MTD 705

Dissertation

Enhancing Mathematics Through Dance: an investigation into the possibility of raising attainment in primary geometry through the use of dance as a teaching tool.

ABSTRACT

In this action research project, I explored the effectiveness of two different teaching approaches in raising attainment in Grade 2 and Grade 3 class assessments using a quasi-experimental method. The Grade 2 experimental group studied geometry using choreographed dances incorporating shapes and concepts prescribed by the British Columbia curriculum and performed some small group explorations. In the Grade 3 group, this was supplemented by the use of detailed explanations and inclusion of 3-D solids as visual aids. Quantitative and qualitative data was collected from the prior learning assessment, post-test, and student responses regarding learning preferences, enjoyment of mathematics and of the dance geometry unit. It was found that students could learn geometry most effectively through choreographed explorations and practical investigations in small group tasks combined with use of props and visual aids. There was also a sizeable difference in practical results compared with written results for several students, particularly those with low reading ability or focus issues. In addition, no correlation was found between student perceptions or enjoyment and their attainment. Overall, dance was found to be an effective teaching tool without written work. However, in order to achieve more satisfactory written test results for all students, some written work is recommended.

INTRODUCTION

Background to the Research Project

Mathematics has, as the subtitle of Jo Boaler's book (2008) states, been the "most-hated subject" for students and, as such, has been in need of pedagogical approaches which not only help pupils to learn effectively, but also to enjoy that learning (3). One way of doing this, and a method which is becoming increasingly popular in Canada, is through the arts (exemplified though the *ArtsSmarts,* and *Learning Through the Arts* programs). Dance, although a part of the arts in such approaches, is under-represented and, in fact, has little or no representation in schools in some areas of Canada, despite being part of provincial Fine Arts and Physical Education curricula. Even the extensive *Learning Through the Arts (LTTA)* studies have had a limited number of dance artists involved and have provided few substantive results as to the effects of dance on understanding and learning. In the school that provides the context for my research there is also, according to class teachers and several students (with whom I have conversed on an informal basis over the past couple of years), a similar view of mathematics, and teachers are keen to address this problem with creative solutions such as the one I am proposing.

From the turn of this century, there has been an increase, in North America, in scholarly inquiry into the benefits of including the arts in the school curriculum (Csikszentmihaly 1997; Green 1995; Jensen 2001; Patteson, Upitis & Smithrim 2005). James Catterall (1998) assessed one of these benefits as increased academic achievement, and neurologists and educational scholars have highlighted the positive effects of the arts on brain development and learning (Rauscher et al 1997; Sylwester 1998; Jensen 2001; Sallis & McKenzie et al 1999).

Canadian action research initiatives such as *ArtSmarts* and *Learning Through the Arts* have been instrumental in raising the profile of the arts as a tool for learning in schools, especially in the eastern provinces. Much of this research, however, has focused on how the arts increase motivation in other subjects. Anecdotal evidence of academic benefits is provided by way of teachers' and principals' responses to surveys or interviews where it has been stated that teaching professionals believe that increases in academic achievement are probably due to the involvement of the arts (LTTA, Ontario Student Studies 2008-2009, 2009-2010; LTTA Teacher Study 2009-10; Patteson 2010). There is, however, little research dedicated exclusively to the effects of using dance to teach other subjects even though the roles of physical activity and music have been examined from scientific and educational viewpoints (Feinstein [ed] 2006; Reed 2009; Sallis & MacKenzie et al 1999; Trost [ed] 2007). These subjects have a clear connection to dance and so this information is useful in part. Nonetheless, the explicit study of dance as a learning tool needs further exploration and research.

The connections between mathematics and dance are, in part, related to the connections with music such as fractions, counting or grouping. Dance also relates well to other concepts in geometry, tessellation, symbols and algebra, for example. A few scholars and practitioners have begun to recognize this (Dr. Schaffer & Mr. Stern of *Mathdance*; Hackney 2006; Watson 2005).

Schaffer and Stern travel extensively teaching math through dance, although the ongoing nature of math teaching is not necessarily impacted by one-off performances such as these. Some studies and scholarly articles express the need for dance related to cognitive outcomes such as the effects of movement on memory, attainment tests, and thinking skills (Hanna 2001, 2003; Keinänen, Hetland & Winner 2000). However, there is an agreement that not enough studies have been done to gain a reasonable perspective on dance and cognitive outcomes as a comprehensive meta-analysis of research in this area states (Keinänen et al 2000, 295-306).

Statement of the Problem

The Elementary School where this research will take place is a designated multiple intelligences school where different styles of learning are encouraged and the arts are welcomed as learning tools. One of the areas barely used in regular teaching is dance.

The use of dance as a learning tool has been researched to some extent but much of the research into the effectiveness of using dance to teach other subjects has been anecdotal or subsumed by multiple arts research such as the Canadian *Learning Through the Arts* programme. Evidence pertaining to dance is fairly scant, although there is some evidence to suggest that movement improves demonstrated learning and attainment in a variety of subjects (Catterall 2005; Gilbert 1978,1979; Ratey 2001, Rose 1999). Research also shows that active learning, using experiential and hands-on approaches, is beneficial for all students and, in fact, contributes to the development of the brain, thinking and learning skills (Diamond 2000). The Literature Review below highlights this research.

The *Integrated Resource Package* (IRP) for Mathematics K-7 in British Columbia states that “a variety of instructional approaches” should be used “in order to reach a variety of learning styles and dispositions” (31) to foster the development of positive attitudes in the subject. Furthermore, the *Applying Mathematics* section exemplifies cross-curricular integration using spatial awareness in dance and geometric shapes in visual arts, drama and dance (33). Despite these statements, dance has not been used in the teaching of mathematics in this school or, according to various teachers I have talked with from different schools, in other public schools in the district.

Dance and mathematics share a number of concepts such as the use of patterns, shapes, counting and angles, which suggests that the use of dance in teaching the subject would be beneficial for all learners, particularly for those who respond better with kinaesthetic or hands-on types of education. Teaching geometry to Grade 2 and 3 pupils using dance should create a fun, active way of learning and demonstrating mathematical concepts, enhancing their classroom experience.

If a positive outcome is achieved, in other words, if dance is shown to be a useful tool in teaching this area of mathematics, the school and school district may be inclined to use dance in the classroom, and could offer more opportunities for dance professionals and generalist teachers to use dance in schools. Also, as the majority of schools that I have worked in have rarely or never used dance or arts to teach mathematics, as encouraged in the IRPs, I would be opening up a new approach in the local area. This could, therefore, have an impact on my own teaching role in local schools which, until now, has been purely on an artist in residence basis.

Purpose of the Study

The school in which I conduct the study embraces Gardner's *Multiple Intelligences Theory*. Here, the arts are appreciated and valued within the learning environment. Dance has occasionally formed part of the physical education curriculum when a specialist teacher (primarily from a private dance studio) has been available on a voluntary short-term basis. I provided two short courses for two classes and, following that, was the artist in residence last year. However, dance has been restricted to performance-based projects rather than being an instrument of learning in itself. There has also been no intentional connection between dance and other subjects. Geometry and dance are connected in a variety of ways including the use of shapes and patterns, measurement and angles. To facilitate learning in mathematics and also integrate dance into the general curriculum, I aim to use dance as a learning tool while maintaining the artistic, choreographic nature of dance. Due to the constraints of the project, I am unable to assess learning and achievement in dance as well as mathematics. Accordingly, my primary focus is on establishing whether mathematics can be taught successfully using dance as a teaching tool.

Research Questions

I hypothesise that using dance as a teaching tool will lead to increased, demonstrable knowledge and understanding of mathematical concepts and, therefore, lead to raised attainment levels in Grade 2 and 3 unit tests following a four week unit.

