tools for abstract concepts in geometry (NCTM, 1989; NCTM, 1991). These tools are used as a means of exploring ways in which mathematical ideas are expressed in concrete materials and real-life situations through discussions, social interactions, problem-solving, reading and writing mathematics.

These teaching tools are recommended to facilitate students' physical movement as means for manipulating objects, observing phenomenon, and engaging in a discussion. These teaching tools, however, do not allow kinesthetic learners to develop understanding

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[7]Tactile and kinesthetic learning styles were defined by Dunn, 1983. See Definition of Terms section for tactile learning style.

of mathematical ideas because they involve the use of external physical objects to explore mathematical concepts rather than the individual's own body.

Research Problem

Students identified as kinesthetic learners, who previously failed on mathematics performance tests, were able to improve their performance significantly in both post and delayed post tests, when a teaching strategy based on dance activities was applied (Hohl & Smith, 1996). Hohl & Smith's (1996) conclusions and data support the proposition that kinesthetic learners need kinesthetic-based activities, in this case dance, to construct mathematical understanding. Such students are, however, mostly taught with traditional teaching strategies that are not compatible with their learning style nor with their dominant intelligence. The result is that kinesthetic learners are not able to develop their full potential understanding of mathematical concepts.

Research Questions

This study's research question was: what are kinesthetic learners' learning processes[8] as they use kinesthetic activities, in this case dance, to learn and demonstrate a) an understanding of geometrical concepts;[9] b) problem-solving skills;[10] and c)

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[8]See definition of terms section for learning process.

[9]The geometrical concepts are slides (transformation), flips (translation) and turns (rotation).

[10]Problem-solving skills refers to the ability to find several ways for representing, solving and explaining solutions to mathematical problems (NCTM, 1989, p. 23).

mathematical-thinking processes?[11]

The Purpose of the Study

The purpose of the study was to a) identify kinesthetic learners' learning processes when taught geometrical concepts through dance activities; b) identify characteristics of dance activities used as a teaching strategy for geometrical concepts; and c) provide a teaching model that includes strategies showing how dance activities can be incorporated into geometry curriculum instruction to accommodate kinesthetic learners' learning styles.

Need for the Study

The need for this study emerged from the following research findings: a) kinesthetic learners currently are being mislabeled as underachieving in mathematics because they are taught through teaching strategies that do not accommodate their learning styles (DeGeest & Wills, 1992; Hohl & Smith, 1996); b) students' learning styles and dominant intelligences should be identified so that teaching strategies can be tailored to overcome underdeveloped ways of learning that create problems in traditional school situations (Gardner, 1993); and c) the construction of abstract mathematical understanding depends, to a large extent, on a teaching strategy that incorporates meaningful whole body physical activities (Von Glasersfeld, 1990).

Assumptions

The assumptions of this study were derived from over ten years of teaching dance

[11]David Niemi asserts that the mathematical-thinking process is demonstrated by students' ability to consciously provide evidence of their knowledge (Niemi, 1996).

to fourth-grade students. Students identified as LD[12] or HAHDD[13] and reported as being problematic in school demonstrated in the researcher's private (i.e., non-school) dance classes a high level of attention[14] and innovation[15] when it came to problem-solving through movement.[16]

Students who were identified as performing poorly in school (many of whom were kinesthetic learners) and brought by their parents to dance class as a means of instilling discipline showed an extraordinary ability to express their thoughts clearly as they danced and moved in space.[17] Although at school these students were identified as slow readers and weak in mathematics, in the researcher's dance classes they demonstrated a high level of spatial-analytical ability.[18]

Students identified as having a visual-perceptual deficit and who performed poorly

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[12]Learning Disabled.

[13]Hyper Attention Hyper Deficiency Disorder.

[14]Students were able to concentrate and focus on one activity for periods exceeding fifteen minutes.

[15]Students were able to suggest, demonstrate and explain fully at least three alternative ways for solving a given problem.

[16]Harold N. Friedman's report also suggests that movement activities, among others, were useful to enhance visual perceptual and motor sequencing in students with learning difficulties.

[17]Students were able to verbally explain the relation between dance moves they created and their specific thoughts.

[18]Students were able to recognize movements in space and be able to rotate, transfer, and translate these shapes to other body parts and different locations in space.

in traditional mathematics classes demonstrated an extraordinary ability, in the researcher's dance classes, to visualize shapes and spatially manipulate them in a variety of forms such as rotations, reflections and slides.

Limitations of the Study

There were two observers in addition to the researcher who video-taped the sessions (see Chapter 3 Methodology). The presence of the two observers could have created a potential participant's reactions to the observers. This was minimized by a) introducing the observers to the students at the beginning of the first session; b) explaining the observers' functions; and c) conducting an exercise for students to experience how the observers function during the sessions.

Another potential limitation was the observer's reaction to the participants that could influence their objective observation of the student's learning processes. This limitation was minimized by a) training the observers to recognize their reactions to students' learning processes and record that reaction as part of the study; and b) holding a discussion between the observers and the researcher at the end of each session relating to the observers' reactions to the participants.

The use of observers as a tool for data-collection could have also produced flaws in the data recording, as observers could have failed to record important data. This was minimized by training the observers one week prior to the beginning of the study to prepare them and to ensure that all relevant information is recorded. Update sessions will be held every two weeks to refresh the observer's awareness regarding data recording criteria and processes.

Qualitative research designers[19] suggest that a qualitative study's validity are enhanced by addressing the observers' bias towards participants. In this study, this concern was addressed by conducting a discussion of the observers' views and interpretations at the end of each session. Denzin & Lincoln (1994) suggest that a high degree of internal coherence, plausibility and authenticity can be added to a qualitative study by including as many of the participants' own words as possible in the researcher's analysis. This approach was applied by incorporating as many of the participants' relevant comments as possible into the analysis section.

Denzin & Lincoln (1994) suggest that a qualitative study's reliability is strengthened by spreading the study over a long period of time to ensure accurate understanding of the phenomenon. This study was spread over a period of fifteen and a half weeks and included twenty-four, ninety-minute observations to strengthen the reliability of the findings.

The researcher assumed that the variety of dance activities and the length of the study would provide an extensive look at the learning processes of the three kinesthetic learners observed. This assumption could have been found invalid and, as such, would constitute a limitation.

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[19]Among the qualitative research designers are Denzin & Lincoln, 1994; Schatzman & Strauss, 1973.

Significance of the Study

This study is significant for several reasons. First, this study adds to the body of knowledge that explains the behavior responses of kinesthetic learners as they attempt to make sense of abstract mathematical concepts in the context of kinesthetic learning environment. Second, the study identifies the characteristics of dance activities that facilitate kinesthetic learners' process of constructing abstract geometrical concepts. Third, the data analysis of this study enabled the construction of a new mathematics teaching strategy that addresses the needs of kinesthetic learners in the mathematics classroom.

Definition of Terms

Auditory Learning Style: refers to the ability to listen to any information presented orally for periods of about forty to fifty minutes, and be able to remember at least seventy-five percent of what was said (Dunn, 1983a).

Cumulative Problem-Solving: in the last activity of a dance class that provides students with the opportunity to further develop their awareness of abstract concepts expressed through a whole body physical experience (archives of Dr. Prevots).

Dance: a human behavior that is created for a purpose, that includes intentional rhythm and expresses cultural environment through motion (Hanna, 1979).

Dance activities: are assignments involving a whole body action that includes the elements of dance (time, space, force/energy) presented through situations that require students to find and apply alternative solutions (archives of Dr. Prevots).

Exploration: is an activity used to introduce abstract concepts verbally and is meant to encourage students to explain and explore the concepts through social interaction, and by providing examples from concrete objects found in the classroom (archives of Dr. Prevots).

Flips: (also referred to as reflection or transformation) is a change in the position or direction of the axes of a coordinate system without changing their relative angles (Borowski & Borwein, 1991).

Horizontal: means parallel to, in the plane, of the horizon (Webster's New Collegiate Dictionary, 1977).

Intersecting lines: are the set of points common to a figure (Borowski & Borwein, 1991).

Kinesthetic Intelligence: a cognitive potential realized by activities that allows one to use the body to express a thought or a goal directed action (Gardner, 1983, 1993, 1996).

Kinesthetic Learners: people who learn best by incorporating motion, emotion, thoughts and ideas expressed through the human's motion (H'Doubler, 1940, 1978a).

Kinesthetic Learning: learning triggered by sensations that are generated by the body through motion, emotion, thoughts and ideas, and that is expressed through movement of the human body (H'Doubler, 1978a).

Kinesthetic Learning Style: learning triggered by a whole body engagement in a physical activity (Dunn, 1983a). Kinesthetic activities are unique in that they require students to translate abstract concepts through their body without the involvement of other physical objects.

Learning process: students' verbal and physical manifestations relating to how they develop an understanding of concepts.

Line: a straight one-dimensional figure of infinite length and no thickness (Borowski & Borwein, 1991).

Line Segment: a part of a plane or solid figure cut off by one or more lines or planes that intersect the figures (Borowski & Borwein, 1991).

Mathematical Thinking Process: the ability to conduct a cognitive thought process that is characterized by concise logic and that relates to the world of numbers and shapes (Niemi, 1996).

Methodological Note (MN): statement that reflects an operational act completed or planned such as the timing, sequencing, stationing, stage setting, or maneuvering — remarks relating to the methodology process of the study (Schatzman & Strauss, 1973).

Observational Note (ON): statement made upon events experienced through watching and listening such as the who, what, when, where and how of human activity (Schatzman & Strauss, 1973).

Parallel: (of a pair or set of lines in Euclidean geometry) never meeting or intersecting however far extended (Borowski & Borwein, 1991).

Point: a basic element (along with LINE) having no dimensions (Borowski & Borwein, 1991).

Problem-Solving: an activity that allows students to explore abstract concepts by pursuing possible solution processes and pursuing their own solutions (archives of Dr. Prevots).

Problem-Solving Skills: the ability to find several ways of representing, solving and explaining solutions to problems (NCTM, 1989).

Slide: (also referred to as translation) the moving of a coordinate system to another position while the new axes are parallel to the original figure (Borowski & Borwein, 1991).

Space: refers to the sub concepts of direction, floor pattern, body facing, focus, range and level (see complete definition in Appendix V: Dance Elements) (archives of Dr. Prevots).

Tactile Learning Style: learning triggered by body movements such as note taking and knitting (Dunn, 1983a).

Theoretical Note (TN): represents self conscious attempts to derive meaning from one or several observations and can include interpretations, hypothesis, new concepts to be considered later, and links to older notes or events (Schatzman & Strauss, 1973).

Time: refers to the concepts of tempo, accent, underlying beat, measure, meter, duration, rhythm (see complete definition in Appendix V: Dance Elements) (archives of Dr. Prevots).

Turn: (also referred to as rotation) a circular motion around a given point (the axis) or line without a change in shape (Borowski & Borwein, 1991).

Visual Learning Style: learning triggered by seeing and identified by the ability to recall 75 percent of what has been read or observed (Dunn, 1983a).

Vertical: located at right angle to the plane of the supporting surface (Webster's New Collegiate Dictionary, 1977).

Organization of the Study

The second chapter reviews the literature on the teaching practices currently recommended by NCTM in the area of geometry and the nature of constructing mathematical understanding and its dependence on kinesthetic types of activities. Also included is the nature of kinesthetic learning and the importance of incorporating kinesthetic learning into mathematics teaching strategies. The third chapter discusses the methodology of this study. The fourth chapter presents the analysis of the data, and the fifth chapter presents a summary of the study, conclusions and recommendations.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

The NCTM's mathematics standards (1989, 1991) were created to reform mathematics teaching in the United States by implementing the constructivist approach to the construction of knowledge. The standards' goals were to allow every child[20] to feel powerful about mathematics[21] and to become mathematically literate.[22] The standards were constructed as a framework based on the constructivist philosophy of the construction of knowledge and as such it includes an explanation of the new ways mathematics teaching and learning should be facilitated. These new approaches include,

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[20]Every child meant students who have been denied access in any way to educational opportunities, students who are African-American, Hispanic, American-Indian, and other minorities as well as those who are considered to be part of the majority, students who are female as well as those who are male, and students who have not been successful in school and in mathematics as well as those who have been successful (NCTM, 1991a).

[21]To feel powerful about mathematics meant to be able to explore, conjecture and reason logically, solve non-routine problems, communicate about and through mathematics, connect ideas within mathematics and between mathematics and other intellectual activities, and develop self-confidence using quantitative and spatial information to solve problems and make decisions (NCTM, 1991a).

[22]To become mathematically literate meant to develop a solid understanding of mathematical ideas, positive attitude towards mathematics, confidence in their own ability to do mathematics, flexibility of thought and approach to problem-solving, willingness to explore new questions and horizons, and be able to use technology appropriately (The Regional Laboratory for Educational Improvement of the Northeast and Islands, 1995).

among others, a focus on the diversity of learning styles—auditory, visual and tactile. It appears that the standards do not address the issue of kinesthetic learning because of the lack of literature addressing the issue as it relates to mathematics learning.

The first part of this chapter introduces a discussion of the constructivist perspective on teaching and learning as it relates to mathematics education, and outlines the standards and the ways in which these standards implement the constructivist approach. This section concludes with an assessment of how the standards implement constructivism as it relates to the needs of kinesthetic learners in the mathematics classroom.

The second part of this chapter presents theories supporting the existence of a learning style labeled "kinesthetic." A discussion of research studies by dance educators follows showing that: a) dance activities used in these research studies correspond with both Gardner and Dunn's criteria for activities stimulating Kinesthetic Intelligence and kinesthetic learning style; and b) a teaching strategy that is based on dance activities was found to be an effective teaching tool for abstract concepts.

This section concludes by presenting the overall structure of the literature review and a macro perspective of the ways in which this study's research questions are relevant based on the presented literature.

Part I: The Constructivist Perspective on Mathematics Knowledge, Learning and Teaching

Introduction

The constructivist school of thought addresses the issue of knowledge formation and the role of learner and teacher in the learning process. Specifically, constructivism represents the view that obtaining knowledge is the result of a conscious cognitive activity that takes place through active personal experience (Confrey, 1990; Von Glasersfeld, 1984). Confrey (1990) explains that the origins of constructivism are found in the work of Jean Piaget, who recognized that some children's process of constructing mathematical understanding did not always parallel the process of adults with experience in mathematics. Piaget pointed out that some children lack both the understanding of mathematical processes as well as the techniques and methods used to construct different forms of arguments (Confrey, 1990, p. 109).

Piaget's research laid the foundation for a new school of thought addressing the issue of knowledge construction in general and in mathematics education in particular—constructivism. Constructivism, as it is applied in mathematics education,[23] accepts the following three assumptions regarding the process in which mathematical knowledge is constructed: first, the construction of knowledge is not obtained through

[23]The constructivist philosophy does not distinguish between abstract understanding as it is constructed in mathematics and geometry, as geometry is a sub area of mathematics. In this section, therefore, abstract mathematical-thinking refers also to the understanding of abstract geometrical concepts.

passive listening and rote memorization—because knowledge is not an iconic set of data. It is the freedom to choose from a variety of ways (physical and other) for acting and thinking that is essential to fulfill one's goals (Noddings, 1990; Pirie & Kieran, 1994; Von Glasersfeld, 1987, 1990, 1995a). Second, knowledge is obtained through the opportunity to think sequentially in a problem-solving situation that requires abstraction (Von Glasersfeld, 1990). Third, knowledge is obtained by the use of language as a guiding tool for developing understanding, investigation of concepts and ideas, rather than merely a vehicle for transporting information (Cobb, Yackel & Wood, 1992; Pirie & Kieran, 1994; Von Glasersfeld, 1990).

Mathematics researchers have expanded on each of these assumptions to increase the applicability of constructivist theory in the mathematics classroom. The following discussion addresses researchers' views of knowledge from three perspectives: a) an active learning process; b) a problem-solving process; and c) a process obtained by social interaction.

Knowledge—Active Learning

From the active learning perspective, the nature of mathematical understanding is grounded within a person, a topic and a particular environment (Pirie & Kieran, 1994). That is, the focus in constructing knowledge is on the learners and their actions.

Ernst von Glasersfeld writes that mathematical knowledge is gained by allowing a person to obtain an actual physical experience that serves to compare abstract knowledge previously constructed with current real-life experiences (von Glasersfeld, 1995a). He provides an example of the physical experience needed to construct a meaningful understanding—an infant's intuitive way of making sense of the world by moving the entire body (von Glasersfeld, 1995a). In the past, von Glasersfeld claimed, psychologists overlooked the whole body interaction and focused only on the motion of the arms, while it is the whole body's motion that facilitates understandings (von Glasersfeld, 1995a, p. 371).

Pirie & Kieran (1994) argue that much of mathematical understanding comes from the ability to construct and work with mathematical ideas that are not dependant upon physical context and that are expressed symbolically. To help students achieve mathematical power, the teaching should emphasize the learners' process of constructing a meaningful understanding of mathematical concepts rather than presenting students with formalized ideas (Pirie & Kieran, 1994, p. 39). These researchers advise that accepting the perspective that knowledge construction is an on-going process, occurring over time and defined by experience and exposure to a variety of teaching approaches, will assist teachers in helping students construct mathematical understanding (Kieran, 1994, p. 589).

Acceptance of this view of the nature of knowledge construction led researchers to examine new teaching practices in the mathematics classroom. Such practices include providing students with the freedom to develop mathematical relationships by engaging in social communication, allowing students to initiate and pursue highly intuitive situations (Cobb, Yackel & Wood, 1992), and having students pose, identify and solve issues they see as problematic (Anderson & Piazza, 1996; von Glasersfeld, 1990, 1995a, 1995b).

Anderson & Piazza (1996) added that providing students with the autonomy to take responsibility for determining right from wrong answers by using logical reasoning and sense-making is another strategy for having students develop meaningful understanding of mathematical concepts through active learning.

Knowledge—Problem-Solving

Constructivism represents the notion that expressed knowledge demonstrates an individual's subjective interpretation of real-life situations (Steffe & Weigel, 1992), which implies that there are a variety of ways in which a solution can be obtained (von Glasersfeld, 1995b). It is this assumption about the nature of knowledge that brings researchers to see problem-solving as a crucial part of creating a constructivist environment in the mathematics classroom (Cobb, Wood & Yackel, 1991; Confrey, 1990; von Glasersfeld, 1987).

Problem-solving is viewed by Cobb, Wood & Yackel (1991) as the asking of students to share their thought processes through social interaction. The researchers explain that asking students to verbalize the nature of their thoughts helps students formalize their mathematical understandings (Cobb, Wood & Yackel, 1991). The researchers suggest several ways for applying problem-solving in the mathematics classroom. One alternative, for example, is to develop activities that are relevant to the students' interests and apply them in context (Anderson & Piazza, 1996). Another alternative is to provide these activities to groups of students and to individuals who will work on ways of presenting their thought processes (Cobb, Wood & Yackel, 1991).

Knowledge as Obtained by Social Interaction

According to the constructivist perspective, knowledge is established when cognitive processes are stimulated through social and cultural interaction (Cobb, Wood & Yackel, 1991; Cobb, Yackel & Wood, 1992). This view has brought researchers to argue that to know means to be able to participate in a social interaction, and that there is one main strategy that encourages such knowing—communication as a tool for teachers and students to negotiate ways of interpreting verbal and mathematical language (Cobb, Wood & Yackel, 1991; Cobb, Yackel & Wood, 1992; Noddings, 1990; von Glasersfeld, 1990).

The means for constructing knowledge through social interaction and communication include discussion that requires students to verbalize their mathematical-thinking, i.e., explain and justify proposed solutions and resolve conflicting points of view. Engaging in such communication helps students to construct a common language as a tool for talking about mathematical ideas (Anderson & Piazza, 1996; Cobb, Wood, & Yackel, 1991).

Ernst von Glasersfeld (1990) elaborated on the issue of using communication in the mathematics classroom. He argued that effective communication is created when both parties understand the meaning of the words used. A common problem, he claimed, occurs when each party believes that the words used have a fixed objective meaning, which results in misunderstanding and misinterpreting the language used. A strategy for solving this problem, von Glasersfeld suggested, is for both sides to view their own statements as expressions of a subjective world which results in the ability to expand on what is heard.

Although the literature provides significant interpretations of the nature of knowledge construction, it is the application consequences of constructivism that are needed to implement this theory in the mathematics classroom. The following section provides a discussion of such application consequences as they relate to the function of mathematics teachers.

Constructivism in the Mathematics Classroom— Implication of Teacher's Function[24]

Assumptions Relating to Knowledge Construction

The application of constructivism in the mathematics classroom means that teachers assume students' meaningful understanding of mathematical ideas is the result of subjective interpretations of observations and experiences obtained in real-life situations (Anderson & Piazza, 1996; von Glasersfeld, 1987, 1984, 1995a, 1995b).

Teaching that applies this philosophy is characterized by allowing students to construct understandings of the relationship between mathematical ideas and concepts. This can be achieved by the teachers perceiving themselves as the facilitators of an exploration process conducted by students (Cobb, Yackel & Wood, 1992). These researchers also suggest that teachers need to be prepared to accept students' ways of

[24]Applying the constructivist approach in the mathematics classroom has significant implication on the function of students. Because the students' role and function in this setting can only be changed by teachers' actions, the emphasis in this section is on the teachers' role and function as facilitators of change in the mathematics classroom.

presenting their understandings in their own language, which the teacher can then use as foundation for strengthening and expanding on students' understandings of higher mathematical concepts (Cobb, Yackel & Wood, 1992).

Teachers' Goals

Researchers conducting studies attempting to implement the constructivist perspective in the mathematics classroom agree that a teacher's goal should be to encourage students to verbalize their mathematical understanding and solution processes as part of students' construction of a meaningful understanding of mathematical ideas (Cobb, Wood & Yackel, 1991; Kieran, 1994; Simon, 1995). It has also been added that individual growth in mathematics is promoted by students' examining their own philosophy of mathematical concepts (Anderson & Piazza, 1996), and that only after students pose their own mathematical goals are they able to achieve this through individualized experiences of reflection, critical thinking, coordination of viewpoint, reading and writing on current issues of mathematics (Cobb, Yackel & Wood, 1992; Simon, 1995).

Identifying Students' Understanding of Mathematics

The identification by the teacher of the students' mathematical understanding is another aspect of implementing the constructivist perspective in the mathematics classroom. This issue is raised because of the constructivist view that knowledge is a subjective construction of real-life experiences and observations and, as such, teachers need to understand students' perception of mathematical concepts for them (the teachers) to devise activities that facilitate the students' learning and exploration (Steffe & Weigel, 1992; von Glasersfeld, 1995b).

Cobb, Yackel & Wood (1992) add that interpreting students' understanding is crucial for teachers to map and develop their teaching approach. Teachers, however, need to be aware of their own mathematical knowledge and understandings for them to achieve this goal (Steffe & Weigel, 1992).

<u>The Role of Planned Lessons</u>

Ernst von Glasersfeld (1991) argues that planned instruction is essential for teachers to be clear on their instructional goals. At the same time, Simon (1995) notes that there is a constant tension between the planned lesson and the actual learning that takes place by students, because of the gaps between the planned instruction and what students need to know for them to process the new information. Simon (1995) compares teaching to a sailing journey where the sailor can pre-determine the journey's destination, but cannot foresee conditions along the way, i.e., what students actually understand. Teachers need to have a clear idea of the instruction's goals and destination, but they must also be able to re-create and re-direct their lesson plan and its activities to address issues raised by students as the lesson progresses (Simon, 1995).

<u>Teaching Strategies</u>

Researchers examining the ways in which the constructivist perspective can be implemented in the mathematics classroom adopted an inquiry approach, i.e., involving students through active participation, investigation and reflection. Cobb, Wood & Yackel

(1991) suggest that to achieve this goal, teachers need to establish social norms and communication patterns relating to issues of how to work together, ways for negotiating a working process, sharing materials and listening respectfully to each other.

Among the ways that social norms and communication patterns are established are: a) communicating to students that thinking about a problem and obtaining a solution process through clear verbalization are important learning goals, and that students' understanding should be respected when shared with the whole class (Simon, 1995); b) facilitating dialogues that give rise to learning opportunities such as raising different points of view and various solutions, conflicts, and resolutions that require negotiations (Cobb, Wood & Yackel, 1991; Simon, 1995); c) teachers responding to students who make mistakes to avoide embarrassing students;[25] d) teachers accepting all answers without grading and discussing, and the re-framing of conflicts as they arise (Simon, 1995); e) using both small group and whole class activities (Simon, 1995); and, f) creating students' seating arrangement around individual tables (Simon, 1995).

Teaching Aids

The use of teaching aids and manipulatives is supported by the belief that students' meaningful learning takes place through an interaction between them and their environment. The manipulation results in the creation of an organizational structure that produces learning (Kieran, 1994). Cobb, Yackel & Wood (1992) refer to this process

[25]The teacher might say "what is important in this class is the thinking about mathematics, not just the right answer."

when explaining that meaningful learning is achieved when students attempt to make sense of the world. The use of teaching aids to facilitate mathematical understanding is based on creating real-life situations that can be manipulated and explored by students. Among the teaching aids that are suggested are counters, multi-based blocks, centimeter rods, pencil-and-paper activities, pictures and diagrams (Simon, 1995).

Teaching Methods

Numerous researchers address the issue of incorporating a variety of teaching methods in the mathematics classroom. Each provides a slightly different perspective on the reasoning for this argument. Wittrock (1974) argues that, since individuals construct thought processes differently, a variety of teaching methods are needed to accommodate the different ways of learning. Steffe & Weigel (1992) claim that since many students perceive mathematics as a remote discipline that is not connected to their lives, the teaching of mathematics should, therefore, emphasize real world situations and actions through which mathematics can be explored. Wood, Cobb & Yackel (1995) claim that meaningful knowledge is constructed through a process of engaging cognition with social and cultural processes which means that teachers need to be more aware of their students' ways of learning.

Conclusion

The constructivist school of thought places the learner at the center of the learning process. The argument is that meaningful mathematical knowledge is the result of individuals fully engaging their cognitive potential through social and cultural communication that takes place in real-life situations. The teacher's role in this process significantly changes towards becoming facilitators of learning opportunities by encouraging mathematical communication and problem-solving through social interaction and by integrating a variety of manipulatives and other teaching aids.

The researchers also recognize that, for teachers to facilitate students' mathematical understanding, they need to recognize their students' learning styles and knowledge level so that instruction can be designed accordingly. The following section presents a discussion of the mathematics standards and the ways in which the standards reflect the constructivist approach for knowledge construction.

The NCTM Mathematics Standards

The mathematics standards reflect a growing recognition in the United States mathematics community[26] and around the world[27] that mathematics performance needs to be strengthened and that mathematics instruction needs to be reformed so that mathematics become accessible to every child (NCTM, 1989). The Curriculum and Evaluation Standards for School Mathematics (1989) present four areas through which the teaching of mathematics should be guided—problem-solving, communication,

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[26]The growing recognition that mathematics performance in the United States needs to be improved was expressed by the National Commission on Excellence in Education; The National Science Board Commission on Pre-college Education in Mathematics; the Board of the Mathematical, Science and Technology; and the Board of the Mathematics Science; the constructivist philosophy and constructivist researchers and the NCTM.

[27]The international awareness that mathematics performance needs to be improved is evident in the participation of over 50 countries in the Third International Mathematics and Science Study (TIMSS) (TIMSS, 1996).

reasoning, and connections. Problem-solving, communication and connections for kindergarten through fourth grades are relevant to this discussion.

The problem-solving standard provides that students should be able to: a) investigate and understand mathematical content; b) address problems from everyday situations and mathematical context; c) apply a variety of strategies to solve a wide range of mathematical problems; d) verify and interpret results relative to the original problem; and e) gain confidence in using mathematics in a meaningful way (NCTM, 1989). The means for achieving these goals are through social interaction that includes encouraging students to verbalize their understandings, raise questions, present speculations, conduct investigations and explorations of the context discussed. Teachers are encouraged to help students feel comfortable sharing their understanding by explaining it to their peers (NCTM, 1989, p. 23-25). The standard also emphasizes the importance of presenting mathematics in the context of real-life situations that enable students to better understand the ways in which mathematics is related to the real world.

The communication standard provides that students should have numerous opportunities for communication so that they are able to: a) relate physical materials (such as pictures and diagrams) to mathematical ideas; b) express their understanding of mathematical concepts and situations; c) relate their everyday language to formal mathematical language; and d) realize that activities such as discussing, reading, and writing about mathematics are an integral part of learning, understanding and using mathematics (NCTM, 1989, p. 26). The means for achieving these goals are through social communication that includes "exploring, investigating, describing, and explaining mathematical ideas" (NCTM, 1989, p. 26). Teachers facilitate this process by posing questions and inviting students to explain their thinking to others (NCTM, 1989, p. 26-27).

The connection standard calls for mathematics instruction to enable students to be able to: a) link conceptual and procedural knowledge; b) relate various concept representations to one another; c) recognize the relationship among topics; d) use mathematics in other curriculum areas; and e) use mathematics in their daily lives.

The standards explain that the importance of the connection standard is in students' developing the understanding of how different areas of mathematics connect among each other as well as to other real-life situations, concepts and experiences (NCTM, 1989, p. 32).

The NCTM attempted to reform curriculum assessment and instruction in three documents: the Curriculum and Evaluation Standards for School Mathematics (1989), the Professional Standards for Teaching Mathematics (1991), and the Assessment Standards for School Mathematics (1995). The Professional Standards for Teaching Mathematics (1991) includes an extensive discussion of all aspects of mathematics teaching. Among the standards relevant to this study are: worthwhile mathematical tasks, the role of teachers and students in discourse and tools for enhancing discourse.

Worthwhile Mathematical Tasks

Worthwhile mathematical tasks (standard number 1) are those that are based on: a) sound and significant mathematics; b) understanding of students' interests, experiences and understanding of mathematics; and c) knowledge of the range of ways that different students learn mathematics (NCTM, 1991).

This standard sets the following goals: a) engage students' intellect; b) develop students' mathematical understanding and skills; c) stimulate students to make connections and develop clear framework for mathematical ideas; d) develop problem formulation, problem-solving and mathematical reasoning; e) promote communication about mathematics; f) represent mathematics as an ongoing human activity; g) display sensitivity, and draw on students' diverse background experiences and dispositions; and h) promote the development of all students' dispositions to do mathematics (NCTM, 1991, p. 25).

The recommended activities in the Professional Standards for Teaching Mathematics include problem booklets, computer software, practice sheets, puzzles, manipulative materials, calculators and textbooks (NCTM, 1991). All of these teaching aids provide activities and tasks that can be used as is, but can also be used as resources for teachers to create activities that are tailored to students' level of understanding.

Tailoring activities to individual students' needs facilitates their developing understanding of mathematical concepts and stimulates better learning. The first standard also emphasizes that a wide range of activities can, and should, be presented in many interesting and legitimate ways, and that legitimatizing students attempts to find numerous solutions is a teaching strategy that encourages classroom discourse. Such an approach requires students to reason about different mathematical strategies, outcomes, alternative methods and allows them to pursue a chosen path (NCTM, 1991, p. 26).

The first standard also addresses the issue of teachers assessing their students from psychological, cultural, sociological and political perspectives, specifically recommending that these aspects should be taken into consideration when choosing activities and tasks. It is also mentioned briefly that a variety of activities that engage the mind both through pictures and writing are required to provide students with a wide range of opportunities to model and investigate concepts (NCTM, 1991, p. 27).

The Role of Teachers in Discourse

The role of teachers in discourse (standard number 2) calls for teachers to orchestrate discourse by a) posing questions and tasks that elicit, engage, and challenge each student's thinking; b) listening carefully to students' ideas; c) asking students to clarify and justify their ideas orally and in writing; d) deciding what to pursue in depth from among the ideas that students bring up during discourse; e) deciding when and how to engage mathematical notations and language to students' ideas; f) deciding when to provide information, clarify issues, provide a model and when to let students struggle on their own; and g) monitor students' participation by deciding when and how to encourage each to participate (NCTM, 1991, p. 35).

The second standard explains that mathematical discourse that includes reasoning, posing questions and alternative thought processes should be the norm in the mathematics classroom, and that it is up to the teacher to create an environment that allows such discourse to take place. There are several ways for teachers to create discourse in the mathematics classroom: a) choose tasks requiring group deliberations; b) present students with questions such as "why?" regarding their proposed processes and asking them to explain in writing their choices; and c) cultivating a tone of interest to help establish norms of civility and respect rather than criticism and doubt (NCTM, 1991, p. 35).

Teachers also need to move away from functioning as the source of information by lectures and modeling, and toward having students provide solution processes and reasoning. This requires teachers to become listeners and as such they need to be able to filter those points that will lead to student explorations and solutions in the mathematical realm (NCTM, 1991, p. 36).

The Role of Students in Discourse

The role of students in discourse (standard number 3) calls for students to be able to: a) listen, respond and question the teacher and one another; b) use a variety of tools to reason, make connections, solve problems and communicate; c) initiate problems and questions; d) make conjectures and present solutions; e) explore and present counter examples to investigate a conjecture; f) try to convince themselves and each other of the validity of particular representations, solutions, conjectures, and answers; and g) rely on mathematical evidence and argument to determine validity (NCTM , 1991, p. 45).

The third standard argues that a major factor in students' learning of mathematics is classroom discourse. Students should take the responsibility to engage in making conjectures, propose approaches and solutions to problems, and argue about the validity of particular claims. Students should also learn to verify, revise and discard claims on the basis of mathematical evidence and be able to use a variety of tools for that purpose.

Students should also be able to work together in small or large groups providing each other with comments, aiming to convince or question their peers. The focus of these interactions should be on making sense of mathematical ideas, and on using these procedures to solve mathematical problems (NCTM, 1991, p. 45).

Tools for Enhancing Discourse

Tools for enhancing discourse (standard number 4) provides specific examples of the type of teaching aids and strategies that mathematics teachers should use in the classroom that include: a) computers, calculators and other technology; b) concrete materials used as models; c) pictures, diagrams, tables and graphs; d) invented and conventional terms and symbols; d) metaphors, analogies and stories; e) written hypotheses, explanations and arguments; and f) oral presentations and dramatizations (NCTM, 1991, p. 52).

The fourth standard explains the importance of establishing discourse focusing on exploration of mathematical concepts through a variety of teaching strategies and aids. Such teaching aids can include drawings, diagrams, invented symbols, and analogies, all of which are used to explore mathematics both informally and formally. Teachers should feel free to both encourage students to use available technology aids such as computers and calculators, as well as feel confident allowing students to choose the means that best facilitate mathematical discourse (NCTM, 1991, p. 52).

Conclusion

The mathematics standards lay the foundation for curriculum reform through a constructivist-based approach. The standards specifically address the following aspects related to achieving this goal: the roles of teacher and students in the mathematics classrooms; the function and use of classroom discourse; and the use of a variety of teaching aids and strategies, i.e., problem-solving, communication, reasoning and connections.

Review of the literature shows that the standards adopt the constructivist view of the nature of knowledge construction. The standards argue that knowledge construction is the result of engaging cognitively, socially and culturally in real-life experience that needs to be explored and discussed in context in order to become meaningful for students. Social interaction and language communication are viewed as the main vehicles for constructing mathematical knowledge.

Teachers are viewed as facilitators of this process and are provided with freedom to make decisions regarding the ways in which mathematical ideas are explored, investigated and socially expressed. Common to both the constructivist literature and the mathematics standards is that activities and teaching strategies recommended are tailored to students who have well developed auditory, visual and tactile learning styles[28], i.e.,

[28]See definition of terms section for tactile learning style definition.

students who are verbally fluent and are able to efficiently use verbal communication, social interaction and tactile learning as vehicles for constructing mathematical understanding.

This researcher claims that kinesthetic learners, and their unique ways of learning, were not addressed by the mathematics standards. von Glasersfeld's work, in which he indicates that a physical experience that incorporates the entire body and not just the hands is required to construct mathematical knowledge, supports the need to recognize kinesthetic learning as a distinct type of learning (von Glasersfeld, 1987, 1990, 1995b).

The issue of incorporating teaching activities that are designed for kinesthetic learners into mathematics instruction is important because it is estimated that about seventeen percent of fourth-grade students are kinesthetic learners. These students currently fail on mathematics tests (Hohl & Smith, 1996) mainly because the teaching strategies do not include activities tailored to their unique learning style, preventing them from fully developing mathematical knowledge. The second part of the literature review chapter includes a discussion of the nature of kinesthetic learning and evidence that a teaching strategy designed for kinesthetic learners is essential for those students to develop and demonstrate their mathematical knowledge.

Part II: Kinesthetic Learning

Introduction

Learning facilitated by dance activities has been discussed for some time by dance educators[29] who have used dance activities as a strategy to enhance students' understanding of a variety of abstract concepts. The issue of learning by engaging in dance activities is referred to in the literature in several ways including kinesthetic learning, kinesthetic learning style, and stimulating the Kinesthetic Intelligence.

The purpose of this section is to discuss and clarify these terms and present evidence showing that kinesthetic learners can demonstrate an increase of understanding abstract concepts (mathematics or other) when dance activities are incorporated into their instruction.

Kinesthetic Learning

Margaret H'Doubler,[30] a dance educator and philosopher, has addressed the issue, nature and importance of kinesthetic learning for human development and learning. She states that kinesthetic learning is the result of stimulating the kinesthetic sense, i.e., the movement sense, and it is realized by sensations expressed by the human body's motion which in turn generates new sensations (H'Doubler, 1978a, p. 12).

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[29]These dance educators include DeGeest & Wills, 1992; Green Gilbert, 1979, 1992, 1994; Heausler, 1987; Hohl & Smith, 1996; and Pylyshenko, 1996.

[30]Margaret H'Doubler did most of her work in the 1930s and 1940s (see bibliography). The current article was based on a presentation given in the mid-1960s and was included in a collection of essays written by various dance educators throughout the 60s and 70s, edited by Dennis J. Fallon and published in 1978.

H'Doubler explains that kinesthetic learning is facilitated by the cerebral cortex (at the center of the neural system) that receives and processes sensations generated by the body as a reaction to both its own being, and to the outside world. The first stage of cerebral processing is perceptual, i.e., unconscious sensations: ideas, thoughts and images are generated by the cerebral cortex as a result of dance and movement experience. The cerebral cortex serves as the facilitator—turning intuitive sensations into conscious awareness by exploring, rationalizing, judging, comparing and analyzing the information it receives (H'Doubler, 1978a, p. 13).

Referring to when movement and dance become a part of the learning process, H'Doubler explains that because of the natural ability of the body to both generate sensations and to use movement in space as a form of self expression, dance activities are natural channels through which an exploration and expression of these sensations can take place. Dance and movement activities are, therefore, essential tools through which meaningful exploration of concepts can be conducted and therefore should be incorporated as an integral part of the curriculum (H'Doubler, 1940).

H'Doubler provides an extensive discussion of the nature of dance and movement activities in education. She states that the teaching of dance in education should not aim to produce dancers who are able to execute a particular dance style. Rather, the goal should be to build upon creativity in motor experience as the basis for learning and exploration. Dance activities that apply this perspective trigger emotions, intellect and physical expression through conscious experiences and as such contribute to the fullest development of personal growth (H'Doubler, 1940).

H'Doubler talks about kinesthetic learning from the perspective of applying it through dance activities that are based on creativity, exploration of emotions and thoughts through a physical experience. She states that dance teaching can be successfully implemented into curriculum and education at both the elementary and secondary levels (H'Doubler, 1940).

Kinesthetic Learning Style

The psychologist Rita Dunn has written extensively about the importance of matching learning styles to type of teaching strategy to maximize learning (Dunn, 1983a, 1983b, 1983c). Dunn defines learning styles to include twenty-one different elements among which are auditory, visual, tactile and kinesthetic.[31] Kinesthetic learning style is identified by the preference to learn by engaging in a physical activity and performing physically energetic tasks. Dunn's recommendation for students who are identified on the Learning Style Inventory (Price & Dunn, 1997) as kinesthetic learners is to incorporate in the teaching instruction body games, physically engaging activities, and tasks requiring active socializing with others such as engaging in conversation (Dunn, 1983b, c).

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[31]See definition of terms section.

Kinesthetic Intelligence

The issue of learning by engaging in kinesthetic activities was also raised by the psychologist Howard Gardner,[32] who used the term Kinesthetic Intelligence to describe the ability to use the body in a highly skilled way to express a goal-directed action with a combination of fine and large muscle groups (Gardner, 1983). Gardner explained that intelligence has a biological and psychological component which can be developed, to a greater or lesser extent, as a consequence of exposure to life experiences (Gardner, 1996). He also states that each intelligence functions to facilitate a thinking process.

Gardner tested The Theory of Multiple Intelligences[33] for the purpose of identifying students' existing intelligences and the ways in which these intelligences facilitate students' learning (Gardner, 1993). To accomplish this task, each intelligence was assigned psychological attributes—specific characteristics—identifiable through students' behaviors. The psychological attributes assigned to Kinesthetic Intelligence were identical to traditional ways of interpreting dance ability and talent: sensitivity to rhythm, expressiveness, body control, generation of movement ideas, and responsiveness to music (Gardner, 1993, p. 91).

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[32]Howard Gardner is the creator of Theory of Multiple Intelligences which describes nine cognitive areas that respond to stimulation by different type of activities (Gardner, 1983, 1993, 1996, 1997).

[33]Testing of The Theory of Multiple Intelligences was done through Project Spectrum—a teaching-learning project that relied on the assumption that "every child has the potential to develop strength in one or several areas" (Gardner, 1993, p. 89).