Questions considered:

- Does my teaching of geometry using dance lead to enhanced understanding of concepts and retention of knowledge for all of the students engaged in this unit of study?
- Can students clearly demonstrate learning through naming, describing and physically showing shapes and concepts and completing a written test devised by collaborating class teachers?

- How may the results of my research impact future units of study in mathematics in the school?

Nature of the Study

This study is based on an action research model. I use a quantitative and qualitative (mixed method) design to measure the results of, and gain a better understanding of, the use of dance as a teaching tool. The data is then reviewed and the impact and implications of the study assessed.

LITERATURE REVIEW

In this literature review I explore two fields of source materials relating to my action research: cognitive transfer in the area of neuroscience, and educational theories and research related to dance and mathematics. Much of the material has arisen since the 1990s. More recently there have been collaborations and conference presentations between mathematicians and dance educators, although most of these are poorly documented other than by brief references stating that the work was done. I examine interdisciplinary learning and multiple intelligences models, theories that are prevalent in British Columbia (B.C.) schools and provincial curricula. These theories and their subsequent practice have affected learning in most B.C. schools, although any link between dance and other subjects has been subject to little research or study.

A variety of arts subjects yield viable sources including research and academic papers in drama, music and physical education (Reed 2009; Sallis & McKenzie et al 1999; Sylwester 1998). As previously stated, dance is not well represented in scholarly articles and writings. The majority of dance related articles and books contain teaching materials and advice for classroom teachers, including lesson plans or ideas for teaching mathematics units (Gilbert 1992, 2002, 2006; Watson 2005; Zakkai 1997). In addition, most of the scant evidence cited for student attainment and learning in mathematics through dance is anecdotal or related to students' or educators' perceptions rather than specific data (Keinänen, Hetland & Winner 2000). The focus and conclusions of some studies highlight student enjoyment and provide broad qualitative assessments (Gilbert 2006; Upitis, & Smithrim 2003), and other literature provides teaching ideas based on movement and creative dance principles rather than using choreographic ideas used to teach math (Brehm & McNett 2008; Twomey 2002). This lack of material creates a gap which I begin to address in my action research project.

Science: providing a foundation for learning through dance.

Movement is "crucial to every other brain function, including memory, emotion, language and learning" (Ratey 2001 in Brehm & McNett 2008, 20). In this statement, John Ratey highlights the important role of movement in learning. This role is verified by neurologists and psychologists (Brown, Martinez & Parsons 2006; Catterall 2005; Jensen 2000; Reed 2009; Trost [ed] 2007; Van Braekel et al 2007), who agree that movement is essential to making neural connections and to developing brain functions and thinking skills pertinent to learning. If movement is vital for overall learning in young children, then the use of dance, which includes movement and music, would, I suggest, enhance learning and lead to greater attainment in other subjects such as mathematics. This transfer of learning, highlighted in various arts projects (Catterall 2005; Keinänen, Hetland & Winner 2000; Upitis & Smithrim [eds] 2003), provides the impetus for my research. However, James Catterall, points out that "scholarly documentation is thin" on arts-based learning despite a growing body of scientific research suggesting that neural development is affected positively by arts-based learning, particularly in music (2005, 2). In his article, *Conversation and Silence: Transfer of Learning Through the Arts,* he argues that

> [t]he Rosetta stone for understanding transfer from learning in the arts to other domains may emerge as comprehension of the impact of arts-related neurological development on individual abilities to accomplish nonarts (sic) tasks.
>
> Catterall 2005, 6

Here, Catterall suggests that a deepening of learning occurs through experiential reinforcement and, therefore, the arts may provide a means of effective learning for other subjects. Countering this, Elliot Eisner (1998, 2001) warns that “to use the arts primarily to teach what is not truly distinctive about the arts is to undermine, in the long run, the justifying conditions for the arts in our schools” (1998,12). He believes that false claims are being made regarding transfer from arts to other subjects which may ultimately “backfire by society dismissing the benefits of the arts altogether” (2001, 4). He does, however, place importance on the arts in education. I agree with Eisner that the arts have their own distinct value and should not merely become an instrument of learning for other subjects. Nonetheless, if dance can help students learn curriculum more effectively while maintaining its artistic value undiminished, I see this as an important benefit of using dance as a teaching tool.

Dance can be enjoyed for its own sake *and* provide a means of learning concepts for other subjects. The use of dance to enhance subject learning has often been reduced to using basic movements and dance activities which require little or no expertise on the part of the teacher. These activities perhaps lack the artistic and technical development of the art form itself, as feared by Eisner (1998,12). This is undoubtedly due to the lack of dance teachers and training in dance for elementary teachers (B.C. teachers are trained as generalists). The dance education afforded to teachers in initial degree programmes is meagre. For example, in an informal survey that I carry out of teachers attending my courses and seminars (participants come from western Canada and the north-west United States), teachers report that they have studied dance for just one half day as part of a physical education unit or have had no dance instruction at all. Many of these teachers are, nevertheless, responsible for dance in their schools. Resources abound for helping such teachers incorporate movement ideas into the curriculum. The *Physical and Health*

Education Canada dance resources web page shows typical examples, containing books such as *Building More Dances* (2001) which “covers all the fundamentals so that even teachers with little or no dance background will feel comfortable teaching students how to build dances” (PHE Canada 2010, n.p.). Such an approach seems, to me, to diminish the importance of dance as a subject in its own right as well as its status or role in the curriculum. This lack of attention to dance in education is also evidenced in the scarcity of literature and research on dance in both scientific and educational fields. Although there is a growing body of scientific research in physical education, music and the arts in general, very little research focuses on the use of dance and its possible effects on memory, learning or understanding.

In a meta-analysis on dance and the effects on cognitive skills, Keinänen, Hetland & Winner concur that there is a lack of substantiated evidence available for the effects of dance on cognition and achievement while there is a great deal of anecdotal evidence (2000, 295-306). This corresponds with my findings in an investigation of a variety of sources and in discussion with dance and education researchers and practitioners. Keinänen, Hetland & Winners’ extensive search of published and unpublished materials reveals only a handful of studies (2000, 295), and the authors were unable to conclude whether positive results were due to teacher expectancy effects or other reasons. Further quantifiable studies are, therefore, encouraged. This is an area I begin to address and which could lead to studies being conducted on a larger scale than is possible for my research.

Dance educators, Mary Ann Brehm and Lynne McNett, whose influences include Barbara Mettler, Margaret H’Doubler and Rudolf Laban, focus on the integration of the arts in the whole school curriculum in their book, *Creative Dance for Learning: The Kinesthetic Link* (2007). They approach the subject of creative dance from an extensive background in dance education and advisory work throughout the United States. Some scientific and educational perspectives of selected scholars are included (Bainbridge Cohen 1993; Hannaford 1995; Jensen 1995; and Ratey 2001). With these perspectives in mind, the authors explore the importance of dance and movement in: physical and neural development; the engagement of sensory learning modes; effectiveness of memory; assimilation and sequencing; and the use of high level thinking skills. Brehm states that movement can "help students learn concepts, solve problems, and thereby understand core academic subjects" (2007, 4) although the research behind this is not explored in any detail. The importance of using creative dance for learning is supported by reference to John Ratey's work (2001). Ratey expresses that learning, memory and other brain functions evolve from and are dependent on movement (148). Studies in Australia (Dwyer, Sallis et al 1999), Korea (Won, Lee & Kim 2003) and the United States (Knight & Rizzuto 1993) seem to support this view from the area of physical activity related to academic performance and achievement. Again, it is not clear whether increases in learning and test results are due, for example, to more efficient brain function or from the benefits of engaging in a pleasurable activity. Indeed, it is difficult to assess how much of a role pleasure plays as a motivation for learning compared to the lesson content, structure or mode of learning (for studies on motivation and learning, see the work of Maslow 1954; Elton 1988; and Leonard, Beauvais & School 1995). To clarify whether pleasure is a factor in acquisition of knowledge and, therefore, in attainment, I explore student enjoyment as part of my data analysis.