Gardner's study concluded that there was no indication of the ways in which the activities used to stimulate Kinesthetic Intelligence contributed to students' learning process. It was recognized, however, that the study's methodology was limited by the small group sample of four year-old children.[34]

These findings regarding the functions of Kinesthetic Intelligence in students' learning process are surprising because of the reports of learning by students when taught through dance activities. The following section presents research studies conducted by dance educators demonstrating that dance activities incorporated into curriculum areas such as mathematics for students in first through fourth-grade can serve as an effective teaching strategy resulting in substantial improvement in students' academic performance. It will also be shown that the dance activities used in these studies correspond to the criteria and activities described by Gardner and Dunn as stimulating Kinesthetic Intelligence and kinesthetic learning style.

Dance Educators Perspective

The studies of dance educators focused on students' performance and understanding of abstract concepts as a result of a teaching strategy based on dance activities. The following section discusses these research studies, their purpose, methodology, type of dance activity used and findings. It will be shown that: a) dance activities used in these studies correspond to the criteria and activities described by

[34]The sample group included nineteen four-year-old students in the 1986-1987 academic year and twenty students in the following year, which is too few to be representative of the whole four-year-old population.

Gardner and Dunn as stimulating Kinesthetic Intelligence and kinesthetic learning style; and b) that dance activities are a useful teaching strategy for students to construct and demonstrate understanding of abstract concepts. This section will conclude with an explanation of the ways in which this study's questions and methodology logically evolve from the existing research studies.

The dance educators Hohl & Smith (1996) studied the extent to which dance activities affect mathematics performance of third-and fourth-grade students. This study's participants were divided into two experimental and two control groups. Both experimental groups were taught mathematics through dance and computer activities, and both control groups were taught mathematics curriculum through computers and traditional teaching strategies such as modeling, guided practice and independent practice.[35] The dance activities in the experimental group sessions were incorporated throughout the guided practice section of each session. During the study, conducted over two to three weeks, the third-grade curriculum emphasized multiplication and the fourth-grade curriculum included measurements[36] (Hohl & Smith, 1996, p. 10).

The students' understanding of mathematics curriculum was recorded by pre-and post-tests administered to both experimental and control groups. These tests were composed of story problems that the experimental group was asked to respond with one

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[35]The independent practice was assigned both as classroom as well as homework (Hohl & Smith, 1996, p. 10).

[36]The measurement curriculum was aligned with the school district learning outcomes for students (Hohl & Smith, 1996, p. 10).

movement solution. Data was also collected by establishing focus groups whose participants were randomly assigned from the entire pool of third-and fourth-grade students participating in this study. The focus groups were conducted before and at the end of the research and information was collected about the multiplication and measurements curriculum taught, as well as the participants' attitudes and feelings as they relate to mathematics.

The type of dance activities used to teach multiplication included: a) express in movement the product of 4 times 2; b) express the product of 2 times 8 through the concept of time; and c) combine two body parts that come in 2s to form a product of 2 times 2. The type of dance activities used to teach measurement included:
a) move the amount marked on the ruler both in length and height; b) create a movement pattern that does not go beyond 12 inches; and c) express in a shape the length indicated such as foot or yard.[37]

Hohl and Smith's data showed that fourth-grade students who perform below grade level[38] (about seventeen percent) when taught mathematics with traditional teaching strategies were able to increase their mathematics performance on an average of forty-eight points when dance activities formed the foundation of teaching instruction. The researchers emphasize that the students who were able to use dance as their primary tool of communication were identified as kinesthetic learners.

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[37]Hohl & Smith, 1996, p. 24.

[38]Scores of 43 out of a possible 100 are considered below grade level.

Dance educators DeGeest & Wills (1992) studied the extent to which dance activities improve four-and five-year-old students' recognition and retention of geometrical structures in comparison to traditional teaching strategies. The curriculum chosen for this study was based on geometrical structures of squares, rectangles, diamonds and ovals. The group of kindergarten students were taught over three weeks diamond and oval shapes through creative movement activities; square and rectangular shapes were taught through pencil and paper worksheets.

All lessons began with a children's story as a method for introducing the curriculum and proceeded with either dance activities or with pencil and paper worksheet activities. The creative movement activities included assignments such as:
a) dancing freely while creating paths that represent the geometrical shape; and b) creating geometrical shapes with different parts of the body.

Students' recognition and retention of the curriculum was gathered through pre-, post- and delayed-post-tests that were conducted at the beginning, end and three weeks after the study had ended. The tests were based on students' verbal identification of the geometrical shapes and included geometrical structures of square, rectangle, diamond and oval.

Researchers were able to compare students' retention rate of geometrical structures relative to teaching instruction. They concluded that teaching instruction consisting of creative movement activities were four times more effective than teaching strategies consisting of books and worksheets. Delayed post-tests strengthened these findings, showing that curriculum taught through creative movement was better retained than curriculum taught through pencil and paper instruction (DeGeest & Wills, 1992).

Personal interviews were also conducted with each participant at the end of the study. The researchers stated that the interviews provided the most dramatic indication that creative movement should be considered as a teaching strategy in the mathematics classroom (DeGeest & Wills, 1992, p. 10). They concluded that the study on the use of creative movement to teach geometric shapes seems to show that creative movement is a viable alternative teaching method. They found that students learned better, retained more, enjoyed the lessons and demonstrated greater enthusiasm towards learning mathematics when these methods were applied (DeGeest & Wills, 1992, p. 10).

Ann Green Gilbert's study (1979) aimed to discover whether movement activities can be used to directly increase students' learning of language art skills. Set up as an experimental teaching program, this study was conducted over a period of six months. There were fifteen participating language-arts teachers in two inner-city schools and students ranging from kindergarten through sixth-grade. Dance activities were tailored to each grade's language-arts curriculum.

The kindergarten and first-grade students discovered forty ways to reinforce letter shapes and names by calling out the letter name and dancing its shape. Sixth-grade students explored newsletter headings such as "Factory Burns" and "Blizzard Rages" through movement phrases, and by talking about what associations the headline evoked in them. The second-grade students studied rhymes by molding their bodies into shapes representing rhymes for a given key word. For example, for the key word "might" there were body shapes of knight, tight, flight, slight, night, bright and fright.

Green Gilbert's data was generated by administering the Metropolitan Achievement Test to students participating in the study, as well as to an equivalent group of students for comparison. Interviews were also conducted throughout the study with both teachers and principals for the purpose of obtaining subjective data on physical, emotional and social benefits of this program.

Green Gilbert's findings included the following: a) the kindergarten and first-grade class increased its percentile rank from 25th to the 43rd; b) second-grade class increased their percentile rank from 20th to 33rd; c) the third-grade class increased its percentile rank from 50th to 76th. Green Gilbert also identified "a direct relationship between the amount of movement used by the classroom teacher and the percentage increase of students' tests scores" (Green Gilbert, 1979, p. 7). The class that showed the least improvement used dance activities for only fifteen minutes per week, while the class that showed the most improvement used dance activities for fifteen minutes per day.

Compared with the district-wide test results, the scores of third-grade students in the study increased by 13 percent in reading while the school-district students' scores increased on this subject only by 2 percent. The researcher also noted other effects as a result of this teaching method such as: a) an increase in cooperative behavior between the genders; b) an increase in bodily control that improved spatial awareness (some hyper-active children were better able to control themselves); c) an increase in student motivation; d) an increase in creativity; and e) a change in teachers' attitude towards certain children because they were able to see the children functioning and expressing themselves in ways different than when traditional teaching strategies were applied in the classroom.

All of the dance education studies examined whether dance activities were a useful teaching strategy enhancing students' performance on tests related to abstract concepts of mathematics and language-arts. The dance activities (examples listed above) were based on stimulating students to: a) express themselves through movement; b) demonstrate coordination and body control; c) generate movement ideas as related to given tasks; and d) use rhythm sensitivity as a tool for exploring and analyzing given assignments. All of these contingencies correspond to Gardner's criteria for activities that stimulate the Kinesthetic Intelligence, as well as Dunn's definition of activities that are tailored to stimulate the kinesthetic learning style by engaging students to physically move their entire body.

The quantitative research strategy selected by dance researchers (to answer their research questions) provided numerical data relating to cause and effect, i.e., does a teaching strategy based on dance activities affect students' understanding of abstract concepts in mathematics and language-arts. In this study, a qualitative research approach will be applied to investigate and document the ongoing process of students' learning.

Conclusion

This paper began with a discussion of the construction of knowledge as understood or explained by the constructivists. Next, a discussion of a sub-set of learners, kinesthetic learners, was presented. The question that this study asks is: how do kinesthetic learners use kinesthetic activities to construct understanding of abstract concepts?.

One of the constructivist propositions is that knowledge is created through a whole body physical activity. Construction of abstract concepts requires an understanding of the context in which such concepts are relevant and a whole body physical activity is one way to gain such understanding. The whole body physical activity produces comprehension of context by the learner interacting with the environment.

Kinesthetic learners develop knowledge in a different way from non-kinesthetic learners. The studies of a variety of dance educators have identified a causal relationship between dance as a teaching tool and increased academic performance among kinesthetic learners. This is an example of the constructivist's theory in action: a whole body physical activity, i.e., dance, serves as the means to developing comprehension of context through which abstract concepts can be explored and, through this exploration process, an understanding of the abstract concept itself can be achieved.

The question posed by this study is how do kinesthetic learners use kinesthetic activities to construct understanding of abstract concepts? The constructivists indicate that understanding of abstract concepts requires a comprehension of the context of the abstract concept. The dance educators identified a causal relationship between dance as a teaching tool and increased performance in kinesthetic learners. This study focuses more closely on how students learn abstract concepts and examines how kinesthetic learners use dance to develop an understanding of these concepts.

CHAPTER III

METHODS AND PROCEDURES

Purpose

Dance activities in the mathematics classroom have been found to be an effective teaching strategy for helping kinesthetic learners improve performance on mathematics tests (DeGeest & Wills, 1992; Hohl & Smith, 1996). The purpose of this study was to: a) identify the learning processes of fourth-grade kinesthetic learners (ages eight to ten, generally) when taught geometrical concepts through dance activities; b) identify the characteristics of dance activities used and found effective for teaching geometrical concepts; and c) provide a teaching model that includes strategies showing how dance activities can be incorporated into geometry curriculum instruction to compliment kinesthetic learners' learning styles.

The constructivist theory of knowledge provides the theoretical, methodological and procedural basis for this study. It is also particularly well suited to the issues examined in this study because it takes into consideration a variety of learning processes.

The curriculum chosen for this study included the geometrical concepts of slides, flips and turns. Foundation concepts included a point, a line, a line segment, an angle (right and acute), horizontal and vertical lines, and a line of symmetry.[39] The methodology

[39]The curriculum is based on Heddens and Speer mathematics curriculum Today's mathematics (part I): Concepts and classroom methods (1997) (geometry chapter).

chosen for this study was selected to enable the researcher to develop a deep understanding of the learning processes[40] of kinesthetic learners as they use kinesthetic activities, in this case dance, to learn geometrical concepts.

Rationale for the Qualitative Paradigm

A qualitative case study was chosen to investigate this question because such a research approach allows for detailed observation of students' perceptions relating to their learning processes as it occurs over time. The qualitative case study is an intensive study of a phenomenon, using a variety of sources and methods through a process of triangulation (the use of multiple sources) to support findings (Creswell, 1998). Stake (1995) explains that the purpose of qualitative research is to increase the understanding of a particular case—its uniqueness, complexity and interaction within its context. The question central to this study was how, and in what way, kinesthetic learners use dance activities to construct understandings of abstract mathematical concepts.

Population

Merriam (1988, p. 48) addresses the issue of the nature and size of the participant group. She writes that the size and nature of the sample group should be selected to best facilitate examination of the central questions of the study. This approach was implemented by selecting a group of up to twelve fourth-grade students, from which three were closely observed. The three closely observed students were primarily kinesthetic

[40]See definition of terms section.

learners identified with the Learning Style Inventory (Price, & Dunn, 1997).[41] The remaining nine participants were needed to facilitate a class environment that allowed social interaction among participants.

The variety of dance activities and the length of the study was extensive, as set forth in the outline section that follows. The assumption was made that there was no need to observe more than three kinesthetic learners to obtain answers for the research questions, because of the number of observations made over a long time period.

Setting, Timing, Permission for the Study

This study took place at a public school in Montgomery County, Maryland and was conducted over a period of fifteen and a half weeks. Meetings were held twice a week for ninety minutes each. Students' participation in this study was dependant upon parental permission as the students are minors.

Data-collection

Data was gathered from three points of view: the researcher, the observers and the students. Each data source was assigned several data-collection methods to ensure that each perspective was well documented and accurately interpreted. The three data-collection sources were the researcher (who functioned as a participant observer), two

[41]To ensure that there are three kinesthetic learners in the group, only students reported as experiencing difficulties with mathematics and demonstrating strengths in physical activities that involve whole or parts of the body (such as riding, moving, manipulating objects) were considered for this study. Interviews with the kinesthetic learners' mathematics teachers were conducted to strengthen the overall understanding of students' performance in mathematics as it is manifested during school hours. See Appendix IV: Teacher Interview Format.

outside observers (who provided interpretation of the kinesthetic learners' behavior responses), and the three kinesthetic learners. The data-collection methods used by the three sources include: video recording, field notes, a students' questionnaire, and group interviews.

Video Taping

Two video cameras were used to document the kinesthetic learners' learning processes as well as the classroom environment. The video cameras were used to documented the students' verbal and physical manifestations as they occur quickly, spontaneously and simultaneously with other events—verbal or movement. The video cameras also noted the time and date of the activities, which enabled efficient data documentation at the analysis stage.

Field Notes

Field notes were taken by the observers and the researcher to record three types of data[42]—Observational, Theoretical and Methodological—all of which, once transcribed, documented the observers' perspective.

Student Questionnaire

The kinesthetic learners' understandings of their own learning processes of mathematics were recorded through a student questionnaire.[43] Information gathered in this questionnaire addressed four areas: a) curriculum; b) teaching strategies and practices;

[42]The three types of notes referred to in this study are based on Schatzman & Strauss (1973, p. 99) recommendation for taking field notes.

[43]See Appendix II: Questionnaire for Students.

c) reactions to classroom activities; and d) students' ability to identify their own learning process. The questionnaires were administered at the beginning and end of the study to allow for analysis of the students' ability to identify their learning processes (as it relates to the study of mathematics) before and after kinesthetic-teaching instruction was applied.

Group Interviews

Group interviews[44] were held at the end of each teaching session with the three kinesthetic learners, the observers and the researcher.[45] The purpose of the group interview was to allow the students to share understanding of their own learning process. Group interviews were chosen as a data-collection method because it was felt that fourth-grade students would be better able to express themselves in a group setting. Also, it was the researcher's experience that at this age, students like to help each other by sharing their learning experiences through a group discussion, which strengthens their individual awareness. The group interviews took up to fifteen minutes and were videotaped.

Verification

Qualitative studies follow protocols indicating triangulation that help confirm the accuracy of the information gathered. Stake (1995) describes triangulation as incorporating different data sources to validate descriptions and statements made about events. In this study, four data sources were used to determine the accuracy of the

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[44]Creswell in his 1998 book suggests that, depending upon the circumstances, group interviews should be considered as a better option than individual interviews (Creswell, 1998, p. 124).

[45]See Appendix III: Group Interview Format.

interpretations made about events: observations, participant observations, student questionnaires and group interviews.

As part of this study's verification process, the researcher provided detailed descriptions of the data-collection process, the defining of categories, and the decision-making process throughout the study and data analysis. This increases the reliability of the study as it enabled other researchers to replicate this study according to its original methods and procedures. This verification process is referred to by Sharan Merriam (1988) as audit trail method.

Data Analysis

Data was collected to describe and analyze how the kinesthetic learners use dance to develop and demonstrate their understanding of abstract geometrical concepts. A conceptual framework was developed to express the relationship between the learning process and the characteristics of dance activities that facilitate these processes.

This framework was created based on transcripts of the students' verbal and physical expressions as captured on the audio and video tapes, and with the help of Life Forms, a computer program that creates a three-dimensional representation of kinesthetic expressions. These representations were used to produce a more precise analysis of the students' movement choices.

Life Forms allowed an analysis and comparison of the changes in kinesthetic responses over time in terms of their speed, range of motion, height and direction. The first step was to key in the kinesthetic responses of each kinesthetic learner, organized by individual response. The second step involved an examination of the changes in response by each participant over time and in relation to the mathematical activity involved. The result of this analysis was an outline of the changes in movements relative to mathematical understanding observed over time.

A second computer program was also used—NUD*IST.[46] This program was used to index the kinesthetic learners' behaviors into defined categories and to search for a relationships between these categories. The program also allowed an analysis of whether the presentation mode of a particular activity triggered certain responses in the kinesthetic learners. Finally, the program allowed an exploration of trends in the responses of kinesthetic learners.

About thirty categories were defined and created in NUD*IST[47] that included information in the following areas: a) lesson curriculum content;[48] b) curriculum level;[49] and c) the kinesthetic learners' responses in areas of kinesthetic, writing and oral communication. The exploration of the relationship between categories (in the context of

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[46]NUD*IST is the acronym for a Non-Numeric Unstructured Data Indexing, Searching and Theorizing.

[47]Information is stored in NUD*IST in the form of nodes, the storage area for text units.

[48]Curriculum content refers to the concepts of a point, a line, a line segment, horizontal, vertical, diagonal, parallel, a transformation, and translation, an axis and a rotation.

[49]Curriculum level refers to the mathematical activity specifically instructing participants to provide their mathematics reasoning and problem-solving in one or more of the following modes: oral, writing or kinesthetic.

the participants' learning process as observed throughout instruction) focused on three time periods: a) during the three informal sessions; b) during the early stages of the study (up to session eight); and c) and throughout the advanced stages of the study (sessions nine through twenty four). This was done to show the change in the kinesthetic learners' behaviors over three time periods and relative to the curriculum taught.

The data analysis process followed Coffey & Atkinson's (1996) recommendations that includes establishing categories and coding leading to an in-depth analysis. Establishing categories refers to identifying common characteristics of information segments that have been gathered through different data sources and methodologies. Coding, in this study, referred to labeling the categories by a word or phrase to enable: a) data simplification and reduction; b) retrieval of information; c) identifying and reordering of data by idea; d) identifying the learning processes sequences[50] of the kinesthetic learners; e) identifying examples of learning process sequence; and f) analyzing sequences for possible commonalities, differences and patterns in students' learning as they relate to the use of dance activities.

The analysis stage included: a) retrieval of information under each code to allow an exploration of the composition of each code content; b) production of a data display that included a concept diagram, a code diagram, and a chronological narrative of each concept; c) analysis of codes for themes and regularities as well as contrasts and

[50]Learning process sequence refers to the characteristics of the order in which learning process takes place.

irregularities; and d) generalizing and theorizing from the data. The data analysis was not expected to be a linear process, but was highly interactive as the data was being collected, categorized, displayed and reexamined before conclusions are drawn. The following diagram provides a visual representation for the data analysis process:

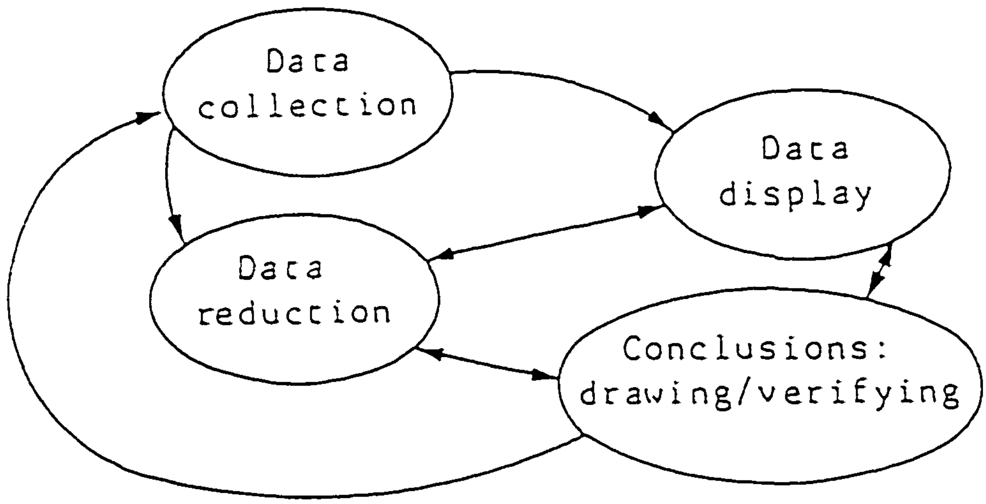

Diagram #1: Data Collection Diagram

*Source: Miles & Huberman, 1994.

CHAPTER IV

FINDINGS

Introduction—Purpose and Methods

The purpose of this study was to understand the learning process of the kinesthetic learners as they attempt to make sense of abstract concepts in geometry. The study examined the learning processes of the kinesthetic learners as they used kinesthetic activities, in this case dance, to learn and demonstrate: a) an understanding of geometrical concepts; b) problem-solving skills; and c) mathematical-thinking processes.

Qualitative research methodology was chosen for this study to enable the researcher to develop a deeper understanding of the data gathered relative to the study's questions. Data was gathered from several points of view—the researcher, two observers, the observed participants, their parents and teachers. Several data-collection methods were used to ensure that each perspective was well documented and accurately interpreted.[51]

The study took place at a public school in Bethesda, Maryland. The twenty-four sessions were held on Mondays and Wednesdays starting October 1, 1998 and ending February 1, 1999. This time period included winter vacation and three early dismissal days, which explains the stretch of the study over more than twelve weeks.

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[51]See details in chapter two, Methodology.

Participation in the study was open to all of the school's fourth-grade students. Information about the study was mailed to parents, and fifteen attended the first meeting. The purpose of the study was explained to the parents along with the teaching philosophy and methodology, with emphasis on the importance of administering the Learning Style Inventory[52] (LSI) prior to the beginning of the study. Once parental permission was obtained (in writing), all fifteen children were administered the LSI.[53] The study began with a total number of nine participants, three of whom were identified based on the LSI as the kinesthetic learners to be observed.

The Kinesthetic Learners Observed

Three kinesthetic learners—two boys and one girl identified by Price & Dunn's Learning Style Inventory--were observed by three trained adults[54] throughout the twenty-four sessions of the study.

Kinesthetic Learners' Learning Profile

The LSI provided a profile of the kinesthetic learners' learning style, i.e., auditory,

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[52]See population section in methodology chapter.

[53]Between administering the LSI and the starting date of the study, six children decided not to participate.

[54]The two observers were trained professionals. One was a forty-three year-old male, a clinical social worker with over ten years of experience counseling children. The other was a twenty-nine year-old female with extensive experience working with children in different settings and a certificate in dance. Both observers shared a love for dance and movement and were experienced dancers with well developed understandings of kinesthetic movement. The researcher has over ten years of experience teaching dance to children and an M.A. and B.A. in the field of dance with concentration in pedagogy, history and research.

visual, tactile, and kinesthetic, and the factors influencing their learning such as noise level, light, design[55], structure,[56] teacher/parent motivation and mobility.[57] A more detailed description of their learning styles was obtained through interviews conducted with their teachers and parents.[58] Following is the profile of the participants' learning styles as reported by their teachers and parents and according to the LSI. To preserve their confidentiality, participants will be referred by number.

<u>Participant Number One (A Female)</u>

The first participant was in fourth-grade during the study. Her native language was French, and she began acquiring English only six months prior to the beginning of the study.[59] She was reported as enjoying computer games, Scrabble, card games and dress-

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[55]Design refers to the look of a setting: formal—hard type of furniture, informal—soft chairs (Price & Dunn, 1997, p. 16).

[56]Structure refers to the degree to which activities and assignments are open ended and allow students to work independently (Price & Dunn, 1997, p. 15).

[57]Mobility refers to the degree to which activities are structured to incorporate movement to different locations (Price & Dunn, 1997, p. 17).

[58]The mother of participant number two shared more information with the researcher than the other parents, which results in a longer description in her child in this text.

[59]The fact that English was a recently acquired second language was taken into consideration during the interpretation and analysis of her responses.

up dolls.[60] The LSI results indicted that mobility and kinesthetic activities were her preferred learning styles and that she was highly motivated and relatively persistent in her learning. It also indicted that she found both the presence of teachers and parents beneficial in her learning process.

Participant Number Two (A Male)

The second participant was in fourth-grade during the study. He was reported as enjoying video games such as "X-Men," biking, and boating. His mother reported that he experienced substantial difficulties participating in group sports—he could not focus on more than one activity at a time. For example, in basketball practice he could not both dribble the ball and look at the hoop—he would look down at his feet and stumble.

The mother stated that, after repeated attempts to participate in group sports, her son would get frustrated and pull himself out of the game and begin to cry. The family tried to facilitate one-on-one games with him, which were more successful.[61] In these situations, he would be more active, show enthusiasm, and was able to carry on the game,

[60]She also had a noteworthy physical condition: during 1997 and 1998 she underwent two hip operations and was instructed by her doctors to avoid walking and to use a wheel chair for a period of four months to minimize any motion in her hip joint. At the beginning of the study, she could walk in a relatively stable manner, but did not have the strength to lift herself from sitting on floor to standing even with an adult's help.

[61]The one-on-one games were more successful because their loose structure enabled him a degree of freedom and flexibility to express himself that was not allowed in the structured group games.

according to his mother.[62]

The LSI indicated the he was a kinesthetic learner and that he was extremely dependant upon moving extensively in space to learn efficiently. It also indicated that he had extremely low self-motivation and was not motivated by a teacher's presence, but was highly motivated by his parents.

Participant Number Three (A Male)

The third participant was also in fourth-grade during the study. Both his parents and teacher reported that his academic performance in mathematics was between two and three levels below his grade level. He was reported as enjoying moving in space and engaging in a variety of physical activities including bike riding, soccer, basketball, ballet and jazz dance. While participating in this study, he also attended an opera class.

Participant number three's scores on the LSI indicated that he needed mobility while learning as well as kinesthetic movement. The LSI indicated that he could not tolerate structured activities and was extremely teacher motivated while unmotivated by his parents.

Interviews with the kinesthetic learners' teachers revealed that all three children had difficulty focusing and maintaining concentration during: a) oral presentations; b) situations requiring multi-step operations that were introduced as a whole set; and

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[62]The mother also indicated that, as an infant, he used to demonstrated aggressive-destructive behavior—hitting himself and others, kicking, and throwing himself to the floor. "He seemed to need physical movement relentlessly—pressing himself between two of the kitchen counters while kicking his legs wildly in the air," she said.

c) activities that required independent work for more than five minutes. The teachers also indicated that participants had difficulty with pragmatic language in situations requiring: a) the identification of hidden cues in questions presented orally or in writing; and b) social interaction and constructive communication.

The Data Analysis Process

Defining Categories

One of the characteristics of a qualitative data analysis is that it begins during the data-collection stage. While the data is still being collected, the researcher establishes and refines the objects of the study (Adler & Adler, 1994, p. 381). That is, the information to be recorded changes in response to what is observed. During this study, the kinesthetic learner's responses were examined as manifestations of their understanding of mathematical concepts. Their actions (both written and kinesthetic) and interactions with each other and with the researcher were observed to develop an understanding of how they perceived mathematical concepts.

The study's questions guided the researcher in maintaining the focus on relevant responses, i.e., problem-solving skills, mathematical-thinking process and the understanding of geometrical concepts that could be demonstrated in any of three modes: verbally (through social interaction), in writing and kinesthetically. The responses were coded into categories that were later explored to identify common themes in the learning of the kinesthetic learners.

Design of Lessons' Structure

Prior to the study, a general mathematics and dance concept map was created[63] as a guide for the order in which concepts would be explored in each curricular area. The purpose was not to implement the structure rigidly, but to use it as a guide from which the researcher could develop new directions as needed, while maintaining the original plan.

The data was analyzed at the end of each session in light of the structure, teaching approach, and activities of that session to develop an understanding of what worked with the kinesthetic learners. Prior research indicates that kinesthetic learners need actual experience to learn, but does not indicate what experiences work (DeGeest & Wills, 1992; Hohl & Smith, 1996). During this study, as particular activities showed promise through positive response by the participants, more data was collected relating to these particularly effective activities. In this way, the design of the classes changed to reflect what worked with the kinesthetic learners.

Data Analysis: Computer Applications

Once the data-collection ended, transcripts of all recorded activities were prepared. Transcripts were created for: a) notes taken by the researcher and the two observers; b) audio and visual recordings of all lessons; and c) interviews with participants, parents and teachers. The transcripts presented: a) the curriculum and concepts explored and discussed, the order in which activities were presented, and the type of activities

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[63]See Appendix I: Lesson Plan Structure that shows how both mathematics and dance concepts were divided among the twenty-four lessons so that each concept could be explored in four consecutive lessons.

included;[64] b) both general and specific descriptions of each participant's responses —kinesthetic, verbal and written; c) the language used by the researcher;[65] d) the specific mode of each activity; and e) whether or not the kinesthetic responses observed at the beginning of the study changed throughout the study relative to the kinesthetic and mathematical experience gained.

Life Forms 3.0

In order to understand whether the kinesthetic responses changed throughout the study, Life Forms 3.0, a computer program that produced a three-dimensional representation of movements, was used. It allowed an analysis and comparison of the changes in kinesthetic responses over time in terms of their speed, range of motion, height and direction.

NUD*IST

After reviewing the transcripts, it was concluded that only a micro perspective of this study's questions could be obtained. That is, it was only possible to obtain a clear picture of the individual participants' responses relative to each activity. The researcher was interested in determining whether there were commonalities or similarities among the kinesthetic learners' responses and whether the presentation mode of a particular activity

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[64]Type of activities refers to the mathematical concepts that activities were designed to address: a) recognition of concepts presented in concrete context through either verbal or kinesthetic response; b) identification of concepts presented in concrete context through both verbal and kinesthetic response; and c) regeneration of concepts presented in an abstract context through both verbal and kinesthetic response.

[65]The use of language refers to the emphasized content as a tool for clarifying, explaining, and reasoning mathematical activities.

triggered certain responses in the kinesthetic learners.[66]

Outcomes

This section presents the outcomes of the study in general terms and provides the framework of the data analysis along with a few short examples. An in-depth discussion of the outcome of this study is found in the Analysis section. The general outcomes of this study relate to the kinesthetic learners' responses in the learning environment created in this study, i.e., the kinesthetic approach for teaching mathematics. The responses demonstrated by the kinesthetic learners are discussed here relative to three time periods: the informal sessions conducted prior to the beginning of the study, the first stages of the study (up to the eighth session), and as the study took place (sessions nine through twenty-four).

In general, weak or negative responses present at the beginning of the study faded as the study progressed and were replaced with responses that could be characterized as positive and beneficial to learning. For example, during the informal sessions, the kinesthetic learners' behavioral responses indicated that they were experiencing difficulty processing auditory and written information. Throughout the advanced stages of the study, the kinesthetic learners showed eagerness to understand information presented orally or in writing. This indicates that the kinesthetic activities assisted learners to overcome the problems processing information they experienced in the early stages of the study.

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[66]See Chapter II data analysis section for elaboration.

Another example of kinesthetic learner's negative responses that faded during the study was physically destructive responses. At the early stages of the study, the kinesthetic learners would hit and kick the walls and were not respectful towards their own space and body. These behaviors disappeared as the study progressed and were replaced with the kinesthetic learners working together cooperatively, i.e., they would ask to be given the opportunity to dance with each other.[67]

Analysis—Introduction

The data gathered in this study was analyzed to answer to the study's questions, i.e., what are kinesthetic learners' learning processes as they use kinesthetic activities, in this case dance, to learn and demonstrate: a) an understanding of geometrical concepts; b) problem-solving skills; and c) mathematical-thinking processes.

Because both the purpose of this study and its research methodology are unique and unfamiliar to most researchers, two issues were clarified prior to presentation of the discussion of the data analysis. The first issue was the founding principle of the kinesthetic-teaching approach (specifically in the context of teaching dance), and the second was the classification of different modes of behaviors all of which are referred to as "responses."

Principles of Kinesthetic-Teaching

The teaching of dance, an example of a kinesthetic activity, is based on the

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[67]See discussions in sections: Kinesthetic Learners' Responses in a Learning Environment as Observed During the Early Stages of the Study.

teacher's ability to use words to explain the meanings of what is to be done or should be experienced. The teacher uses language to trigger imagery, words of connotation and association in the minds of the listeners. It is the students' ability to understand that language that opens the door for them to benefit fully from the kinesthetic experience.

In this study, while the researcher was using the kinesthetic-teaching approach, she also made sure that the kinesthetic learners understood the language used throughout the instruction. This was done in response to many instances where it was clear from their behavior that the kinesthetic learners did not know the words used by the researcher. Work was done, therefore, to develop the kinesthetic learners' mathematical vocabulary through the kinesthetic-teaching approach. The researcher implemented this by first constructing activities and experiences that were tailored to facilitate the kinesthetic learners' understanding and ability to connect physical experiences with the new introduced vocabulary.[68]

At the second stage, activities introduced required the kinesthetic learners to explain, reason, and find words to describe their experiences. At first, the kinesthetic learners struggled to find their own words to describe their mathematical understandings, and gradually they gained confidence finding their own words to describe their mathematical thoughts, in addition to learning the mathematical language. This was due

[68]In retrospect, it was found that the kinesthetic learners did not know both everyday vocabulary such as the words "precisely" and "particularly," as well as words that belong to the mathematics world such as horizontal, vertical, perpendicular, parallel and axis.

to repeated and deliberate activities designed to connect the kinesthetic experiences with informal and formal mathematical language.[69]

At the core of this process is the researcher's belief that the kinesthetic learners' ability to understand mathematics, i.e., reason, problem-solve and verbally communicate solution processes, is tightly connected with their being given the opportunity to see the connection between their kinesthetic manifestations and the formal mathematical language they attempt to acquire. In other words, introducing formal mathematical language disconnected from concrete kinesthetic experiences interferes with the kinesthetic learners being able to develop an understanding of the meanings of mathematical ideas and their relationship to formal mathematical language.

This position is consistent with the three fundamental (mathematics teaching) principles of the constructivist view of knowledge. First, communication, i.e., discussions held among students and teachers, is a primary way for students to negotiate ways of interpreting verbal and mathematical language (Cobb, Wood & Yackel, 1991; Cobb, Yackel & Wood, 1992; Noddings, 1990; von Glasersfeld, 1990). In this study, activities were designed to require the kinesthetic learners to verbally explain their thought

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[69]For example, observations suggested that the kinesthetic learners did not know the meaning of the word vertical, although they could create "bodily shapes" that were pointing in the shortest possible line between sky and ground. At the first stage, several kinesthetic activities were designed and given to facilitate the kinesthetic learners' ability to associate what they felt through the kinesthetic action, and the named word, in this case vertical. At the second stage, the kinesthetic learners were given mathematical problems introduced through formal language, i.e., the word vertical, and were asked to construct a kinesthetic solution and be able to present and explain it to the entire group.

processes and ask questions about mathematics concepts explored.

Second, mathematical knowledge is gained through an actual physical experience that serves to compare abstract knowledge previously constructed with current real-life experiences (von Glasersfeld, 1995a). In this study, von Glasersfeld's approach was applied by providing the kinesthetic learners with the opportunity to establish this relationship and practice the connection between what they did kinesthetically, the mathematical concepts discussed, and the formal language used to describe such events.

And third, according to constructivist theory, the means for constructing knowledge through social interaction and communication includes discussions that require students to verbalize their mathematical-thinking, i.e., explain and justify proposed solutions and resolve conflicting points of view. Engaging in such communication helps students to construct a common language as a tool for talking about mathematical ideas (Anderson & Piazza, 1996; Cobb, Wood, & Yackel, 1991). In this study, kinesthetic activities were designed to facilitate social interaction and communication as related to finding commonalities among kinesthetic experience and mathematical concepts.

Kinesthetic Learners' Apparent Responses: the Informal Sessions

Prior to the beginning of the study, three informal sessions were held to administer the LSI which was to identify the kinesthetic learners to be observed in this study. To help the participants feel comfortable with the researcher, informal group activities were conducted to facilitate an interaction between the children and the researcher. The researcher's hope was that these activities would help the children to get to know the researcher, the environment of the study, and would result in their full cooperation in taking the LSI.

The responses of children found to be kinesthetic learners suggest that they all experienced difficulties processing auditory and written information and were inclined towards movement. The diagram on page 72 provides a visual representation of kinesthetic learners' apparent responses during the informal sessions.

From these informal sessions, common themes in the behavioral responses of the kinesthetic learners were identified: difficulty processing auditory and written information, and the inclination towards movement.

Theme One: Difficulty Processing Auditory
and Written Information

This theme includes three categories: a) lack of focus; b) inability to listen/read directions; and c) dislike/resistance towards reading and writing.

The lack of focus. The lack of focus refers to behaviors characterized by the children "spacing out," looking away from where the "action" (the demonstration) was, finding books or other things to be busy with, and when called on to provide a response of what was discussed their response was: "hhhaaa?"

The inability to listen/read directions. The inability to listen/read directions refers to behaviors characterized by the children not being able to respond to the discussion or the problem presented orally or in writing. At the beginning of the study, they would simply stand silently, or pull themselves out of the group immediately when it was their turn to answer.

The dislike / resistance towards reading and writing. The dislike/resistance towards reading and writing refers to behaviors characterized by the children agonizing and complaining every time a writing activity was presented to them.[70] They would also move their bodies in ways that indicated that they were not comfortable with activities that required writing and reading—they would pull away from the paper where the activity was presented. They would also move back and forth to the paper having difficulty keeping their eyes on what was written on the paper.

Theme Two: Inclination to Moving Extensively in Space

This theme includes five categories: a) free shaking; b) creativity; c) constant movements; d) voluntary movements; and e) confidence moving extensively in space.

Free shaking. Free shaking refers to the participants pulling themselves out of the space where the instructional activity was taking place and wildly and very rapidly shaking their limbs. It was observed that, when participants were prevented from conducting their free shakes, they lost concentration, but when allowed to initiate the free shaking, they demonstrated extraordinary focus and concentration levels.

One example was when participant number two pulled out of the group to conduct his free shakes while the researcher continued to give the instruction. Upon coming back to the group, participant number two was asked to provide the answer to the problem presented while he was away. He not only knew the correct answer, but also reasoned

[70]These behaviors were more common at the early stages of the study.

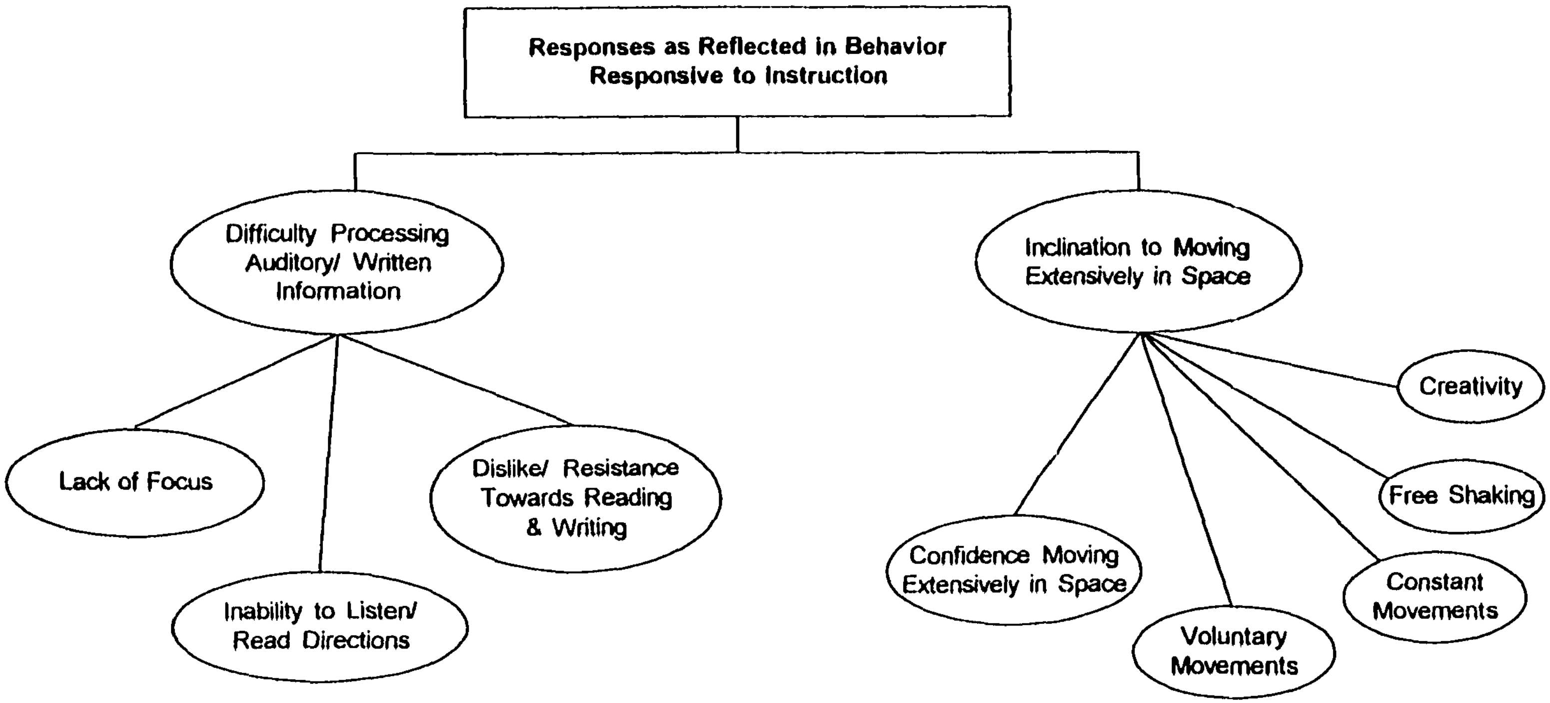

Figure #2:
Kinesthetic Learners' Apparent Responses--
During Informal Sessions

and shared his thought process with the group. This type of behavior was observed dozens of times throughout the study. It has led the researcher to conclude that allowing the kinesthetic learners to conduct such free shakes when they have a need to do so facilitates their concentration, ability to reason, communicate and problem-solve mathematically.