Adele Diamond begins to address the area of brain functions in her research. She reveals the close interrelationship of motor development and cognitive development of the cerebellum and prefrontal cortex of the brain that are related to movement, memory and learning (2000, 50) indicating that cognition and movement are not restricted to one area of the brain. Instead, there is an interrelationship between motor and learning skills. She also points out that there is little work done on the links between the two, cognition and motor skills usually being researched separately (44). Consequently, more work is needed that involves the relationship of thinking skills and memory to movement.

Julian Reed (2009) also explores the links between movement and enhanced cognition in children. He supports his comments with several examples of brain research and scientific educational research primarily between the 1990s and 2009. In a recent report released by Legacy Charter School, SC (July 22nd 2010), following a year long action research study of an entire K-5 school student population, Reed adds:

> These cognitive measures are critically important components of intelligence and this finding suggests that Legacy Charter School students have a greater ability to think quickly, problem-solve and think abstractly, than their counterparts who do not participate in daily physical activity. I'm unaware of any program with this kind of holistic approach that extends to the entire school community.
>
> Reed 2010 n.p.

Reed found great improvements in the results of cognition tests and achievement following daily physical activity. Possible reasons for this, however, are not relayed in the report. The school principal merely notes that feeling better equates to learning better. This is an aspect explored in David Sousa's work (2000) in which memory, and therefore learning, is affected by emotional states and motivations. The exercise element of dance alone may have a similar impact on learning. If linked with music and choreographic elements, it is possible that attainment may be even greater.

It is possible that an extended project could arise from my study, especially when research on the effects of music on cognition and achievement reveals improved grades and higher scores in cognitive tasks including mathematical skills (Fujioka et al 2006; Hazlewood, Stouffer & Warshauer 1989; Hoffman 2005; Schellenberg 2004; Schlaug et al 2005).
Reed's exploration of the links between movement and enhanced cognition tallies with the work of James Sallis and Thomas McKenzie in Project SPARK. Sallis and McKenzie collected national data on Physical Education and academic achievement in the U.S. and conclude that the inclusion of more physical activity in the school curriculum (meaning less academic subject time in most cases) does not have a detrimental effect on academic achievement and may, in some instances, boost achievement (2010, 70 & 127-134). In *Active Education: Physical Education, Physical Activity and Academic Performance*, Trost ([ed] 2007) summarizes the most current research findings from the U.S, Canada, U.K, Hong Kong and Australia, and reports that similar results are found including, in some cases, improved grades. Enhanced concentration and classroom behaviour are cited as possible reasons for this. These factors, along with teaching styles and other motivational factors, cannot be excluded from possible reasons for improvement, so it is important that I am aware of this in my research.

Eric Jensen (2000) points out that movement activities are needed in order to assimilate new information as some neural circuits that regulate physical tasks are used with thinking processes including recall, evaluation and sequencing. This line of thought forms the basis of the *Brain Gym* and brain-based learning systems which are popular worldwide (21, 145). *Brain Gym* assessments have been conducted which suggest that this active learning method effectively enhances learning. However, the nature of the resulting educational benefits has been disputed by independent neurologists such as Usha Goswami (2006) and John Bruer (1997, 1999). These scientists refer to an "over-literal interpretation of hemispheric specialization" (Goswami 2006, 2) in the educational sphere where left-brain and right-brain activities are over-simplified resulting in unsubstantiated claims that a series of simple body movements will "integrate all areas of the brain to enhance learning" (Cohen & Goldsmith 2000). Although they do not dispute that learning *may* be enhanced through the use of movement strategies, they are wary of exaggerated claims, pointing out that "brain-based programmes currently in schools [have] no scientific basis" (Goswami 2000, 6). It is, therefore, important from a scientific point of view that some quantitative assessment is provided alongside anecdotal and qualitative evidence. Consequently, Including some quantitative aspects into my study is a valuable part of recording results, perhaps resulting in deeper investigations using quantitative and qualitative methods in the future.

Arts Education and Learning

Often without reference to specific scientific studies (Cohen & Goldsmith 2000; Frith 2000; Goswami 2006), arts and educational professionals have begun to stress the role of the arts in learning. Many scholars have contributed to the present climate of interdisciplinary education and multiple intelligences theories, frequently referring back to experiential education ideas of pioneers such as John Dewey and extensively citing evidence from observations and practice. Many anecdotes or inferences are included without much in the way of supporting studies or actual action research to substantiate claims.

Tracey Tokuhama-Espinosa highlights the lack of connection between the scientific and educational fields. In support of her stance she quotes Blakemore and Frith who posit that, "despite remarkable progress, brain research has not yet found an application in theory or practice of education" (2008, 6). Her review of brain-based education literature from 2002 to 2007 reveals the plethora of scientific research on the brain and different aspects related to learning, but also the lack of connection between the fields of education and science. Despite an enormous amount of references to research and practice, no dance studies are mentioned, perhaps indicating the lack of information available, or, possibly, the lack of status of dance as a subject area (it is not included in her list of subjects considered). Tokuhama-Espinosa suggests that educational experts seek to bridge the gap between science and education with their defined styles of learning and "neuroeducation" despite little scientific evidence to support their theories (11). In this regard, she refers to the work of Howard Gardner and Eric Jensen among others as examples of neuroeducationalists who seek to support their arguments with unsubstantiated scientific claims.

Gardner's *Multiple Intelligences Theory* (1983, 2006) and Jensen's brain-based learning strategies (1998, 2000, 2006) are frequently used models in education and teacher training in Canada (also suggested reading in teacher conferences I have attended). Gardner's theories are used as guidelines in the B.C. curriculum while Jensen's books are standard texts in teacher education, promoted and published by the *Association for Curriculum Development* (ASCD). The school in which I am conducting the action research also adheres to the notion that each child is smart in certain ways, for example, "body smart" if they prefer learning by using their bodies, drawing on Gardner's theory. Despite many critics of his theory, especially among intelligence theorists, Gardner's ideas are used widely in schools. His theory is deemed by some to have no empirical foundation (Brody 1992; Jensen 2008) or to be too broad for useful application (Sempsey 1993). There is benefit, though, in Gardner's work in that he has encouraged teachers to consider that children have different learning preferences. Teachers may, therefore, adapt modes of instruction to include a variety of approaches instead of using one particular teaching method. Bearing this in mind, I feel it is important to ascertain students' learning preferences to discover if these affect their assessment results. Professional development specialist and brain and learning expert Robert Greenleaf (2003) also refers to the importance of motion/movement in learning, although does not enter the arena of dance education.

Dance, Learning and Achievement

Established author and founder of *Dance: Current Selected Research,* James H. Humphrey focuses on the role of dance in *Child Development and Learning Through Dance* (1987). Humphrey attempts to explain different ways of using dance such as cognitive dance (56-61), that is, dance used as a learning medium for other subject areas. He believes that pleasurable physical activities such as dance aid learning and develop thinking skills linking cognitive development with pleasure. He does not substantiate his claims, though, and Humphrey fails to consider that not all learners will find dancing or other comparable physical activities pleasurable. If learners do not find dance pleasurable, would it still enhance their learning? This is an aspect which I feel needs to be considered in my research. However, if dance is, in the same way as movement, an important way of helping the memory and thinking skills function better, then it may not be entirely dependent upon enjoyment.

Anne Green Gilbert, an established leader in dance education and founder of *Brain Dance*, has created several resources which encourage the use of dance in the classroom (1992, 2002, 2006). Although there are some general comments regarding the importance and link between brain development, movement and subject learning, and some reference is given to Jensen, Gardner and Piaget, Gilbert does not attempt to justify her stance using data or by quoting research in detail, but gives anecdotal evidence from her own and other teachers' experiences. Although Gilbert and her colleagues initiated studies involving movement in physical education and its effects on attainment (Corbin [ed] 1978, Gilbert 1979), this work has not continued or progressed despite promising initial results. The reasons for this are not stated. Similarly, other dance scholars and educationalists (Hackney 2006; Hanna 2001, 2003; Zakka 1997) emphasise the benefits of including dance in the curriculum, most of them alluding to Gardner's *Multiple Intelligences Theory*, some relating practical experience (e.g. Hanna 2001, 2003), but few supporting their stance with reference to research. Several teachers' guides (e.g. *Movement on File*, CAHPER 1990; *Active Education: Lessons for Integrating Physical Activity with Language Arts, Math, Science and Social Studies*, Reed 2009; *Dancing in Your School*, Dunkin 2006; *Teaching the Three Rs Through Movement Experiences: a handbook for teachers*, Gilbert 2002) promote the use of dance for learning other subjects. Most of these present geometry lessons in a similar way: having students create shapes, using little, if any, musical accompaniment, and concentrating on non-locomotor activities such as static shape-making rather than using dance in a more choreographed manner which I explore in this research project.

The *Learning Through the Arts* (LTTA) project over the last ten years is one of the most extensive attempts to integrate the arts and academics carried out in Canada. This project, and the similar work of the *ArtsSmarts* organisation, has given a new impetus to using the arts as a learning tool. In the LTTA final report (Upitis & Smithrim 2003) the findings suggest that arts subjects enhance academic study by improving engagement, focus, certain skills (through kinaesthetic learning) and social elements. However, this study does not offer specific findings for dance. Likewise, the *ArtsSmarts* research does not provide findings on dance and mainly focuses on reactions and responses of teachers and students. Ann Patteson, editor of the LTTA pilot program in the UK (2009), also agreed that dance as a learning tool is not well researched and was not a major part of the LTTA program (message to author, 2010). Several practitioners use dance to teach academic subjects without providing much in the way of concrete evidence of improved attainment. These practitioners include: *MathDance* pioneers, Dr. Schaffer & Mr. Stern; Galeet Westreich in her ten step learning system, *Kinematics;* and Karen Kaufmann in *Math Movers*. Dance is clearly being used as an instrument of learning but specific findings are lacking.

Oxford University scholar, Anne Watson (2005), delineates dance structures that may help in learning mathematics, in particular promoting engagement and learning in four areas: spatial, rhythmic, structural, and symbolic. Watson cites several theorists and practitioners including Bruner (theory of instruction and representation/symbol), Laban (spatial elements), Vygotsky, Papert, and Gardner. Although several references are old, they are considered classic (Laban, for example). Watson, along with Judith Lynne Hanna and Madeleine Hackney, are major proponents of using dance to teach mathematics. Hackney focuses on the links between dance and mathematics rather than the results of using dance (2006, 23-25). Hanna (2001; 2003, 78) reviews the work of the REAP (Project Zero's *Reviewing Education and the Arts Project*) group, concluding that research on cognitive transfer needs to be done by cognitive scientists and dance experts to "document what many of us already believe intuitively and know from our experience in teaching dance". The assumption here is that dance enhances learning and attainment. The REAP report (Hetland and Winner [eds] 2000) confirmed that there was little research found for transfer between dance and academic achievement and that it was not possible or useful to justify the arts instrumentally (n.p.). Further research is advised on if and how transfer occurs, the former being an area that I begin to address in my study.

A number of scholars are concerned that justifying dance by integrating it into other subject areas weakens the validity of the subject itself. Also, instrumental reasons for learning are not the only or, necessarily, the best reasons for learning a subject. Canadian scholar Sheryle Bergmann (1995) and Scottish education advisor David Carr (1984) are among those who agree that dance should also have an aesthetic purpose. I believe that dance needs to have a dual role in education and can be used to teach subject matter while retaining an aesthetic quality that makes it dance rather than movement. For this reason, I use choreographed dances as well as physical exploration of concepts within my study and students are able to perform as they would do if they were in an exclusively dance programme. In this way, students are able to appreciate and practice dance and learn mathematical concepts simultaneously.

RESEARCH METHODOLOGY

Introduction to the Research Design.

In this study, I employ a mixed method design to address the main research questions. I believe that quantifiable data collection is valuable. However, qualitative aspects cannot be ignored when researching with young people and so I include both methods. Here is a summary of the research design. The detailed outline is contained in the Research Design section following.

- *Prior Learning Assessment (pre-test):* informal oral-based questions to assess knowledge and understanding of shapes and concepts.
- *Research project:* One month (seven lessons) of teaching the geometry unit using dance to explore shapes and concepts contained within the prescribed learning outcomes of the B.C. curriculum. Control group to teach the same learning outcomes.
- *Ongoing assessment and observation:* log maintained of student responses to questions and lesson tasks including ten shape recognition questions during final two weeks. General student remarks also noted including comments on enjoyment and difficulty of tasks.
- *Modification of lessons:* lesson plans modified and adapted as necessary according to completion of tasks and success of teaching methods.
- *Post-test:* written test (90%) and practical test to construct a 3-D shape (10%).
- *Data analysis:* collation, analysis, comparison and interpretation of results.

A pre-test and post-test (quasi experimental) design along with continuous informal assessment through questioning, observations and feedback can provide useful measures of learning which occurs in a variety of ways.

Some learning, for instance, may be demonstrated through action or hands-on responses to tasks, while other learning or understanding may be shown in written test answers. It is, therefore, my belief that combining quantitative and qualitative methods using a quasi experimental design, plus observation and continuous assessment of responses to activities, provides a balanced perspective on the effects of using dance as a teaching tool. The theoretical foundations for my methodology are outlined below.

In some measure, I agree with post-positivist scientific methods where measurable truths may be found, but are subject to individual bias and fallibility. As post-positivist pioneer, Thomas Kuhn, states in *The Structure of Scientific Revolutions* (1962);

> Each paradigm will be shown to satisfy more or less the criteria that it dictates for itself and to fall short of a few of those dictated by its opponent...no paradigm ever solves all the problems it defines.
>
> Kuhn cited in Haselhurst & Howie 2005, n.p.

Theories are, therefore, revisable as they are subject to multiple sources of observation and measurement as well as different perceptions of reality.

I also embrace the connectivist theory of learning where it is recognised that "learning is a process that occurs within nebulous environments of shifting core elements – not entirely under the control of the individual" (Siemens 2005, n.p). George Siemens and Stephen Downey (2005) point out that there are influences on an individual (external or internal) which affect learning and knowledge. One of the major influences is the exponential growth of networks, both digital and social, which means that knowledge sources are both accessible and sharable and each individual – even at the lower Grade levels – can access or be exposed to diverse information. In addition, individual preferences, abilities, social situations and neurological states will affect learning. This can mean a change in, for example, the results of otherwise objective tests due to variable access to sources, timing of the test or social factors and so could have an impact on the written post-test at the end of my project. I understand that personal bias may affect students and teachers, and circumstances and emotional states can have a bearing on results on a given day or time. In order to be aware of anything that might affect the students, communication with the class teachers is particularly important. Considering this, I aimed to connect regularly with the class teachers who updated me on factors that might affect learning on a particular day for a particular pupil such as the imminent move of a student's close friend, or the excitement of a group of boys about to head off for a provincial hockey tournament. This gave me prior warning of possible focus or other issues that could arise although it would be impossible to consider every variable in circumstances or state of mind which might affect learning.

Social constructivist methods value and recognise each learner's unique qualities and learning style. It is posited that knowledge is socially or culturally constructed through interaction with others and the environment (Prawat & Floden 1994; Vygotsky in Rieber & Carton [eds] 1987). This leads to the ideal of maximising the potential of all learners through any available means, especially through the use of peer investigation and mentored work rather than teacher directed lessons. I agree that students should have the benefit of learning using different methods and be exposed to different teaching styles to help them learn effectively, although there needs to be consideration of the teachers' strengths and each school's ability to carry out an all-encompassing method of teaching and learning. Consequently, I included some consideration of unique learning styles when teaching and assessing the students' learning whilst considering the ideals held by the school and B.C. education authority. This school, for example, embraces Howard Gardner's *Multiple Intelligences Theory* (1983, 1999). Some children prefer hands-on methods, others enjoy using stories or images to learn and so on. The B.C. Ministry of Education also encourages different ways of teaching, learning and assessing mathematics to achieve required learning outcomes (*Mathematics Grade 2* IRP 2007; 58, 105).