Creativity. Creativity refers to the participant's kinesthetic manifestations that are surprising in light of the fact that they did not have any background in dance or dance training. For example, participant number one was observed at the beginning of the study to mainly move standing upright. Her kinesthetic expressions were indexed under the creativity category when she began initiating rolling movements on the floor that were not part of the researcher's initiated activities.

Constant movement. Constant movement refers to participants' kinesthetic and verbal manifestation indicating that they need to continuously move in space. Verbal indications were statements such as: "can we please have free dance?," "can we dance now?," or "when can we dance again?." Indications of constant movement were observed when the kinesthetic learners were not asked to initiate kinesthetic expressions on their own and chose the kinesthetic movements for exploring and expressing their mathematical understandings.

There were times when the kinesthetic learners initiated kinesthetic expressions while they were talking or explaining something verbally. On one occasion, participant number two was asked to analyze the position in space of a body shape. As he was explaining the position of the shape, he began making the shape himself and announced "look here, my arm is horizontal and my leg is vertical."

Many other responses were seen where the kinesthetic learners simply could not stand still, while an explanation or presentation of a problem was taking place, i.e., they would continuously dance or move in space, creating dance moves that could be characterized as highly energetic.

Voluntary movement. Voluntary movement refers to kinesthetic responses that were initiated by participants without the researcher specifically indicating that this was the mode through which an exploration or an answer was to be presented.

Confidence in moving extensively in space. Confidence in moving extensively in space refers to kinesthetic manifestations where the participants did not hesitate to move their bodies in space—they were not holding back when moving, but were using their body as a tool for exploring dance moves in new heights and transitions in space.

Kinesthetic Learners' Responses: the Early Stages of the Study

Introduction—The Teaching Emphasis

The first eight lessons of the study were structured to teach the most basic elements of two curricular areas: mathematics and dance. The emphasis in the teaching of mathematics was placed on making the connection between concepts, properties, and the mathematical language that describes the two. In addition, emphasis was placed on developing class norms where reasoning and problem-solving are an integral part of the mathematical experience. Interviews with the kinesthetic learners' teachers confirmed that social interaction among the children, providing out-loud reasoning for mathematical solutions, was not the norm in their regular mathematics classroom at school. Since in this study the kinesthetic-teaching approach was structured around the physical experience enhanced and developed through the communication and social interaction, it was essential to have all of the participants feel comfortable and safe speaking in class. To achieve this, the researcher explained the importance of communication and social interaction to the participants and facilitated activities that required participants' responses in these areas.

Dance was chosen as the art form through which the participants' kinesthetic sense was probed. Two concepts fundamental to the art of dance were emphasized as part of the kinesthetic-teaching strategy: Space and Force.[71] Exploration of Space was done through activities that required taking into consideration of one's own dancing (body movements "carving" through space) relative to other's dancing. For example, during the early stages of the study, it was observed that all three kinesthetic learners had low spatial awareness—they would dance in the room in a group and be oblivious to their surroundings, tackling objects and other children and be completely surprised when such events took place. In short, they were not able to simultaneously pay attention to both their own movements and the surrounding environment. By the end of the study, the

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[71]These concepts were chosen because of the researcher's belief that, for kinesthetic learners, the ability to understand abstract geometrical relationships is directly connected with the ability to understand one's movements in space. Exploration of the relationship between geometrical concepts and their representation in human motion was done through the exploration of Space and Force concepts.

participants had developed a strong sense of awareness of space: when dancing in a group they were sensitive to their own movements as they related to other's movements and objects.

Observations of the kinesthetic learners' responses to the learning environment in the early stages of the study focused on areas of kinesthetic awareness,[72] social interaction, verbal communication and spacial awareness. Analysis of the responses suggested that seven behavior response themes were common to all three kinesthetic learners:
a) physically destructive response; b) fixity; c) frustration; d) low verbal ability; e) writing skills; f) general involvement—negative; and g) difficulty processing auditory and written information.[73] The diagram on the following page provides a visual representation of the seven behavior response themes as observed at the early stages of the study. A discussion of each behavior response follows.

Theme One: Physically Destructive Response

Physically destructive response refers to behaviors characterized by the kinesthetic learners' hitting their bodies against the walls, objects such as tables and chairs, and into other students. These behaviors were directly related to situations in which participants did not understand instructions or the language used or misinterpreted a situation which caused them to react in a physically destructive way.

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[72]Participants' ability to use movement in space, i.e., dance, as a tool for exploring abstract concepts.

[73]This theme is fully explained in section Kinesthetic Learners' Apparent Responses: the Informal Sessions.

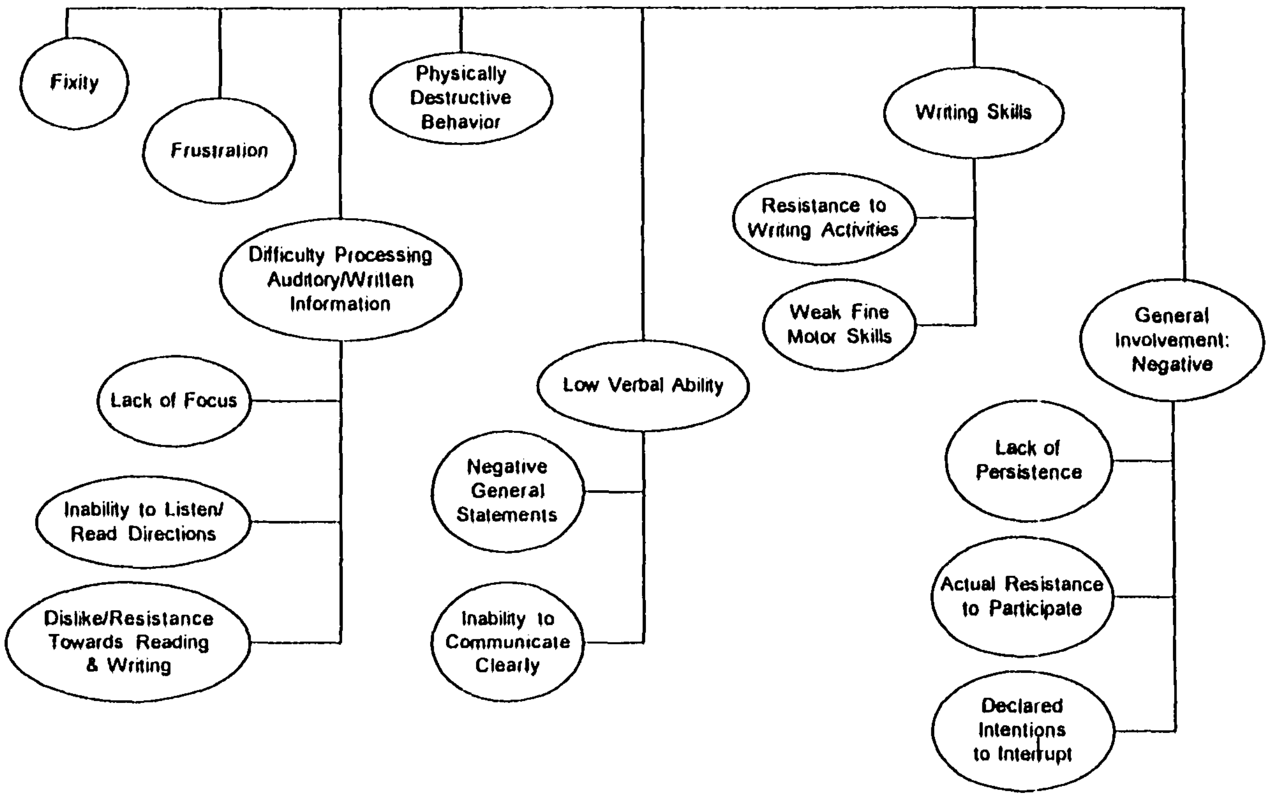

Figure #3
Kinesthetic Learners' Behavior Responses in the Learning Environment as Observed at the Early Stages of the Study

For example, in lesson #3 participant number two was unhappy with an instruction that was given, he said "I hate this" or "I do not want to do this" and pulled himself out of the group, sitting next to the wall hitting his head against the concrete. Later in that session, while participant number three was dancing, it was crowded. He swung his arm angrily at his class mates and began crying in frustration.

Theme Two: Fixity

Fixity refers to the kinesthetic learners having difficulty understanding that a mathematical situation can be explained and discussed from a variety of view points. Verbal responses such as the following statements were indexed as fixity: "but earlier you said something different." This shows that the child was not able to extrapolate and apply the concepts in different situations.

Theme Three: Frustration

Frustration refers to behaviors manifested both physically and verbally that communicate "I have no patience and I do not understand what you (the teacher) want from me." Dozens of verbal expressions were observed in the form of agonizing sounds such as "uuuuf's" and "ooooo's" and other statements indicating frustration. Physical manifestations included placing hands on hips, turning sharply away from the researcher, stomping legs angrily and standing in a position that communicated "me against the rest of the world."

Theme Four: Low Verbal Ability

Low verbal ability consists of two sub-categories: a) general negative statements;

and b) inability to communicate clearly.

General negative statements. General negative statements included statements such as: "I hate this" and "get off my back." The two observers confirmed that the negative statements were apparent whenever the kinesthetic learners were not happy with their own mathematics performance, and instead of saying "I am not satisfied with my own performance," they would yell out negative statements meant to blame the researcher for their dissatisfaction with their own performance.

Inability to communicate clearly. Inability to communicate clearly was demonstrated by the use of incoherent statements. For example, when asked to describe the position of a given horizontal line, they would say "this way and that way" without clearly indicating to what they were referring. This indefinite statement shows their inability, at the early stages of the study, to clearly and precisely describe their mathematical understandings.

Theme Five: Writing Skills

Writing skills refers to the kinesthetic learners' written responses. The researcher observed that the kinesthetic learners experienced physical difficulties writing, such as the inability to hold a pencil firmly or failed attempts to draw a line holding a pencil in one hand and a ruler in the other. Their writing, either in the form of geometrical expressions or letters, was unsteady and unclear.

Theme Six: General Involvement—Negative

This theme contains three sub-categories: a) declared intentions to interrupt; b) actual resistance to participation; and c) lack of persistence.

The declared intentions to interrupt. The declared intentions to interrupt refers to verbal statements indicating that the kinesthetic learners were thinking of interfering with the lesson. Statements indexed in this category included for example: "I will tell (so and so) not to do what you say."

Actual resistance to participation. Actual resistance to participation refers to responses that are characterized by pulling out of the group during group activities and, when working in pairs, demonstrating a lack of cooperativeness, i.e., not helping with finding solutions, not providing feedback and input.

Lack of persistence. Lack of persistence refers to responses that are characterized by constant and frequent interruptions in the learning sequence. For example, when the kinesthetic learners were asked to conduct an exploration in a kinesthetic mode on their own or with a partner, they would begin to work but after few seconds their thoughts would wander off and they would forget their assignment. This was supported by participant number two who stated during an interview that, unless the researcher would work with him through a mathematical problem, he would not continue once he did not understand something.

Kinesthetic Learners' Behavioral Responses: the Advanced Stages of the Study

Introduction—The Teaching Emphasis

Common themes were observed in the learning behaviors of the kinesthetic learners throughout the early stages of the study that confirmed the following assumptions relating to pedagogical elements that are fundamental to the kinesthetic experience: a) after movement, incorporating language in the form of verbal reasoning and discussions should be included as part of the instruction in order to make the kinesthetic experiences fully beneficial to kinesthetic learners; b) the ability to understand mathematics[74] is tightly connected with the opportunity to experience the connection between kinesthetic manifestations and formal mathematical language; and c) negative behavioral responses[75] are a result of the kinesthetic learners not being able to constructively use their energy in a manner that is connected to enhancing the understanding of abstract concepts.

Based on these common themes, and the related fundamental pedagogical elements defined throughout the early stages of the study, further kinesthetic activities were structured to build an understanding of the study's designated curriculum,[76] class norms and expectations as they pertain to the kinesthetic learning environment.[77] Observations of the kinesthetic learners throughout the advanced stages of the study showed a number of common behavioral responses—behavioral themes—that they all shared. The themes confirmed a number of assumptions about the learning process of the kinesthetic learners

[74]The ability to understand mathematics refers to the ability to reason, problem-solve and verbally communicate solution processes.

[75]Negative behavior responses refers to physically destructive responses, frustration, negative verbal statements and negative general participation.

[76]Fundamental curricular concepts in the area of mathematics were translation, transformation and rotation; in the area of dance curricular concepts included awareness of the aspects of Space and Force.

[77]Class norms refers to communication, reasoning and problem-solving as they are defined by the mathematics national standards (NCTM, 1989).

such as the importance of verbal communication and expression in making kinesthetic experiences meaningful and the importance of experiencing the connection between kinesthetic manifestations and formal mathematical language. The observations also support the belief that the kinesthetic learners' negative behavioral responses are caused by restrictions imposed on the learners' use of their own energy. Four behavioral themes were identified at this stage of the study. The diagram on the following page provides a visual representation of these behavioral themes and proceeds with a discussion.

Theme One: Listening—Behavioral Outcomes

One of the instructional goals was to improve the kinesthetic learners' listening skills which were identified as weak during the informal sessions and throughout the early stages of the study. It was observed that, as the study progressed, the kinesthetic learners began to pay better attention to oral instructions and during class discussions, and began to work more effectively in pairs. Improvements in the kinesthetic learners' communication skills were evident in instances where they were able to specifically state their thoughts and intentions, as well as respond in a manner that was closely correlated to the given instructions.

For example in lesson #18 the participants were asked to create a "body sculpture" (i.e., a static pose) consisting of two intersecting lines. They were asked to work with their partners, demonstrate their solutions kinesthetically, and explain in their own words what were the intersecting lines where they were located in the "sculpture." Participant number three said: "[intersecting lines] are lines that touch, here, see how my arms touch

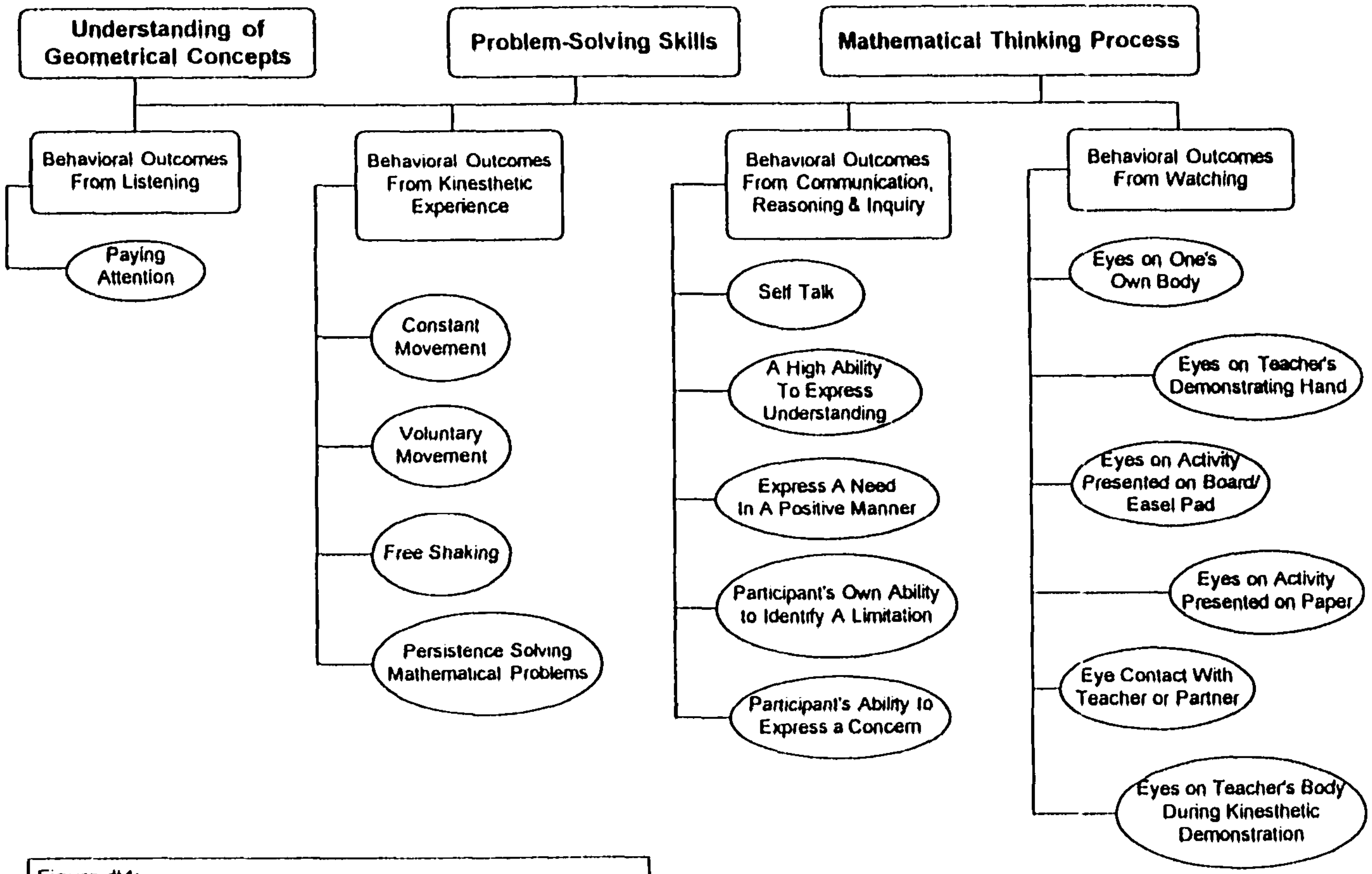

Figure #4:
Kinesthetic Learners' Behavior Responses
in the Learning Environment as Observed
Throughout the Advanced Stages of the Study

right here," and he looked at his elbow as he was demonstrating the pose to emphasize the elbow as the intersecting point between the two arm lines.

Another example is taken from lesson #17, where two of the kinesthetic learners were asked to create a triangle, identify where their body parts intersected, and sketch that shape on paper. The two children were recorded saying the following:

> Participant #2: get down here
> Participant #3: I want to do something on your shoulder
> Participant #2: do I go like this?
>
> (researcher's note): participant #2 got down on his knees
>
> Participant #2: let me show you
> Participant #3: no, no, I want you to stand up
>
> (researcher's note): participant #2 stood up and was helping participant #3 as he was trying different ways of lifting his leg over participant #3's shoulder.
> Once the boys were happy with their solutions, participant #3 declared: we are done, Galeet we are done.
>
> (researcher's note): The two boys received a piece of paper and began to draw the shape they created. This is their discussion:
>
> Participant #3: I am going to draw a little stick figure
> (Researcher's note): participant #3 began to draw the shape and participant #2 was looking closely at what his partner was doing.
>
> Participant #2: no, go here.
> (Researcher's note): participant #2 identified a place where the sketch was not accurate and he was indicating that the intersecting lines should be reconstructed. Participant #3 listened, looked again at his work, and said: yes, you are right. And he corrected his drawing.

This example demonstrates that the two kinesthetic learners were able, at the advanced stages of the study, to communicate effectively, work collaboratively with each other, and had no difficulty stating their intent and discussing their work.

Theme Two: Kinesthetic Experience—Behavioral Outcomes

Observations made of the kinesthetic learners throughout the informal sessions showed that they were inclined to move extensively in space.[78] In the advanced stages of the study, these students were observed to use kinesthetic activities to facilitate mathematical exploration, reasoning and communication. The kinesthetic activities that were observed fall into five sub-categories: constant movement, voluntary movement, free shaking, movement expressions, and persistence solving mathematics problems.

Constant movement. Constant movement refers to the kinesthetic learners' repeated behaviors indicating that they could not sit still, rather chose to continuously initiate dance moves. These behaviors were observed while the researcher was providing verbal assistance, explanation or asking a question, as well as while children were working on writing assignments.