Each of the classes in my study had different group dynamics and varying preferences that I identified broadly in conversation and questions during the prior learning assessment. Further details on this are included below. I decided that I would combine different teaching styles including direct and indirect (mentoring) methods in order to suit the needs of each class and give the opportunity for each child to learn by different means. This included group and individual problem-solving, reflective activities, game-based learning, class discussion, demonstration, direct instruction (particularly in teaching particular dance movements) and questioning. My approach would be adapted to each group throughout the course depending on how well they worked and responded to different teaching styles.

Research Design

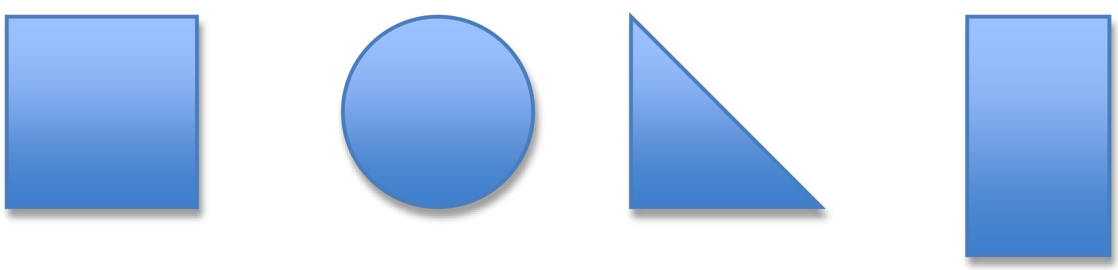
Using a quasi experimental approach, participating classes were selected on the basis of which teachers were available to collaborate with me and each other. One Grade 2, one Grade 3, and a combined Grade 2/3 class were offered for the study. I consulted class teachers on the exact choice of mathematics unit. This depended on what remained to be covered in the curriculum for the year. We agreed that the geometry unit would be suitable as all three teachers had yet to work on this unit. The control group would be the Grade 2/3 class. Ideally, it would have been better to have a second Grade 2 and Grade 3 class for control groups, but there were none available at the school. Also, the teachers felt that the groups would be fairly evenly matched in ability albeit on a smaller scale for the control group. The participating groups would be the Grade 2 class and Grade 3 class. I assigned each student a code which was not known to either students or teachers. The following was then arranged:

Prior learning assessment.

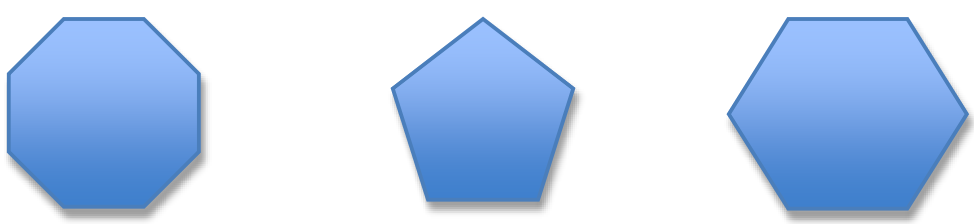
This was an informal pre-test using two-dimensional shapes (fig. 1) and three-dimensional solids such as rectangular prisms, cubes, pyramids etc.

Fig. 1: 2-D *Shape Recognition Chart* (based on learning outcomes contained in the *Integrated Resource Package* [IRP] published by the B.C. *Ministry of Education*, 2007).

Grade 2 shapes



Additional Grade 3 shapes



During the prior learning assessment, students came out of their classroom – at the suggestion of the class teachers – in pairs or groups of three. After reassuring them that I was “just finding out what they already knew” and that it was “fine” if they did not know an answer, students responded to questions to assess prior learning in:

- recognition of shapes,
- application of knowledge to shapes in the world around them,
- understanding of the terms 2-D and 3-D.

To ensure that students did not copy each other, they were asked to identify different shapes selected from the *Shape Recognition Chart* (above). I asked each child to name two shapes and gave no indication as to whether the answers they provided were correct or not. I noted the responses in coded form on a checklist (Appendix A). In addition, I asked how much they enjoyed mathematics, to which they gave responses such as:

“I like mathematics”,
“I like mathematics sometimes/for some topics”,
“I don’t like mathematics”.

These responses were also noted on the checklist. Finally, I asked questions regarding students’ learning preferences. In basic terms, I asked if they preferred to learn, for example, by writing down and working out math problems on paper, by doing hands-on activities or by thinking things through just “in their head”. Again the responses were recorded on the checklist.

<u>Lesson structure</u>

Following the prior learning assessment, the Grade 2 and Grade 3 participant groups took part in four weeks of dance comprising seven half hour lessons in total with small breaks for Easter and a school event.

I taught the Grade 2 participants concepts primarily through choreographed dances and by using some small group investigation work in which I referred to names of shapes and concepts but used little in the way of visual aids, props or explanation. I chose this method to establish whether the dancers could absorb the information physically as they investigated shapes and performed set choreography containing the shapes and concepts. As some of the Grade 2 students generally found it difficult to use props, focus during explanations, or work in groups in a constructive manner (the teacher identified five students with focus issues, for example), it was easier to help them concentrate without the use of many props and manipulatives (fig. 2) so this group was better suited to this approach. I would then be able to examine whether corporeal knowledge would translate into accurate written responses in the post-test.

I included regular informal assessments by way of activities which would show a knowledge of concepts and their use. For example, I would initiate a game where small groups made 2-D or 3-D shapes with their bodies as quickly and accurately as they were able. Noting these responses in a reflective journal, along with levels of enthusiasm or individual achievements demonstrated, formed an important part of the qualitative assessment process. In particular, if certain teaching methods and activities seemed to be met with more focused or eager responses or helped students to gain a greater understanding of concepts, I was able to adapt future lessons to better suit the groups' needs. Reflecting on these areas after each lesson was, therefore, important in improving my teaching in order to help maximize the students' learning.

Fig. 2: *Manipulatives used: 3-D solids*.

Grade 3 participants were taught choreographed dances and had the added benefit of using 3-D solids and a variety of props/visuals (hoops, balls, cone, can, solid manipulatives). I also provided more detailed explanations regarding the use of concepts, for example, the meaning of dimension in the terms 2-D or 3-D. This grade was more accustomed and amenable to detailed explanations. The Grade 2 class generally needed shorter explanations and greater amount of demonstrations. As the Grade 3 class generally had a greater ability to cope with less teacher-directed activities, I gave the students frequent opportunities to explore shapes and concepts in small groups. Discussions were a regular part of the lesson, and the students and I asked questions frequently. I felt that, by using visual aids and explanation along with keeping the choreographed dance format, I would be able to establish whether the Grade 2 (limited props, visuals and explanation) or Grade 3 teaching approach (detailed explanations and use of visuals) would translate more successfully in the post-test.

The control group was taught using manipulative materials, spelling tests on shape words, and using written and visual aids. To ensure that the same concepts were covered in both groups, I provided lesson plans and concept lists to teachers a little in advance and it was agreed that the B.C. IRP recommendations would be followed. Initially, it was planned that the control group lessons were to take part over the same period in a similar division of lesson times. However, the teacher was unable to do this and decided to teach an intensive over two and a half weeks. This took place after the dancers had finished their unit and this meant that the participant groups had a time gap between completion of the unit and the post-test. In contrast, the control group took the test immediately after their intensive session. All groups did the post-test on the same day to avoid information sharing between groups. In addition, the teacher stated that each lesson was approximately 40 minutes long. The participant groups' lessons were 30 minutes long. The differences in timing and duration of lessons and the post-test could have had an impact on the results and this will be discussed in the next chapter.