For example, the kinesthetic learners would abandon the group activity or their writing assignment, begin dancing spontaneously in the room for a second or two, and then return to what they had been doing. The researcher's impression of such behaviors was that they would cause the kinesthetic learners to loose their concentration and attention, but the opposite was observed. The kinesthetic learners would come back to the activity with the correct answer or with renewed patience towards completing the

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[78]See discussion above regarding the informal sessions.

assignment they were working on previously.[79]

Voluntary movement. Voluntary movement refers to movements incorporated into the kinesthetic learners' explanation of mathematical concepts where the instructions did not require movement as part of the explanation. Numerous instances of voluntary movements were recorded while activities were introduced on the blackboard or the easel pad. For example, in lesson #20 participant number one was asked to look at a geometrical shape and two rotated options already drawn on the paper and choose which of the two options was rotated accurately. An analysis of the video recording showed that the participant was rotating her right palm as if turning a knob before she gave the answer.

Free shaking. Free shaking refers to the kinesthetic learners leaving an activity, moving to the center of the room and conducting some wild, fast movements that are similar to shaking or rattling. While both free shaking and voluntary movement behavioral responses were initiated by the kinesthetic learners, the difference is that free shaking seemed to be used as a release of excessive energy while the voluntary movements were used for the purpose of exploring concepts. After both activities, however, the kinesthetic learners were able to return to the work with renewed focus and attention.

Movement expressions. Movement expressions refer to kinesthetic responses provided when called for as part of the mathematical exploration process. Early in the

[79]Analysis of all constant movement behavior responses indicated that they took place mostly during the advanced stages of the study. This led the researcher to conclude that the kinesthetic learners' ability to use constant kinesthetic expressions (dance moves) in a constructive manner was due to the teaching that emphasized space awareness and the management of energy (the concept of Force).

study there were only a few rather simple movements observed, while in the advance stages of the study, there were more and more sophisticated movement expressions observed. This could be explained by an increase in comfort on the part of the kinesthetic learners as the study progressed—as they gained experience in using kinesthetic activities to explore and express their understanding, they increased the use of such behavior responses.

Persistence solving mathematical problems. Persistence solving mathematical problems refers to the kinesthetic learners committing more time to seeking a solution to a mathematical problem. Early in the study it was observed that, once encountering difficulty with a mathematical problem, the kinesthetic learners would quickly give up, removing themselves from the situation and showing substantial frustration. Later in the study, the kinesthetic learners were observed to devote more time using movement to investigate mathematical problems.

Theme Three: Verbal Communication, Reasoning and Inquiry—Behavioral Outcomes

During the early stages of the study, it was observed that the kinesthetic learners were experiencing difficulties communicating effectively.[80] With the continual emphasis through kinesthetic activities on acquiring informal and formal mathematical language, as well as regular English vocabulary, the kinesthetic learners gradually began to demonstrate a greater level of comfort and more refined verbal communication ability. Five sub-

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[80]See Kinesthetic Learners' Responses in the Learning Environment as Observed During the Early Stages of the Study.

categories of behaviors were observed: self-talk, ability to identify a limitation, the ability to express a need in a positive manner, the ability to express understanding and the ability to express a concern.

Self-talk. Self-talk refers to the kinesthetic learners talking to themselves as they worked on mathematical problems. Self-talk was not apparent during the early stages of the study but began to appear as the kinesthetic learners were given the freedom to pursue this mode as an additional channel through which to explore and examine their own thinking.

Self-talk was characterized by the kinesthetic learners asking themselves a question for the purpose of making sure that they were on the right track, such as "wait a minute, what did I do here?" Self-talk was also used for reexamination and evaluation of their own work such as "let's see now, this line is here, this is there, and this—I do not think I got right because it should be here, not there."

The behaviors identified here as self-talk and the explanation the research provides for this behavior corresponds with Vygotsky view of children's behaviors. Vygotsky explained that children mutter to themselves to guide their behavior and learning (Woolfolk, 1995, p. 47-48).

The ability to identify a limitation. The ability to identify a limitation refers to the kinesthetic learners being able to communicate clearly the obstacles to their understanding the activity. For example, participant number one said: "I cannot see what you mean by this." This statement demonstrates that the participant understood that something was preventing him from being able to successfully process the information, and he was able to state specifically the nature of the limitation.

The ability to express a need in a positive manner. The ability to express a need in a positive manner refers to the kinesthetic learners being able to communicate clearly what they need and to express it in a polite and non-aggressive way. Participant number three said, for example: "Could you say it again? I did not understand what you said."

The ability to express understanding. The ability to express understanding refers to the kinesthetic learners being able to verbally respond to a direct question. All responses in this category arose in situations where a discussion was taking place to assist the researcher in finding out what the kinesthetic learners understood, so that activities could be incorporated into the study which would require children to implement their mathematical understanding in new situations.

The ability to express a concern. The ability to express a concern refers to the kinesthetic learners' ability to verbally express their worries as related to solving mathematical problems. Examples of this include the following statements: "I cannot get this done because (participant so and so) is not helping out," or "I am not good at drawing a square."

Analysis of the behaviors described in these five categories suggests that during the course of the study the kinesthetic learners developed reflective thinking, i.e., the ability to engage in productive verbal communication, understand what was asked of them, identify what they needed to do to solve a mathematical problem, communicate their questions, and express their thought process as they worked towards a solution.

Theme Four: Watching—Behavioral Outcomes

As the study progressed, it was observed that the kinesthetic learners had difficulty keeping their eyes focused on their work and tended to stare off into space. The researcher decided to teach the importance of eye focus as factor in successful learning—concentration, attention, and mathematical reasoning. This was done by defining six areas of focus for the kinesthetic learners: a) eyes on one's own body; b) eyes on the teacher's demonstrating hand; c) eyes on the activity presented on black board or easel pad; d) eye contact with teacher or partner; e) eyes on the activity presented on paper; and f) eyes on the teacher's body during her kinesthetic demonstration. Determining where to look was a function of where an activity was taking place.

As the study progressed, the kinesthetic learners were observed to benefit from instruction that emphasized the eye focus aspect—they demonstrated enhanced ability to stay focused and think sequentially while solving mathematical problems.

Analysis of Findings

This study was conducted to answer the following question: what are kinesthetic learners' learning processes[81] as they use kinesthetic activities, in this case dance, to learn and demonstrate: a) an understanding of geometrical concepts; b) problem-solving skills; and c) mathematical-thinking processes. The context in which the responses took place

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[81]Learning process is the kinesthetic learners' behavioral responses they manifest while in the learning environment in the areas of kinesthetic expression, listening, watching and verbal communication.

was a new mathematics classroom environment characterized by a teaching strategy based on kinesthetic activities, a spacious room containing no tables or chairs, a blackboard, an easel pad and an arm chair. The study's findings relate to three areas that concern both learning of mathematics and learning in general: a) verbal communication; b) fine motor skills; c) viewing angle.

Verbal Communication

As the kinesthetic learners' experience with kinesthetic activities increased, they were more able to communicate their mathematical thought processes, i.e., use vocabulary in the context of formal and informal mathematical and everyday situations, explore mathematical concepts through peer and whole class discussions, explain and reason their solutions. In addition, it was found that the more the kinesthetic learners engaged in kinesthetic activities, the more they preferred to use the kinesthetic mode to examine and confirm their own mathematical understanding.

For example, in lesson #18 the participants were asked to explain what is an axis. Participant number three could not wait for his turn and provided the following answer: "a big line that curves around." Before he finished the sentence, he jumped off his chair, assumed a tower position with his right hand at a 90-degrees angle to his chest, and began turning himself around keeping the axis point stationary. As he demonstrated this, he kept the relationship between the speed of the movement, the direction of the rotation and his right arm's relationship to his chest constant. This is an example of a kinesthetic learner using informal mathematical language to express understanding, and taking initiative by demonstrating his understanding in a context that made sense to him—through kinesthetic expression, i.e., moving in space.

Another example of this was seen in lesson #20, where participant number one was asked to explain why she chose a particular way for mirroring a geometrical shape. She chose to use her pencil and draw two arrow lines that expressed the relationship between the original shape and the mirrored expression. As she drew the lines she indicated correctly the mirrored corners. This form of communication, i.e., in writing, was a breakthrough in the learning process of this participant as she was previously observed to face major difficulties with fine motor skills. Her choice to explain her thinking in writing and with some words assisted her to demonstrate clearly what she meant.

Fine Motor Skills

The kinesthetic activities incorporated in this study helped the kinesthetic learners improve their fine motor skills,[82] which in turn enhanced their confidence in exploring mathematics through written activities. By improving their physical writing skills, the kinesthetic learners were better able to explore mathematical problems in writing. It is the confidence gained through kinesthetic activities that enabled the kinesthetic learners to enhance their written problem-solving skills and demonstrate their mathematical-thinking

[82]Observations of the kinesthetic learners' attempts to solve mathematical problems presented on worksheets suggest that they were very resistant to writing, sometimes to the point where they would be reluctant to participate in the class altogether. When asked why they disliked writing, the kinesthetic learners indicated that writing hurts and they were not happy with their own writing. Based on this information, the researcher decided to designate some kinesthetic activities in each session to improve and refine fine motor skills.

process in writing.

Viewing Angle

The kinesthetic learners' ability to process mathematical information was dependant upon the angle from which they looked at an activity and the amount of space a child was given to move in as he or she explored the activity. Specifically, it was observed that the kinesthetic learners experienced major difficulties processing mathematical information when presented flat on a table or on the floor, i.e., when they were leaning over the activity. However, when the activity was presented on an easel pad or the black board, the kinesthetic learners were able to think critically, analyze the problem and conduct both problem-solving and mathematical reasoning that led them to communicate their mathematical understandings.

Discussion—The Kinesthetic Learning Process

The trends, regularities and common themes relating to the kinesthetic learners' behavioral responses as they attempted to make sense of mathematics can be applied in the construction of a new teaching approach based on kinesthetic activities. The development of such a teaching approach would contain four elements. The first of which is basic assumptions about the learning process of the kinesthetic learners as they attempt to make sense of mathematics. The second consists of the characteristics of the kinesthetic learners' behavioral responses once they gain experience expressing themselves kinesthetically. The third consists of the components of the kinesthetic-teaching strategy, i.e., use of language, activity presentation mode and the ways these are used to facilitate the kinesthetic learners' mathematical exploration, reasoning and problem-solving.

The fourth consists of the nature of the relationship between mathematical concepts, levels of mathematical processing called for by the kinesthetic activities, and the nature of the dance activities designed to facilitate the kinesthetic learners' exploration of mathematical concepts. The diagram on the following page provides a visual representation of the proceeding discussion.

Assumptions About the Learning Process

The data demonstrates that the kinesthetic learners who participated in this study were eager to understand, communicate and take an active role in the learning process, and that they were able to fully accomplish this once the kinesthetic-teaching approach was implemented systematically within the class structure. In retrospect, it appears that if some specific assumptions about the kinesthetic learners' learning process would have been accepted, the researcher would have been better equipped to: a) identify the kinesthetic learners' learning characteristics that stood in their way of making sense of mathematics; and b) be able to sooner design kinesthetic activities to strengthen weak areas of learning.

First, the kinesthetic learners' natural inclination to move extensively in space is powerful to the point where activities based on other learning styles, i.e., visual, auditory and tactile, are far less effective. The kinesthetic-teaching strategy provides a solution to the kinesthetic learners' struggles and frustrations as it allows the exploration of abstract

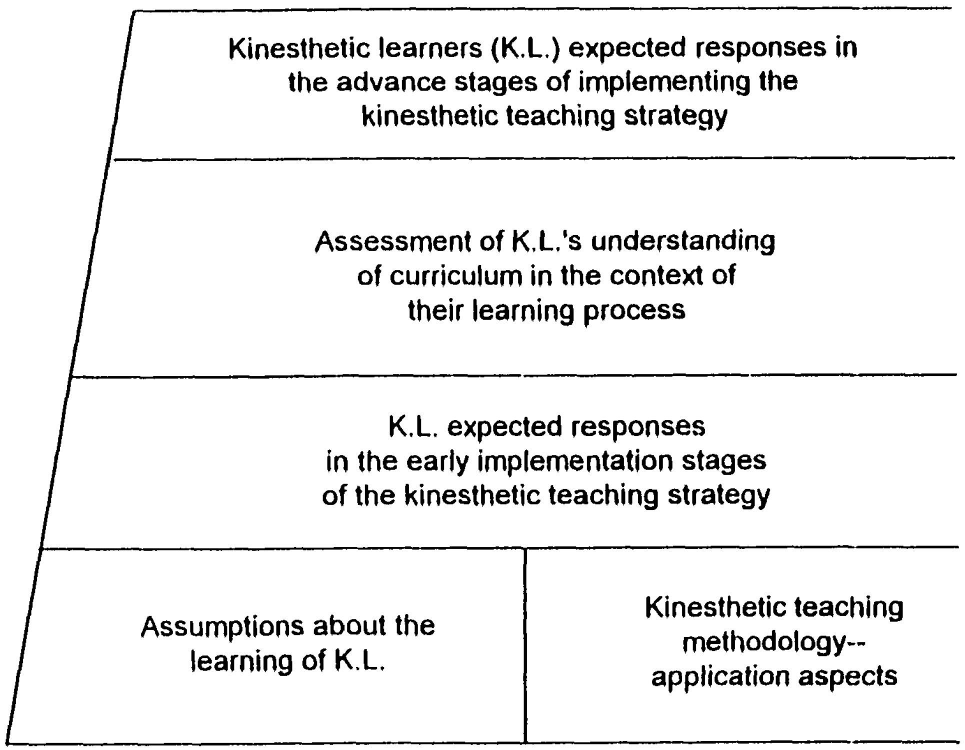

Figure #5:
The Kinesthetic Teaching Strategy:
Fundamental Knowledge
Teachers Must Know

mathematical concepts through kinesthetic activities and attempts to strengthen learning areas that are essential for students to demonstrate their mathematical understanding, i.e., problem-solving, verbal-written and social communication and reasoning.

Second, the kinesthetic learners can demonstrate positive and constructive behavioral responses when the teaching strategy empowers their efforts, desires and their attempts to explore and make sense of information.[83] This learning is promoted by the freedom to dance and move in space when they feel the need to do so.

Third, the kinesthetic learners bring to the learning environment feeling and reactions they have towards the conventional learning environment (mostly at school learning experiences)—rejection, frustration, low self-image and low motivation towards learning. The first few weeks of implementing a kinesthetic-teaching approach need to focus on teaching children the nature and class norms of the kinesthetic environment as they are very different from other educational settings with which children are familiar.

Fourth, the kinesthetic learners, like all children, are eager to succeed. Because they bring to the learning environment many negative feelings, it is important that the learning experiences gained through the kinesthetic experiences be empowering by practicing the following skills: kinesthetic awareness, critical thinking, reasoning, verbal and social communication and problem-solving.

[83]Compare information presented in sections on kinesthetic learners' behavior responses as observed during the early stages of the study and throughout the advanced stages of the study.

Fifth, the kinesthetic learners naturally have loud bodily "voices,"[84] i.e., energies, emotions and sensations, that constantly look for ways to be expressed through highly energetic behaviors, or what could be described as a physically excessive behavior. The teaching strategy must take into account that kinesthetic learners need to build upon their bodily "voices," and must provide a wide range of opportunities[85] to explore these "voices" and release or direct their energy.

Sixth, the kinesthetic learners might also experience difficulties with auditory processing, reading, writing, social and verbal communication. If these difficulties are observed, kinesthetic activities and teacher's emphasis needs to be on strengthening these areas simultaneously with content exploration.

Seventh, the kinesthetic learners constantly change the factors affecting their learning of mathematics—they will continuously change the way they look at an activity and the way they process information. This means that a teacher must have alternative forms for presenting and exploring activities to accommodate the kinesthetic learners' changing needs. The teacher must be both sensitive to the students' needs, be creative and have the confidence to find alternative methods for presenting concepts as new needs are identified.

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[84]See Appendix VI: A Vicious Cycle.

[85]The kinesthetic activities should include different rhythms (slow/fast), variety of spaces (restricted/wide, low/middle/high), variety of energies (sharp-staccato/smooth-legato).

Characteristic Behavioral Responses— After Training

After teaching mathematics to the kinesthetic learners in this setting, it is the researcher's conclusion that it takes children six to nine sessions to trust the teacher and feel comfortable in the kinesthetic learning environment. The learning characteristics of the kinesthetic learners, once they trust the teacher and feel comfortable, include enthusiasm towards exploring mathematical concepts in space through dance, constant need to reexamine their thought processes with the help of kinesthetic movements, and self-talk and verbal communication that is initiated for clarification, exploration, and affirmation of knowledge.

The Kinesthetic-Teaching Strategy

The pedagogical philosophy on which the kinesthetic activities were designed and incorporated in this study represents the view that meaningful teaching must simultaneously consider both the use and purpose of language as it is used by the teacher, and the presentation modes of activities.

The use of language refers to the purposeful choice of words to communicate certain messages, explanations, expectations and positive reenforcements. The choice of language was applied throughout this study and found to be effective in: a) teaching the social, behavioral and communication norms of the kinesthetic environment; b) promoting positive and effective ways of thinking mathematically, i.e., conducting reasoning, problem-solving and communication; and c) building students' confidence and motivation towards engaging enthusiastically in mathematical activities.

The presentation mode of an activity refers to the ways mathematical problems are introduced through auditory, visual and kinesthetic forms. The kinesthetic learners' behavioral responses throughout the study indicate that there were times that they could not process mathematical problems when presented in auditory form or when presented on paper placed on the floor or table. Alternative modes for presenting the mathematical problems were devised and included: visual representations on the black board, on an easel pad, and kinesthetically. The kinesthetic learners' mathematical performance, relative to the mode in which activities were presented, demonstrated that the alternative modes explained above made the mathematics language and concepts more accessible to the kinesthetic learners. The diagram on the following page provides a visual representation of this discussion.

How It All Weaves Together[86]

Prior to the study, a general mathematics and dance concept map was created to provide the researcher with a guide for the order in which concepts in each curricular area would be explored. Mathematical concepts would be introduced and taught in the following order: a point, a line, a line segment, horizontal, vertical, diagonal, parallel, a transformation and translation, an axis and a rotation.

The teaching of the mathematics concepts was designed to require students to process information on three levels: a) recognition of concepts presented in concrete

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[86]See Diagram #6: The Relationship Between Geometry Concepts Taught, Activities Difficulty Level, And Type of Dance Activities Incorporated.

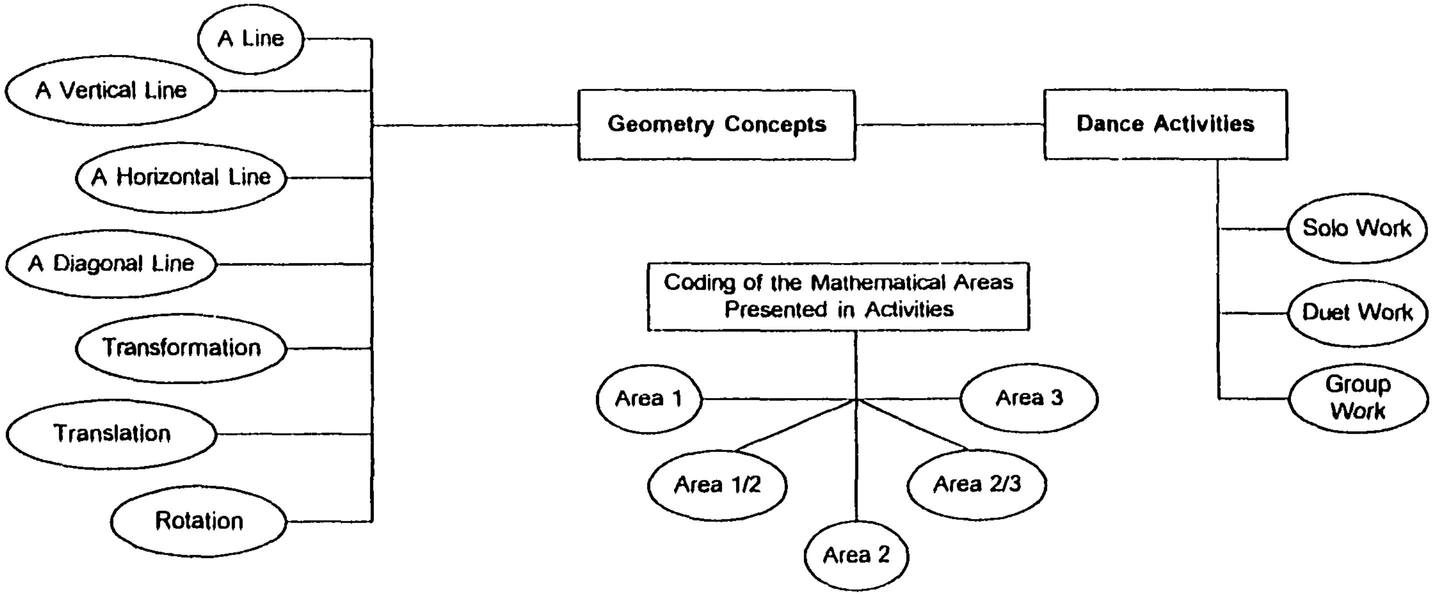

Figure #6:
The Relationship Between:
a) Geometry Concepts Taught;
b) Activities' Difficulty Level;* and,
c) Type of Dance Activities Incorporated in the Kinesthetic Teaching Strategy

*Activities were constructed to enable observation of students' responses to three different mathematical areas:

1) Recognition of concepts presented in concrete context through either verbal or kinesthetic responses.
2) Identification of concepts presented in concrete context through both verbal and kinesthetic response.
3) Regeneration of concepts presented in an abstract context through both verbal and kinesthetic response.

context through either verbal or kinesthetic responses;[87] b) identification of concepts presented in concrete context through both verbal and kinesthetic responses; and c) regeneration of concepts presented in an abstract context through both verbal and kinesthetic responses.[88]

While the first-level activities allowed the kinesthetic learners the freedom to choose the mode through which to explore mathematical understanding, the second-level activities required the use of kinesthetic expression to explore mathematical understanding. The third-level activities were designed for the kinesthetic learners' to practice their ability to process mathematical problems independently from their presentation modes.[89]

The teaching of kinesthetic activities, i.e., dance, was structured around three types of situations: a) solo work; b) partner work; and c) group work. All three types of dance activities were incorporated into each lesson to enhance the learning experience of the kinesthetic learners by enabling mathematical concepts to be explored in different contexts.