The class structure for participant groups included the creation of shapes individually or in small groups. I explained and demonstrated as necessary and students worked to solve mathematical problems or explore concepts. The example of a demonstration of concepts (fig. 3) involved a small group investigation of how students' bodies could form a 3-D shape from a geometric net lying on the floor. Students first examined a geometric solid then formed the net with their bodies. In this example, they looked at a square-based pyramid and then decided on how it would unfold to make the net. Then they transformed it into the three dimensional version as a group.

Fig. 3 *Making a human pyramid skeleton from a net.*

Pyramid net (lying on floor). Square-based pyramid (standing).

I gave each participating class tasks relating to a particular shape or group of shapes each lesson and taught a short dance which included these shapes. Sample lessons for each class are included in Appendix B.

Some props were used within the dance choreography. For the Grade 2 class, this was limited to a ball and giant elastic circle (with which to make shapes in the whole group). Concepts were identified as they were used including terminology such as vertices, nets, two- and three-dimensions, and shape names. Music was used for all of the dances, some pieces containing lyrics related to the theme, and some that were instrumental only. I also chose very varied pieces including classical, jazz, movie music, electronic music and popular music of different eras. This was done for two reasons: to embrace a variety of tastes in music, and to minimise the possibility of a child liking or disliking dances because of their musical preferences. The music also had some relation to the dances. For example, *Take Five* (Brubeck Quartet) was used for part of a dance which used pentagons. This piece of music has 5 beats per bar and so related to the 5-sided shape.

Throughout the lessons, students were asked questions and given the opportunity to share their learning and knowledge in the following ways:

a) Using games e.g. *Shape Sorter*: in groups of four, see if you can make a triangle and a cube – sit down when your group has done it. (Groups shared with the class the different ways they achieved the shapes).
b) Identifying solids (Grade 3): at the end of class each student was asked to name a solid as they were lining up.
c) Answering questions e.g. What is a quadrilateral? How many sides does a cube have?
d) Physical demonstration of concepts and responses to given tasks.

The students were also encouraged to give verbal feedback at the end of each class. Following the lessons, I noted student responses in a reflective journal including accuracy of answers/completion of tasks and also reactions to tasks, for example, enjoyment or frustration shown and student comments made. I then adapted subsequent lessons according to the learning and understanding that had been demonstrated.

<u>Post-test:</u> *Geometry unit test and student response survey.*

The tests for Grade 2 and Grade 3 students were devised in collaboration with the class teachers. As each teacher ordinarily uses different course materials, question types were chosen from each unit test submitted by the teachers. The unit test was then constructed with simple questions such as naming shapes, and questions requiring higher thinking skills, for example, “I have 6 faces, 8 vertices and am sometimes used for building blocks or dice. What am I?”. The final question required application of knowledge to build a three dimensional shape (papers contained in Appendix C). Class teachers administered the test. In addition to the written test, I observed and noted student responses in lessons. The Grade 3 students, for example, were asked to identify geometric solids or to create certain shapes (individually or in groups) at various times during lessons.

At the end of the unit test, I included a voluntary set of questions which, alongside student comments made during the classes, helped give me an impression of how students felt about the unit and any changes in their perceptions or preferred methods of learning from their original comments. This formed an important part of the qualitative aspect of the assessment. Students were also invited to comment freely about the project. These were the questions contained at the end of the post-test:

1. Did you enjoy using dance to learn geometry?

   YES/NO/SOMETIMES

2. Which of the following is true for you?

   a) It was harder to understand the math using dance
   b) It was as hard/as easy as learning math in the classroom
   c) It was easier to understand math using dance

Following the unit study and post-test, I collated the results and responses and conducted a comparative analysis. looking at whole group and individual question responses as well as considering the responses by students and observations I had noted in the reflective log. I also asked class teachers for input on their expectations and reactions regarding each child’s ability and his or her written test results. We also discussed any factors teachers thought might be important such as low reading skills or personal circumstances that might have had an influence on learning. It was also important to take into consideration absences during the research period as certain students missed the initial teaching of particular concepts.

This could also have had an impact on responses to certain test questions. I also conducted an analysis of responses (written and oral) to certain groups of questions such as basic recognition of 2-D shapes, the ability to mentally or physically transform a net into a 3-D shape, and answers to word-based problems involving higher thinking skills. An example of a question requiring higher thinking skills was:

> "You can roll me any way you like, but you can never stack me.
> What am I?"

In this question, students needed to internally visualise 3-D shapes and work out which ones could roll and then which shape would also not stack. They had to connect each part of the question and picture it in their minds in order to work out the answer.

Analysis of data.

I analysed the quantitative data as follows. Full results are contained in the Research Findings section. For each child, the total percentage attained in the prior learning assessment was recorded on an Excel spreadsheet. The class results were then converted into a bar graph to show the percentage of students who achieved results within these mark ranges: 0-20%, 20.5-40%, 40.5-60%, 60.5-80%, 80.5-100%. The participant and control groups for each grade level were included on the same bar chart so that a comparison could be made. After this, I worked out the percentage change from prior learning assessment to post-test written results using the following formula:

$$\frac{\text{Post-test result (a)} - \text{Prior learning result (b)}}{\text{Prior learning result}} \times 100 = \text{percentage increase}$$

These results, again comparing the control and participant groups for each grade, were placed in a line graph as the pattern of increases could be seen easily along with the amount of increase per student.

Following this, I compared the results of the written test with oral and demonstrated responses for each participant group. It was not possible to do this with the control groups as the school district policy is to limit any extra workload of teachers during research studies, so these responses were not recorded. It would, however, have been useful for a fuller analysis and might be possible in future research.

After analysing the quantifiable data, I looked at qualitative data such as student perceptions before and after the geometry unit. This was done with each participant group to assess whether enjoyment of dance or mathematics, or the perceived difficulty of mathematics (with or without using dance as a learning tool) bore any correlation to each student's achievement. I also considered the impact of low reading skills, behavioural issues and emotional factors on results. As there were also some absences during the unit, I took these into account. For instance, two students were absent for over half of the course and so their test results have not been included. Their perceptions were included as these were less likely to be affected by absence than their knowledge and understanding would have been.

RESEARCH FINDINGS

As I stated above, the research involved collection of quantifiable data before and after the study in addition to observations throughout the lessons. Pre-testing was done informally in order to lower any anxiety that students might feel during a formal test and also to ensure minimal formal testing as required by school board regulations. However, this created a variable as responses were oral whereas the unit test was written. It had implications for those who were poor readers but proficient in verbal communication or vice-versa. Without the continuous assessment and monitoring of learning that I carried out in the practical sessions, the written test results, in several cases, showed a different outcome to the practical results in class. The raw data for each kind of assessment is shown below and compared with the prior assessment, then the combined results are given and analysed. I also considered the following factors:

- Students identified with reading/writing difficulties
- Students identified as having behavioural or focus issues
- Students who were absent during the teaching of certain concepts

I considered it reasonable to omit results from two of the participant children who were absent for half of the classes and missed several concepts and shape exploration lessons. Also, because the lessons focused on certain shapes and concepts each time, it was easy to identify potential gaps in knowledge or learning for those who missed one or two lessons. In this way, I was able to not only see the raw marks, but also to adjust the test scores by including results only for the areas that I had taught directly to these students. This would give a more realistic result based on what had been taught, and questions that concerned areas they would have missed could be disregarded. The same approach was adopted for the control group but only one student missed any lessons. It is reasonable that students could have, and some probably would have, gained some of their knowledge by other means, however, it was important for my research to discover the effectiveness of my teaching as far as possible.

Prior Learning Assessment

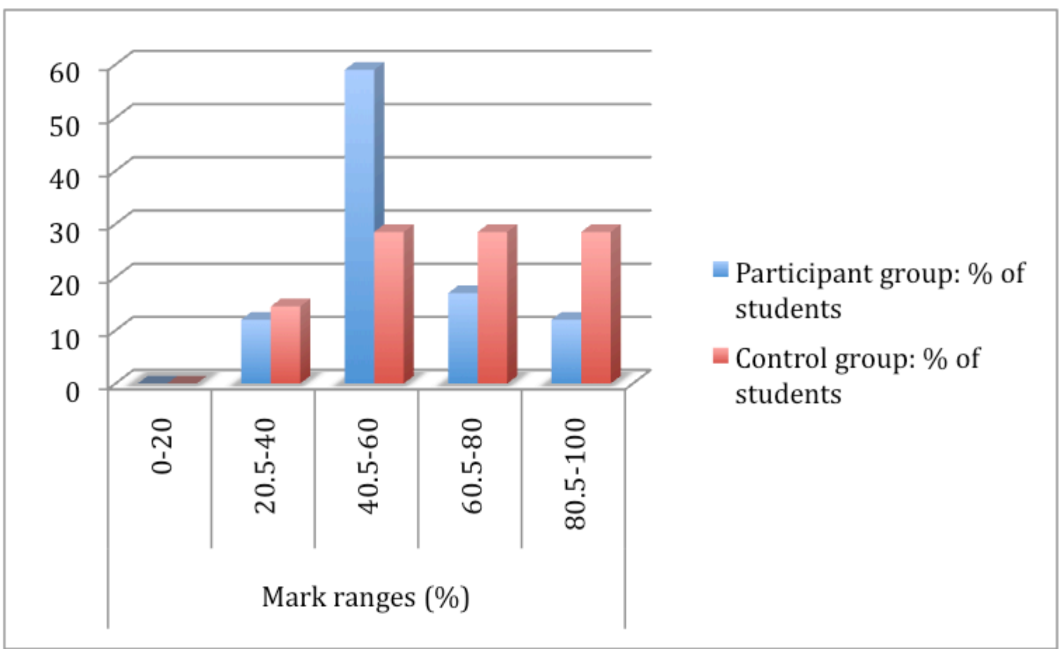
Without exception, the children – most of whom I knew already - appeared relaxed and keen to give answers or tell me about their mathematics experience. This was important in order to gain honest and open responses from the children. As I showed pictures and solids to the children, and asked them to identify shapes and talk about the meanings of two- and three-dimensions, I discreetly checked boxes and made coded notes relating to their responses. The extract below indicates this process and the question numbers refer to specific question types. The questions are shown in Appendix D.

Grade 2	Q1	Q2	Q3	Q4	Q5	Q6	Q7	G1	G2	G3
2AB1	Pop	√	√	√**x**	x	x		N	write	head
2AB2	"	√	√	√	x	√		Y	write	head
2AB3	"	√	x	√	√**x**	√		S	hands	write
2AB4	"	x	x	x	x	√		N	paper	write

The first column contains student identifier codes which were unknown to students or teaching staff. I devised these to retain anonymity of students, a necessary ethical practice in accordance with school board regulations. The "Q" columns are the questions responded to relating to shape recognition and concepts specified in the B.C. IRP learning outcomes. The "G" columns contain student preferences. G1 is whether mathematics is generally liked (Y), disliked (N), or sometimes liked/topic dependent (S). The final two columns contain student responses regarding learning style preferences (G2), and their preferred way of remembering facts (G3).

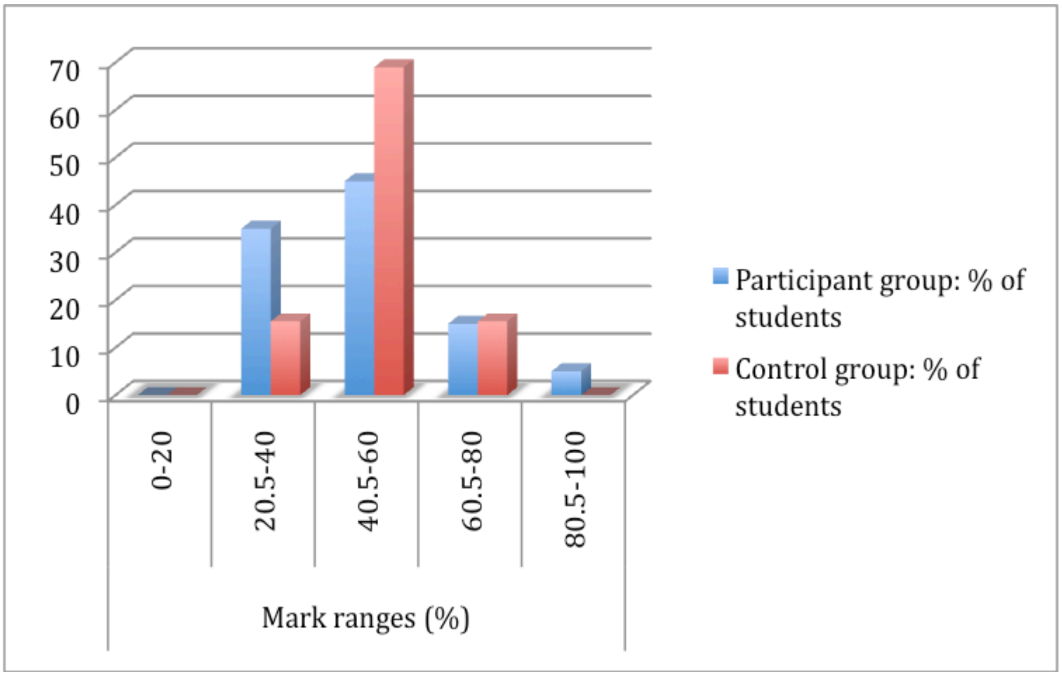
The results of the geometry fact-based questions are shown in figures 3 and 4 below. The percentage of students (vertical axis) in the participating group (blue) and control group (red) for each grade is shown. The horizontal axis marks the percentage range for answers so it can be seen, for example, that the Grade 2 participant group contained a greater amount of students who attained between 40.5-60% than the control group. However, the control group included more students who achieved higher marks (between 60.5-100%) in the prior learning assessment. In the Grade 2 assessment, therefore, the control group as a whole showed greater prior learning than the participant group. I will discuss the implications of this later on.

Fig. 3: *Percentage of Grade 2 students giving correct responses within given mark ranges* (%).



In the Grade 3 assessment, prior learning was generally shown to be less extensive than in the Grade 2 classes with less than 20% of students gaining over 60% correct answers in either group (fig. 4). The control group had significantly more students scoring within the 40.5-80% range than the participant group who had more diverse results, including over a third of the students achieving 40% or less.

Fig. 4: *Percentage of Grade 3 students giving correct responses within given mark ranges* (%).



The reasons for the differences in prior learning may be manifold and include such diverse factors as the teacher's approach and teaching style, or a child's access and exposure to information in various media. Due to time constraints, and for the purposes of this study, these reasons were not analysed. I was concerned primarily with the extent to which my teaching has affected student learning and been demonstrated throughout the unit and in the end of unit tests.