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[87]In this category introducing mathematics concepts was done solely based on kinesthetic and sometimes tactile demonstrations.

[88]In this category mathematical problems were introduced through the auditory mode.

[89]The logic supporting this structure is that eventually the kinesthetic learners will need to be able to communicate effectively in the regular mathematics classroom, i.e., demonstrate proficiency in formal written and verbal mathematical communication. The kinesthetic activities' design was to build on their natural high kinesthetic ability, and gradually require that strengths in kinesthetic areas would be transferred to particular behavioral areas of mathematics: communication, fine motor skills, and problem-solving.

Each mathematical concept was explored as outlined in the concept map through kinesthetic activities. Depending on the kinesthetic learners' responses, different concepts and activities were emphasized to produce the necessary level of processing to allow the kinesthetic learners to move to the next concept. The diagram below provides a visual representation of this discussion.

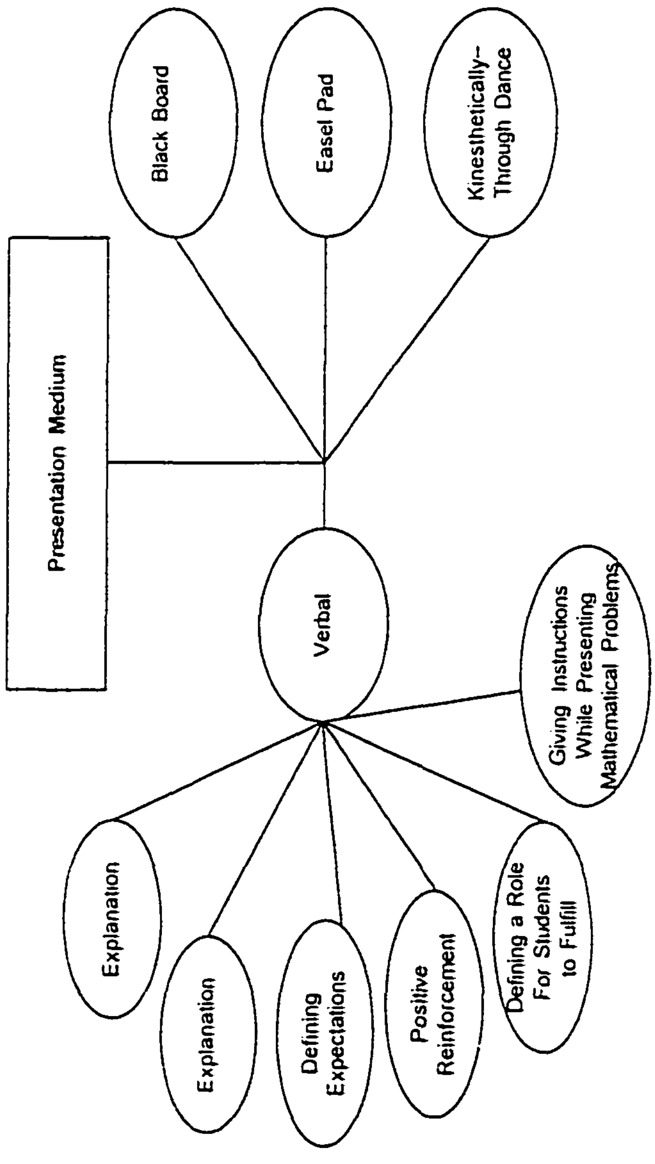

Figure #7:
Modes of Presenting Activities

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Introduction

The purpose of this study was to understand the learning process of kinesthetic learners as they attempted to make sense of abstract concepts in geometry. The study's question: was what are the learning processes of kinesthetic learners as they use kinesthetic activities, in this case dance, to learn and demonstrate: a) an understanding of geometrical concepts; b) problem-solving skills; and c) mathematical-thinking processes.

The overall findings of this study is that kinesthetic activities, in this case dance, facilitate the kinesthetic learners' exploration of abstract geometrical concepts, enhance their problem-solving skills, and enable them to develop a mathematical-thinking process that can be verbally communicated.

These findings are new, unique and add to the literature that, until now, did not offer any specific information about the learning process of kinesthetic learners. The findings of this study will help teachers understand better the normal responses of kinesthetic learners as they struggle in the "traditional" mathematics classroom. It is the hope of the researcher that those who read these findings will understand that the often negative and destructive behaviors demonstrated by kinesthetic learners are a result of a teaching strategy that is not tailored to how they best learn. Further, by implementing the kinesthetic-teaching approach, the teacher will find that kinesthetic learners not only have the ability to demonstrate high mathematical understanding, reasoning, problem-solving and mathematical communication, but that they are eager to prove that they can "make it."

One concern that needs to be addressed is the inherent structure and traditions in which elementary schools operate, and the degree to which these structures allow for implementation of non-traditional teaching strategies. The number of children per classroom, the classroom set up (including the number of tables, chairs, and other teaching materials) and pressures on teachers to teach in conventional ways might interfere with this teaching strategy. Principals and teachers operate schools and classrooms by what they know, feel comfortable with, and know the school system will support or provide. A successful implementation of the kinesthetic-teaching strategy, as it is defined in this study, will require teachers and principals to critically look at where and how inherent structures and traditions can be adapted and possibly changed to better serve kinesthetic learners. Teachers are the key to instituting changes as they are the ones that directly influence students' learning.

Recommendations

Based on the findings of this study, several recommendations are made. The first recommendation is that this study be replicated with kinesthetic learners from a variety of cultural, economic and geographic backgrounds to determine whether kinesthetic learners share learning characteristics regardless of their background.

The second recommendation is that the kinesthetic-teaching strategy should be applied to other areas of mathematics. This is necessary to determine whether teaching through kinesthetic activities is effective to more than just the curricular areas covered in this study.

The third recommendation is that further research be done on additional types of kinesthetic activities that are most effective at helping kinesthetic learners demonstrate increased mathematical understanding.

The fourth recommendation is that teacher education institutions, as well as officers of instructional support services, consider integrating the kinesthetic-teaching strategy into their programming. This will better equip future and current mathematics teachers with the tools for teaching kinesthetic learners.

The findings and recommendations of this study call for future studies to investigate several aspects concerning kinesthetic learners. The first aspect to be examined is the number of students who are kinesthetic learners. It is important to find out how many students are kinesthetic learners, and how their learning style impacts their learning of mathematics and other subjects. Such findings have implications for teacher education programs.

The second aspect to be examined relates to understanding if there is a relationship between students who are diagnosed with learning disabilities and those who are primarily kinesthetic learners. While this study did not focus on students with learning disabilities, the researcher's observations warrant further investigation in this area.

The third aspect to be examined is the implementation of kinesthetic-teaching strategy, as it is defined here, in other areas of the mathematics curriculum. Examples of additional curricular areas include number sense and numeration; whole-number operation sense; whole-number computation; measurement; fractions and decimals; and patterns and relationships. The purpose of such studies would be to specifically define the kinesthetic activities (their type, order and teaching emphasis) that teachers could incorporate in their daily teaching which would produce improvements in kinesthetic learners' mathematics achievement.

The fourth aspect to be examined are teachers' views of the kinesthetic-teaching strategy. Specific areas to be looked at in this category include: teachers' perceptions of using dance and movement in mathematics classrooms, teachers' willingness to implement the strategy in current educational structures, and the ways in which educational structures would need to change and put into practice new perspectives of teaching, learning and assessment.

Commentary

In this study, the kinesthetic learners were reported by their teachers and parents as having little or no attention span, weak fine-motor skills, being hyper, and in some cases diagnosed as having Attention Deficit Disorder or suspected for autism.[90] During their participation in this study, all three kinesthetic learners were able not only to demonstrate

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[90]Parents came forward with this information at the last meeting, after the study was conducted. They explained their decision to provide this information at the end of the study by stating that they did not want this information to influence the researchers' attitude towards the children, but felt obligated to share the "entire truth" about their children.

good mathematical-thinking processes, but also reasoning and problem-solving. This suggests that they were able to overcome their suspected or diagnosed ADD or Autism, fine-motor skills weaknesses and hyper activity and restlessness. Following are several examples that support this statement.

The mother of participant number two reported very close to the beginning of the study that her child (who was suspected of having autism) stopped demonstrating autistic-type behaviors since he began participating in this study. Instead of hitting, kicking and throwing himself on the floor, he would begin dancing and demonstrate all that he learned during the study's lessons to his family members. He would initiate his dances suddenly, spontaneously, and continuously. The mother reported that she would encourage him to continue because she felt these initiatives were enhancing his self-esteem, sense of self, motivation and desire to be involved, and emotional strength, i.e., he began feeling special, having something unique that no one else had and that made him stand out in a positive way.

Participant number two was recorded once commenting while participant number three was dancing: "feel the music, just use your feelings . . . ." This statement is striking and extremely important for understanding the kinesthetic learners' ways of learning—by engaging feelings that are generated as a response to an activity. This statement demonstrates that, by the end of the study, the participant learned to "listen" to his feelings and communicate them to others, in addition to using them as a guide for enhancing the exploration process.

The mother of participant number one reported at the end of the study that her child was demonstrating a greater confidence in expressing her thoughts in writing, a form of communication that she avoided altogether prior to the beginning of the study.

Participant number three was administered the Key Math test[91] and scored in the eighth percentile on all mathematics areas except on the spatial ability section were he scored on the 91st percentile. This is a remarkable achievement as this participant was administered the Key Math once before (two years prior to the study) and scored on the same section at the eighth percentile.

These are only a few of many examples that were recorded throughout the study documenting the kinesthetic learners' responses to the kinesthetic learning environment. What kinesthetic learners need, according to the findings of this study, is to be taught mainly by the kinesthetic-teaching approach, i.e., an approach that builds on their naturally occurring levels of emotions, sensations and energies to produce mathematical understandings. By engaging in dance activities that are tailored to develop mathematical understanding, these students can learn to calm down, focus, think sequentially and develop knowledge that they otherwise could not develop.

An Analogy

The ways that kinesthetic learners learn, as observed in this study, can be described as similar to heated up molecules locked in a closed box. The more teachers require

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[91]The mother of participant number three initiated the administration of this test privately, and the results were shared with the researcher.

kinesthetic learners to sit still, the more the heat in the box increases which results in an inevitable explosion—behavioral characteristics that include kinesthetic learners acting violently, moving restlessly in their chairs, being agitated, impatient, inconsiderate, angry, frustrated and unmotivated.

A learning experience structured around kinesthetic activities, specifically dance activities, opens the box and allows the molecules to take the space they need, which prevents the explosion. The researcher and observers documented hundreds of cases where allowing the kinesthetic learners the freedom to dance in an open space and conduct all types of extraneous, highly creative and energetic dance moves resulted in a release of the enormous pressure that naturally builds up in these children. After such activities, the kinesthetic learners were able to think mathematically, concentrate and focus, listen and infer from information provided to them in writing or verbally. The dancing activities facilitated the positive responses that children should demonstrate as part of an effective and meaningful learning process, i.e., they were able to listen and follow directions, communicate clearly both verbally and in writing, and develop self-confidence in their own ability to do mathematics and motivation for learning.

Concluding Remarks

The conclusions of this research is that kinesthetic learners can be successful in mathematics, and by inference in other curricular areas, if the teaching style used fits the way they learn. Currently, the teaching style that is used with kinesthetic learners asks them to do what they cannot—sit still and learn by looking down at a paper. This is attempting to force a square peg into a round hole.

First, school systems need to acknowledge that because children learn in different ways, different teaching methodologies must be incorporated for the different ways of learning. Second, teachers must be provided with the proper tools—training in the uses of kinesthetic-teaching strategy, class size and structure to allow its application.

Through smaller classes with sufficient space and the application of dance as a teaching tool, students previously labeled as underachievers, disabled or otherwise unable to keep up with their class mates will be given the opportunity to fully benefit from attending school.

APPENDIX I

LESSON PLANS STRUCTURE

The Logic Guiding the Structure and Content of the Lessons

The NCTM explains that geometry and spatial sense are "in part, an additional feel for one's surroundings and the objects in them" (NCTM, 1993, p. 1). The NCTM continues to explain that spatial sense is referred to as spatial perception that is characterized by seven spatial abilities[92] enabling a student to imagine spatial displacement (movement) by mentally rotating, folding, or some other manipulation of visual or virtual representations of objects (NCTM, 1993, p. 1).

This study's curriculum was structured to provide fourth-grade students with the foundation concepts of geometrical understanding: Slides, Flips, and Turns. Slides: the ability to find the figure that would be obtained if it was possible to give the original figure a straight shove in a certain direction and through a certain distance. Flips: the ability to create, for each point of the original figure, a matching point in the mirrored image. Turn: the ability to turn a figure around a given point (Heddens, & Speer, 1997).

The teaching strategy and methodology used in this study represented the belief that abstract mathematical understanding can be created by conducting dance activities that were simultaneously analyzed and investigated by critical cognitive thought

[92]The seven ability characteristics are set forth in chapter three, section 9 titled "The Geometry Curriculum Taught in This Study."

processes.[93]

The critical thought process that accompanies the movement was associated with a physical sensation that, in turn, constitutes understanding of the abstract concept explored.

The dance activities that facilitated cognitive thought processes were characterized by: a) use of one's own body as an object to be manipulated in space; and b) providing students with situations containing a problem, while encouraging students to explore a variety of solutions. The situations presented defined a clear set of boundaries (which is thought of as a picture frame) to which alternative solutions were constructed (which is thought of as the picture's content: shape, texture and shades). Students constructed their solutions by trying out different ways of moving in space, explaining to themselves (in writing or aloud) and to others how their solutions relate to the problem and concept presented. In this process students performed and discussed solutions with their peers.[94]

The geometry curriculum taught in this study was composed of the following concepts: a point, a line, a line segment, an angle, a horizontal, a vertical, a parallel, an angle, a right angle, a slide (translation), a flip (transformation) and a turn (rotation).[95]

The following section contains the overall lesson plan design and two examples featuring two complete lessons that were taught in this study based on the curriculum

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[93]Critical cognitive thought processes that accompany physical activity refered to the expectation that students create movements as solutions to defined geometrical situations by verbally stating the movements' direction, height and relationship in space.

[94]The discussion among students was part of the student-student and student-teacher social interaction that includes question and answers, statements and inquiries.

[95]See definition of terms section for more on the geometry concepts.

concept map presented earlier.

The first four lessons were designed to allow the researcher to achieve two goals:(a) introduce students to the dance elements of time, space and force; and b) introduce the three geometry concepts, a point, a line and a line segment. This was done so that students would have the opportunity to understand the fundamental concepts in geometry as they simultaneously explore a variety of dance activities.

The researcher attempted to revisit the three geometrical concepts throughout the entire study as a means of understanding the ways in which kinesthetic learners use different types and levels of dance activities to develop and demonstrate their understanding of abstract geometrical concepts.

Section I: Lesson #1
Geometry Concept: line. Vocabulary: horizontal, vertical, diagonal. Dance Concept: Body

Lesson #2
Geometry Concept: line. Vocabulary: horizontal, vertical, diagonal. Dance Concept: Space

Lesson # 3 (A Dot's Journey)
Geometry Concept: line. Vocabulary: a dot, a line, a line segment, intersecting lines. Dance Concepts: body, space.

Lesson # 4
Geometry Concept: line. Vocabulary: intersecting lines, parallel, perpendicular. Dance Concepts: body, space.

Section II: Lesson # 5
Geometry Concept: line. Vocabulary: parallel, perpendicular in square, rectangle, diamond, trapizius. Dance concepts: body, space.

Lesson #6
Geometry Concept: line of symmetry. Vocabulary: line of symmetry. Dance Concepts: body, shape.

Lesson # 7
Geometry Concept: line of symmetry Vocabulary: line of symmetry (square, diamond, rectangle, circle. Dance Concepts: body, space.

Lesson # 8
Geometry Concept: line of symmetry Vocabulary: line of symmetry (square, diamond, rectangle, circle. Dance Concepts: body, space.

Section III: Lesson # 9
Geometry Concept: transformation. Vocabulary: transformation (flip). Dance Concepts: body, space.

Lesson # 10
Geometry Concept: transformation
Vocabulary: transformation (flip).
Dance Concepts: body, space.

Lesson # 11
Geometry Concept: transformation. Vocabulary: transformation (flip). Dance Concepts: body, space.

Lesson # 12
Geometry Concept: transformation.
Vocabulary: transformation (flip). Dance Concepts: body, space.

Section IV: Lesson # 13
Geometry Concept: rotation. Vocabulary: axis, rotation. Dance Concepts: body, space

Lesson # 14
Geometry Concept: rotation. Vocabulary: axis line. Dance Concepts: body, space

Lesson # 15
Geometry Concept: rotation. Vocabulary: axis
Dance Concepts: body, space.

Lesson # 16
Geometry Concept: rotation. Vocabulary: axis
Dance Concepts: body, space.

Section V: Lesson #17
Geometry Concepts: transformation + rotation. Vocabulary: translation (slide)
Dance Concepts: body, space (floor pattern)

Lesson # 18
Geometry Concepts: transformation + rotation. Vocabulary: translation (slide)
Dance Concepts: body, space (floor pattern)

Lesson # 19
Geometry Concepts: translation + rotation
Vocabulary: translation (slide). Dance Concept: space (shape).

Lesson # 20
Geometry Concepts: translation + rotation + transformation.
Vocabulary: translation (slide).
Dance Concept: space (body facing, level).

Section VI: Lesson # 21
Geometry Concepts: translation, transformation, rotation.
Vocabulary: culminates all that was explored so far. Dance Concept: body, space.

Lesson # 22
Geometry Concepts: translation, transformation, rotation.
Vocabulary: culminates all that was explored so far. Dance Concepts: body, space.

Lesson # 23
Geometry Concepts: translation, transformation, rotation.
Vocabulary: culminates all that was explored so far. Dance Concepts: body, space.

Lesson #24
Geometry Concepts: translation, transformation, rotation.
Vocabulary: culminates all that was explored so far. Dance Concepts: body, space.

Lesson Plan (Example 1)

Geometry Concept: intersecting lines
Vocabulary: a line—horizontal, vertical, and intersecting
Dance Concepts: Direction and Time

Objective: Introduce the concepts of diagonal and intersecting lines, while reinforcing the previous material of horizontal and vertical lines through the dance elements of Body, Direction and Time.

Goal: Students will be able to describe, identify, draw, demonstrate and create intersecting lines.

Exploration 1: A discussion is facilitated on the nature of intersecting lines. Find a line that is not horizontal or vertical in the room. Describe it and explain its characteristics. Find intersecting lines in the room. Describe them and explain their characteristics.

Exploration 2: Move your body in space to create intersecting lines with your arms. As you create those lines, call out the body part that performs each line. Repeat by including your torso and arms, torso and legs, arms and legs.

Problem Solving 1: Create with your body geometrical structures that include intersecting lines. Draw them on paper. Include different body parts such as forearm, shin, upper arm, thigh, torso and head. Draw your shapes on paper with a ruler.

Problem Solving 2: Everyone gives their drawings to someone else. All try to create body shapes to represent the geometrical shapes that are drawn on the paper.

Problem Solving 3: In couples: the person who created the shapes and the person who learned the shapes from the drawings perform their geometrical structure dances for each other.

A discussion is facilitated on the ways in which geometrical structures are identified, and the possible variety of interpretations.

Problem Solving 4: All children dance together to the music, and when it freezes they create shapes that include diagonal and intersecting lines.

Cumulative Problem Solving: All children move in slow motion shifting from one shape containing intersecting lines to another.

Lesson Plan (Example 2)

Geometry Concept: slide (translation)
Vocabulary: slide (translation)
Dance Concepts: Direction and Time

Objective: Introduce the concepts of slide while reinforcing the previous material taught (horizontal, vertical, intersecting lines) through the dance elements of Body, and Direction and Time.

Goal: Students will be able to describe, identify, draw, demonstrate and create slides of geometrical shapes.

Exploration 1: A discussion is facilitated on the nature of slide. Create a body shape and slide it in space. Describe how you went about creating a slide.

Exploration 2: The teacher shows different dance movements, which she slides in space. The students see and do these movements simultaneously to her demonstration.

Problem Solving 1: Create four geometrical structures. Draw them on paper with a ruler. You can include horizontal, vertical, or intersecting lines. Learn to perform them as well as be prepared to teach them to a friend.

Problem Solving 2: In couples: move in slow motion to perform your four geometrical structures very slowly. Your partner attempts to learn your sequence and together you are to work on sliding the body shapes in space.

A discussion is facilitated on the ways in which geometrical structures are to be identified, repeated and slide in space. Issues of how to make communication clear and precise are brought up.

Problem Solving 3: All couples perform their slide dances.

Problem Solving 4: The entire group dances freely in space. When the music stops, they freeze in a geometrical shape and then in slow motion move their shape to a new place in space.

Cumulative Problem Solving: Each student in turn creates a shape. All children repeat that shape and slowly slide their shape to a new place in space.

APPENDIX II

QUESTIONNAIRE FOR STUDENTS

Questionnaire for Students

Designed by

Galeet BenZion Westreich

The Universe of the Questionnaire

The universe of the questionnaire includes four areas of information that are presented in four sections: section 1, questions 1-8, seeks to reveal students' perception of what is taught in mathematics and in dance classes; section 2, questions 9-18, seeks to reveal students' perception of the teaching of mathematics and the teaching of dance; section 3, questions 19-21, seeks to reveal the type of feelings students develop towards mathematics and dance classes; and section 4, questions 22-29, seeks to reveal students' awareness of their learning processes.

There are several quality control questions that are designed to establish internal validity:

Question Number	Corresponds with Question Number
1	2, 3
2	9
3	11, 13
9	10, 12
4	11, 13
5	6, 7
6	14
7	14, 18
8	15, 16, 17
15	16, 17, 18
19	20, 21

Section 4 is designed to gather information relating to the students' learning processes. The questions presented in this section identify students': a) ability to state their learning process; and b) identify their preferred ways of learning. Conceptually, the questions were created as pairs (23 & 27, 24 & 28, and 25 & 29) but were placed in the questionnaire under the subject titles—mathematics or dance, to continue the logical flow of the questionnaire's structure.

The questionnaire was administered twice, at the beginning and end of the study. The questions included at the beginning of the study emphasized the students' mathematics and dance experiences prior to the study, while the questions included at the end of the study emphasized the students' mathematics and dance experiences gained throughout this study.

SECTION 1: A. About Mathematics you learn at school

1. What is math?
2. What do you learn in a mathematics class?
3. What kind of information do math teachers want you to know?
4. What kind of things (operations) do math teachers want you to be able to do?

B. About Dance

- If you have participated in a dance class before, answer questions: 5, 6, 7, and 8.
- If you have never participated in a dance class before, answer questions: 5, 6a, 7a, and 8a.

5. What is dance?
6. What do you learn in a dance class?
   6a. What would you have learned in a dance class if you had participated in one?
7. What kind of information do dance teachers want you to know?
   7a. What kind of information would the dance teacher have wanted you to know?
8. What kind of moves (things) do dance teachers want you to be able to do?

8a. What kind of moves (or things) would the dance teachers have wanted you to be able to do?

SECTION 2: A. About Mathematics

9. How do math teachers teach math? (What do they do in the class?)
10. What kind of activities do math teachers let you do?
11. What do these activities teach you?
12. What kind of materials do math teachers use when they teach math?
13. What do these materials teach you?

B. About Dance

- If you have participated in a dance class before, answer questions: 14, 15, 16, 17, 18
- If you have never participated in a dance class before, answer questions 14a, 15a, 16a, 17a, 18a to the best of your ability:

14. How do dance teachers teach dance? (What do they do in the class?)

14a. How would dance teachers teach dance had you participated in a dance class? (What would they be doing in class?)

15. What kind of activities do dance teachers let you do?

15a. What kind of activities would dance teacher have let you do, had you participated in a dance class?

16. What do these activities teach you?

16a. What would you have learned from doing these activities?

17. What kind of materials do dance teachers use when they teach dance?

17a. What kind of materials would dance teachers use, had you had the chance to see them teach?

18. What do these materials teach you?

18a. What would you have learned from using these materials?

SECTION 3: A. About Mathematics: circle all the words that best describes how you feel

15. The math teacher makes me feel:
Smart, Bright, Clever, Important, Brainless, Dull, Silly, Slow, Thick, Strong, Weak, Talented, Creative.
Other:

16. Studying math makes me feel
Smart, Bright, Clever, Important, Brainless, Dull, Silly, Slow, Thick, Strong, Weak, Talented, Creative.
Other:

17. Solving math problems makes me feel
Smart, Bright, Clever, Important, Brainless, Dull, Silly, Slow, Thick, Strong, Weak, Talented, Creative.
Other:

18. I am _________ for math classes.
a) Always looking forward to, b) Sometimes looking forward to, c) Never looking forward to.

B. About Dance

19. The dance teacher makes me feel, Or, would have made me feel:
Smart, Bright, Clever, Important, Brainless, Dull, Silly, Slow, Thick, Strong, Weak, Talented, Creative.
Other:

20. Studying dance makes me feel, Or, would have made me feel:
Smart, Bright, Clever, Important, Brainless, Dull, Silly, Slow, Thick, Strong, Weak, Talented, Creative.
Other:

21. Creating all types of dances makes me feel, Or would have made me feel:
Smart, Bright, Clever, Important, Brainless, Dull, Silly, Slow, Thick, Strong, Weak, Talented, Creative.
Other:

SECTION 4: A. About Mathematics

Think of an activity or exercise in math that you did not understand or could not solve during a math class, and answer the following questions:

22. Describe why the activity was hard and what didn't you understand?
23. Did you ask anyone for help?
24. How could that person have helped you?
25. What could you have done to help yourself?

B. About Dance

Think of an activity or exercise in dance that you did not understand or could not do during a dance class, and answer the following questions:

26. Describe why the activity was hard and what didn't you understand?

27. Did you ask anyone for help?
28. How could that person have helped you?
29. What could you have done to help yourself?

APPENDIX III

GROUP INTERVIEW FORMAT

The three kinesthetic learners will sit in a circle with the researcher while the observers will videotape the session from a short distance. The purpose of the group interview is to analyze situations that occur during each session. The researcher's strategy in conducting the interview is to pose questions for all three participants to answer, and to develop a discussion. The group interview format is presented below, and will be adjusted as needed.

1. What activities did you like? Why?
2. What activities didn't you like? Why?
3. What would you suggest to improve this activity?
4. What activities did you feel that you understood well?
5. What activities were not clear?
6. What activities did you like to think about?
7. What activities did you like to explore through movement?
8. What did you find to be difficult or hard?
9. What did you think about when you did (showing a movement)?
10. Please write down for me what you learned in class today?

APPENDIX IV

TEACHERS INTERVIEW FORMAT

1. Please describe the mathematical concepts you are teaching Student A at the moment, as well as what concepts you plan to teach by the end of the December.
2. How would you describe student A's readiness to learn those concepts?
3. From your assessment of student A, what concepts does student A still need to learn in order to be ready for the concepts being taught now?
4. How would you describe the pace in which student A progresses in his/her math work?
5. What type of activities do you incorporate into your mathematics teaching?
6. What activities best facilitate student A's understanding of the concepts explored in your math class?
7. What activities are less effective to facilitate student A's understanding of mathematics concepts?
8. On average, where would you place student A on the achievement continuum?
9. Does student A have specific learning needs?

APPENDIX V

DANCE ELEMENTS

Dance has three elements: time, space and force/energy. Each of the elements includes several aspects. The following section elaborates on each of the elements.[96]

The element of Space includes the following components: direction, floor pattern, body facing, focus, range, level and line.

Direction: the line of motion that the body follows, i.e., forward, sidewards, backwards.

Floor pattern: is the design made by one or more dancers as they move through space. Floor patterns may be either straight or curvilnear. Combinations of these could include zig zag, triangles, rectangles and squares. Curved floor patterns could include variations of a circle or semi-circle.

Body Facing: The dancer's body facing and line of direction may be the same thing, or may be somewhat different. Thus a dancer may be moving in a sidewards direction but be facing forwards. He may then continue moving sideways but change his facing to the back of the stage area.

Focus: Focus may be suggested by the use of the eyes, by other body parts, by general body emphasis or body tension. It frequently gives added impact to the direction

[96]These definitions are used by many dance educators. Dr. Naima Prevots has utilized these in teaching over forty years, and shares them with her students.

of the movement.

Range: Pertains to the amount of space we fill when we move. The two extremes are movement in large and small areas of range. Range is the distance covered by a body part or by the whole body while moving.

Level: Direction is the path taken through space, usually with a shift of the center of gravity. Level is the lowering or raising of the center of gravity.

The element of Time includes the following components: tempo, accent, underlying beat, measure, meter, duration and rhythm.

Tempo: the rate of speed of movement: fast, slow etc.

Accent: accent is emphasis. There are different kinds of accent: a) Metrical Accent: the accent indicating the first bear in every measure; b) Rhythmical Accent: an accent occurring on a beat other than the first beat of a measure and caused by the relationship and duration of the various beats; and c) Accent of Execution: accent occurring at the point of greatest physical effort in movement pattern.

Underlying Beat: the pulse, or steady beat that is continuous throughout the underlying beat can be quick or slow.

Measure: the grouping of intervals (underlying beats) into larger units called measures. We could say that a measure is a sentence of beats (or sounds) instead of a sentence of words.

Meter: a certain number of beats in a measure, played with a certain tempo, creates a definite meter. In music there are whole notes, half notes, quarter notes, eighth notes, sixteenth notes and thirty-second notes. A measure which has three notes each one lasting the time of a quarter note can be said to have a meter of 3/4. A measure which has six notes each lasting the time of an eight note can be said to have a meter of 6/8. A measure which has six notes each lasting the time of a quarter note can be said to have a meter of 5/4.

Duration: the length of time of a sound. We can have sounds of even and uneven duration and sounds of longer and shorter duration.

Rhythm: Rhythm is the element of music or dance which concerns itself with the duration of sound and the stress or accent placed on different sounds. A rhythm pattern is a definite series of sounds or beats related to an underlying beat.

APPENDIX VI

A VICIOUS CYCLE

During the early stages of the study, the kinesthetic learners demonstrated rather alarming behaviors that included physically destructive responses, frustration, negative verbal statements and negative general participation. It has been assumed that kinesthetic learners naturally have high levels of bodily "voices", i.e., energies, emotions and sensations, that constantly look for ways to be expressed through a highly energetic behavior, or what could be described as physically excessive behavior. Consequently, kinesthetic learners face an objective problem: on one hand, current educational settings restrict high energy behavioral responses, while on the other hand they do not know how to express their "voices" in a physically constructive and meaningful way. This circumstance, together with kinesthetic learners' struggles in the areas of auditory processing, reading, writing, social and verbal communication, leaves them frustrated which results in negative type of behavioral responses, such as the ones observed throughout the early stages of the study.

Accepting this assumption about kinesthetic learners' bodily "voices" led the researcher to assert that if kinesthetic learners were taught to "listen" (i.e., be aware and know how to manage) to their bodies' "voices" and learn to use them in a meaningful, powerful and empowering way, kinesthetic learners' negative behavior responses would disappear. In other words, if the teaching strategy was designed to allow kinesthetic learners to build on their bodily "voices" through kinesthetic activities, it would have enabled those students to begin developing feelings of pride and confidence in the resources they possess. Enabling kinesthetic learners to feel confident about themselves functioning successfully in a learning environment would have led them to demonstrate positive behavior responses reflecting high motivation towards learning and exploration, high self-confidence and an ability to work collaboratively and effectively with others.

LIST OF REFERENCES

Adler, P. A., Adler P. (1994) Observational Techniques. In N. K. Denzin & Y. S. Lincoln (Eds.), Handbook of qualitative research (pp. 377-392). Sage Publications, Thousand Oaks: California.

Anderson, D. S., & Piazza, J. A. (1996). Changing beliefs: Teaching and learning mathematics in constructivist preservice classrooms. Action in Teacher Education, 18, 2, 51-62.

Borowski, E. J., & Borwein, J. M. (1991). The HarperCollins dictionary of mathematics. New York: HarperCollins Publishers.

Cobb, P., Wood T., & Yackel, E. (1991). A constructivist approach to second grade mathematics. In P. von Glasersfeld (Ed.), Radical constructivism in mathematics education. London: Kluwer Academic Publishers.

Cobb, P., Yackel, E., & Wood, T. (1992). A constructivist alternative to the representational view of mind in mathematics education. Journal for Research in Mathematics Education, 23, 1, 2-33.

Coffey, A., & Atkinson, P. (1996). Making sense of qualitative data: Complementary research strategies. Sage publications.

Confrey, J. (1990). What constructivism implies for teaching. In R. B. Davis, C. A. Maher, & N. Noddings (Eds.), Constructivist view on the teaching and learning of mathematics. Reston, VA: National Council of Teachers of Mathematics.

Creswell, J. S. (1998). Qualitative inquiry and research design: Choosing among five traditions. California: Sage Publications.

DeGeest, W., & Wills, L. (1992). Teacher as researcher and pilot study. Minnesota, MN: Minnesota Center for Arts Education.

Denzin, N. K., & Lincoln, Y. S. (Eds.). (1994). Handbook on qualitative research. London: Sage Publications.

Dunn, R. (1982). Would you like to know your learning style. Early Years, 13, 2, 27-29, 70.

Dunn, R. (1983a). You've got style. Early Years, 13, 5, 25-31& 58-59.

Dunn, R. (1983b). Now that you know your leaning style-how can you make the most of it?. Early Years, 13, 6, 49-54.

Dunn, R. (1983c). Now that you understand your learning style. . . what are you willing to do to teach your students through their individual styles?. Early Years, 13, 41-43, 62.

Friedman, H., F. (1969). A classroom oriented visual perceptual motor training program. In R. Wold (Ed.), Visual and perceptual aspects for the achieving and underachieving child (pp. 393-200). Seattle, Washington: Special Child Publications, Inc.

Gardner, H. (1983). Frames of mind: The theory of multiple intelligences. New York: Basic Books.

Gardner, H. (1993). Multiple intelligences: The theory in practice. New York: Harper Collins.

Gardner, H. (1996). Multiple Intelligences: Myths and messages. International Schools Journal, 15, 2, 8-22.

Gardner, H. (1997). Beyond multiple intelligence. A lecture presented at the 52nd annual conference of the Association of Supervision and Curriculum Development, Baltimore, MD.

Green Gilbert, A. (1979). Learning language arts through movement. Paper presented at the Dance as learning study conference. Claremont, CA.

Green Gilbert, A. (1992). Creative dance for all ages. Reston, VA: American Alliance for Health, Physical Education, Recreation and Dance.

Green Gilbert, A. (1994, December). Teaching the three Rs through dance. Think, 33-38.

Halpern, D. F. (1986). Sex differences in cognitive abilities. Hillsdale, N.J.: Erlbaum Associates.

Hanna, J. L. (1979). To dance is human: A theory of nonverbal communication. University of Chicago Press.

Heausler, N. L. (1987). The effects of dance/movement as a learning medium on the acquisition of selected word analysis concepts and the development of creativity of kindergarten and second grade children. Unpublished doctoral dissertation, University of New Orleans, Louisiana.

H'Doubler, M. (1940). Dance: A creative art experience. London: The University of Wisconsin Press, Ltd.

H'Doubler, M. (1978a). A way of thinking. In D. Fellon (Ed.), Encores for dance (pp. 12-13). Washington D.C.: The National Dance Association an Association of The American Alliance for Health, Physical Education and Recreation.

H'Doubler, M. (1978b). Paper prepared for AAHPER. In D. Fellon (Ed.), Encores for dance (pp. 14-17). Washington D.C.: The National Dance Association an Association of The American Alliance for Health, Physical Education and Recreation.

Heddens, J. H., & Speer, W. R. (1997). Today's mathematics: Part I—Concepts and classroom methods (9th ed.). New Jersey: Prentice-Hall Inc.

Hohl, D. M., & Smith, C. (1996, July). Ben gay and brownies: A study of the movement experience and how it affects instruction in elementary mathematics. Minnesota, MN: Minnesota Center for Arts Education.

Kieran, C. (1994). Doing and seeing things differently: A 25 year retrospective of mathematics education research on learning. Journal for Research in Mathematics Education, 25, 6, 583-607.

Laban, R. (1948). Modern Educational Dance. London: MacDonald and Evans.

Merriam, S. (1988). Case study research in education: A qualitative approach. San Francisco: Jossey-Bass Publishers.

Miles, M. B., & Huberman, A. M. (1994). Qualitative data analysis. California: Sage Publications.

National Center for Education Statistics (1996). Third International mathematics and science study. U.S. Department of Education, Washington D.C.

National Council of Teachers of Mathematics. (1989). Curriculum and evaluation standards for school mathematics. Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1991). Professional standards for teaching mathematics. Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1991a). Guide to standards presentation materials. Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1993). Curriculum and evaluation standards for school mathematics addenda series, Grades K-6: Geometry and spatial sense. Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1995). Assessment standards for school mathematics. Reston, VA: National Council of Teachers of Mathematics.

Niemi, D. (1996). A fraction is not a piece of pie: Assessing exceptional performance and deep understanding in elementary school mathematics. Gifted Child Quarterly, 40, 2, 70-80.

Noddings, N. (1990). Constructivism in mathematics education. In R. B. Davis, C. A. Maher & N. Noddings (Eds.), Constructivist views on the teaching and learning of mathematics. Reston, VA: National Council of Teachers of Mathematics.

Pirie, S. E. B. & Kieran, T. E. (1994). Beyond metaphor: Formalizing in mathematical understanding within Constructivist environment. Learning of Mathematics, 14, 1, 39-43.

Price, G., & Dunn, R. (1997). Learning Style Inventory. Price Systems, Inc. P.O.Box Lawrence, Kansas.

Pylyshenko, K. (1996). The experience of knowledge: A post-modern somatic approach. Unpublished doctoral dissertation, The Ohio State University, Ohio.

Regional Laboratory for Educational Improvement of the Northeast and Islands. (1995). Facilitating systematic change in science and mathematics education: A toolkit for professional developers. U.S. Department of Education, Office of Educational Research and Improvement.

Schatzman, L., & Strauss, A. (1973). Filed research: Strategies for a natural sociology. New Jersey: Englewood Cliffs.

Simon, M. (1995). Reconstructing mathematics pedagogy from a constructivist perspective. Journal for research in mathematics education, 26, 2, 114-145.

Stake, R. E. (1994). Case studies. In N. K. Denzin, & Y. S. Lincoln (Eds.), Handbook of qualitative research (pp.236-247). London: Thousand Oaks.

Stake, R. E. (1995). The art of the case study research. Thousand Oaks: Sage Publications.

Steffe, L. P. & Weigel, H. G. (1992). On reforming practice in mathematics education. Educational studies in mathematics, 23, 445-465.

Von Glasersfeld, E. (1984). An introduction to radical constructivism. In P. Watzlawick, (Ed.), The invented reality: How do we know what we believe we know? London: W. W. Norton & Company.

Von Glasersfeld, E. (1987). Learning as a constructive activity. In C. Janvier. (Ed.), Problems of representation in the teaching and learning of mathematics. Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc.

Von Glasersfeld, E. (1990). Environment and communication. In Steffe L. & Wood, T. (Eds.), Transforming children's mathematics education. Hillsdale, New Jersey.

Von Glasersfeld, E. (1991). Abstraction, re-presentation, and reflection: An interpretation of experience and Piaget's approach. In L. P. Steffe (Ed.), Epistemological foundations of mathematical experience (pp. 45-67). Springer-Verlag, New York.

Von Glasersfeld, E. (1995a). Sensory experience, abstraction, and teaching. In Steffe L. & Gale, J. (Eds.), Constructivism in education. Hillsdale, New Jersey: Lawrence Erlbaum Associates Inc. Publishers.

Von Glasersfeld, E. (1995b). A Constructivist approach to teaching. In Steffe L. & Gale, J. (Eds.), Constructivism in education. Hillsdale, New Jersey: Lawrence Erlbaum Associates Inc. Publishers.

Wittrock, M. C. (1974). A generative model of mathematics learning. Journal for Research in Mathematics Education, 5, 4, 181-196.

Wood, T., Cobb, P., & Yackel, E. (1991). Change in teaching mathematics: A case study. American Educational Research Journal, 28 (3), 587-616.

Woolfolk, A. E. (1995). Educational psychology (6th ed.). Massachusetts: Allyn & Bacon.