End of Unit Test

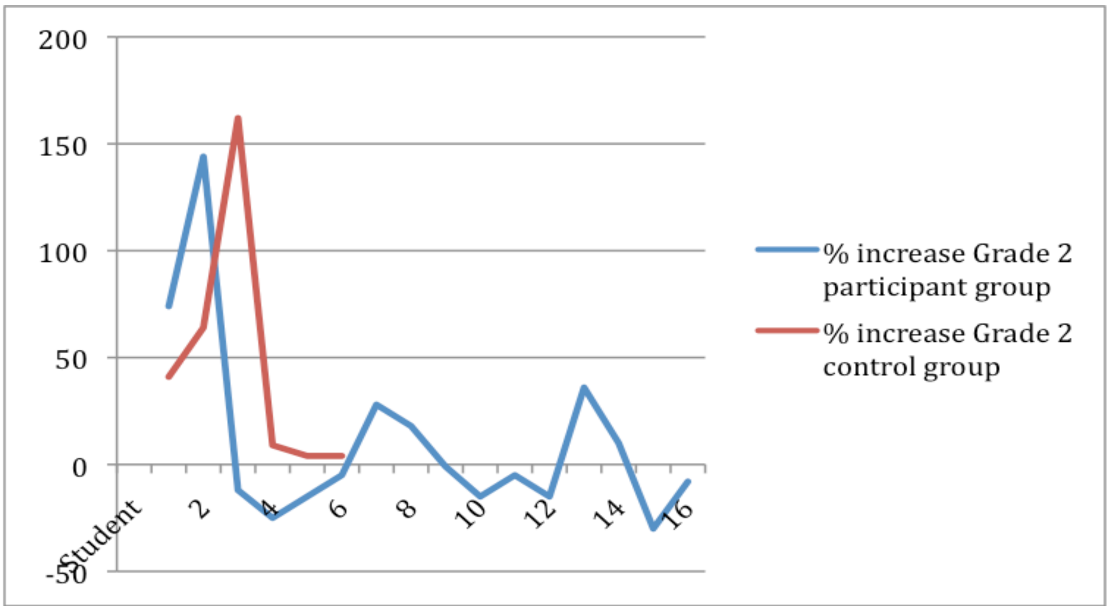
After the unit was completed, students took a test comprised of questions that mostly required single word answers. Students were also asked to construct a cube from marshmallows and sticks provided, choosing the right number of each item and building without assistance. The participant groups were also assessed informally as the unit progressed and I recorded physical and verbal responses after each lesson. Some of the observations were general, for example, recording the success of entire small groups in creating particular 3-D shapes. Other notes were on particular remarks or responses such as a student telling me what dimensions were and demonstrating his learning by showing height, width and depth of an imagined rectangular prism using gestures.

The written test was weighted 90% on written responses and 10% on the cube construction. As it is not usual in provincial testing to have a practical component, the weighting for this was comparatively small as I wanted to find out the degree of transfer from active learning to written responses and the effect that using dance as a learning tool may, therefore, have on standard tests. It was noticeable that every student in control and participant groups successfully built the cube (thereby gaining full marks for this), whereas the results of the written component were extremely varied. Some students improved on their prior learning assessment percentage substantially, while others showed a small change and still others appeared to show a decrease in knowledge. The percentage of increase – or decrease – in attainment is shown in the graphs below (figs. 5 & 6). These raw data outcomes, however, do not allow for the following factors concerning students taking the post-test:

- Students with low reading and/or writing ability,

- Students with test anxiety or emotional difficulties at the time of the test,
- Students who have behavioural or focus issues which may affect responses.

Fig. 5: *Percentage increases from pre- to written post-test (raw data): Grade 2*



In the Grade 2 classes, there was quite a variation in percentage increase or decrease from prior learning assessment to post-test. The control group contained one non-compliant student who had been very responsive in the prior learning (verbal) assessment, but who would not complete the written test. This left only six students for the control group and sixteen for the participant group.

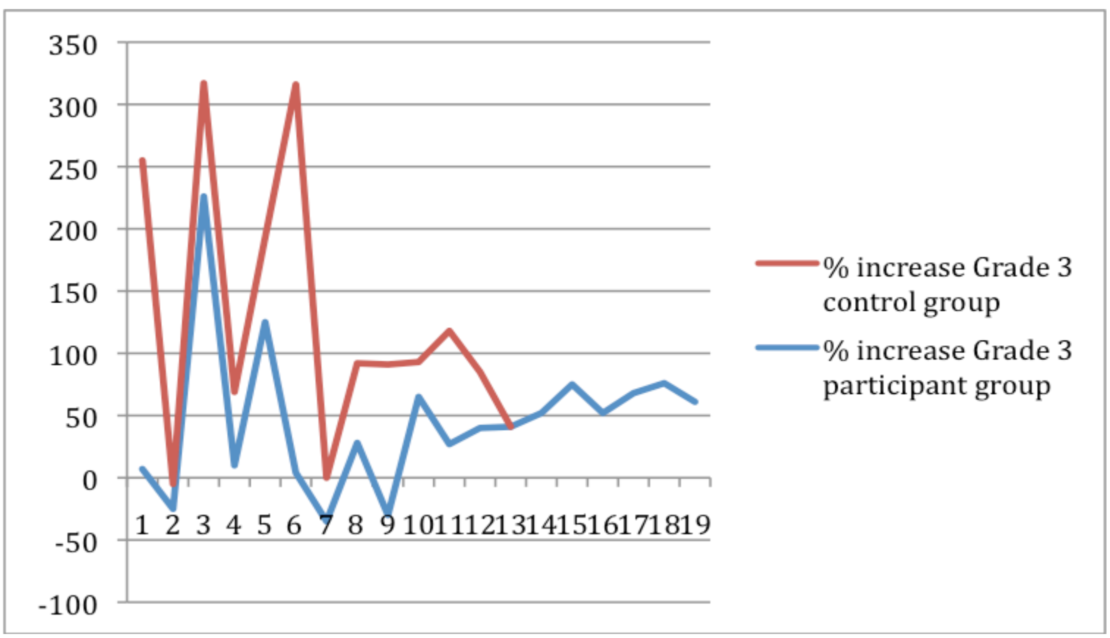
Just over a third of the participant group students showed an increase of 10% to 144% in scores from pre- to post-testing, although the other two-thirds showed decreased results of -1% to -30%. In the control group, small increases (below 10%) accounted for half of the students, the remaining half showing increases of 41%-162%. During their taught unit, written work and vocabulary words were used with the control group including a spelling test. During the post-test, they were also able to see the vocabulary used during the unit. The participant group did not have access to shape or concept words during the test. They also did not work on paper at all. This issue will be discussed in more detail in the following chapter.

Although it is not accounted for in the graphs above (figs. 5 & 6), there were students who have reading or writing difficulties or behavioural/focus issues which undoubtedly affected their test results. Two students in the Grade 2 participant group, for example, have low reading levels and have difficulty with written work. Their results were, as expected, low in the post-test (showing apparent decreases of -30% and -8%), whereas they both achieved over 50% in the oral-based prior learning assessment. Two of the Grade 2 control group children were also identified as having low reading ability, although one of these showed the greatest improvement in their group (162%). The other student only improved by 4%. Another control group child with a 4% increase was said to routinely have “test anxiety” and so this result was expected.

In the Grade 2 participant group, the majority of students were able to demonstrate their learning practically and orally (see fig. 7 below) but the results of the written test were less indicative of student learning. Skills transfer from practical to written responses was not achieved effectively in the majority of cases. However, the results of the written test were satisfactory in terms of overall school standards as the majority of students gained 50% or above. Of the four remaining students (scoring between 35% and 49%), two have a low reading level, and one has behavioural issues that hinder his work. The class teacher expected the results achieved for over half of the group, was disappointed by the results for three students, but was pleased with the unexpected enhanced attainment of four students. In the case of one child, there was a dramatic increase that surprised the class teacher.

Three participant students and one control group student were identified by their class teachers as having focus or behavioural issues which obstructed their learning generally and affected their participation in activities. These students all showed a percentage decrease in the written test and one student did not take it, yet they all scored around or above half marks in the prior learning assessment. For children in these situations, it is clear that written tests cannot be an accurate or sole indicator of learning. The implications of standard written testing methods (which are used in national testing at Grade 4 and 7) for such students will be discussed later.

Fig. 6: *Percentage increases from pre- to written post-test (raw data): Grade 3*

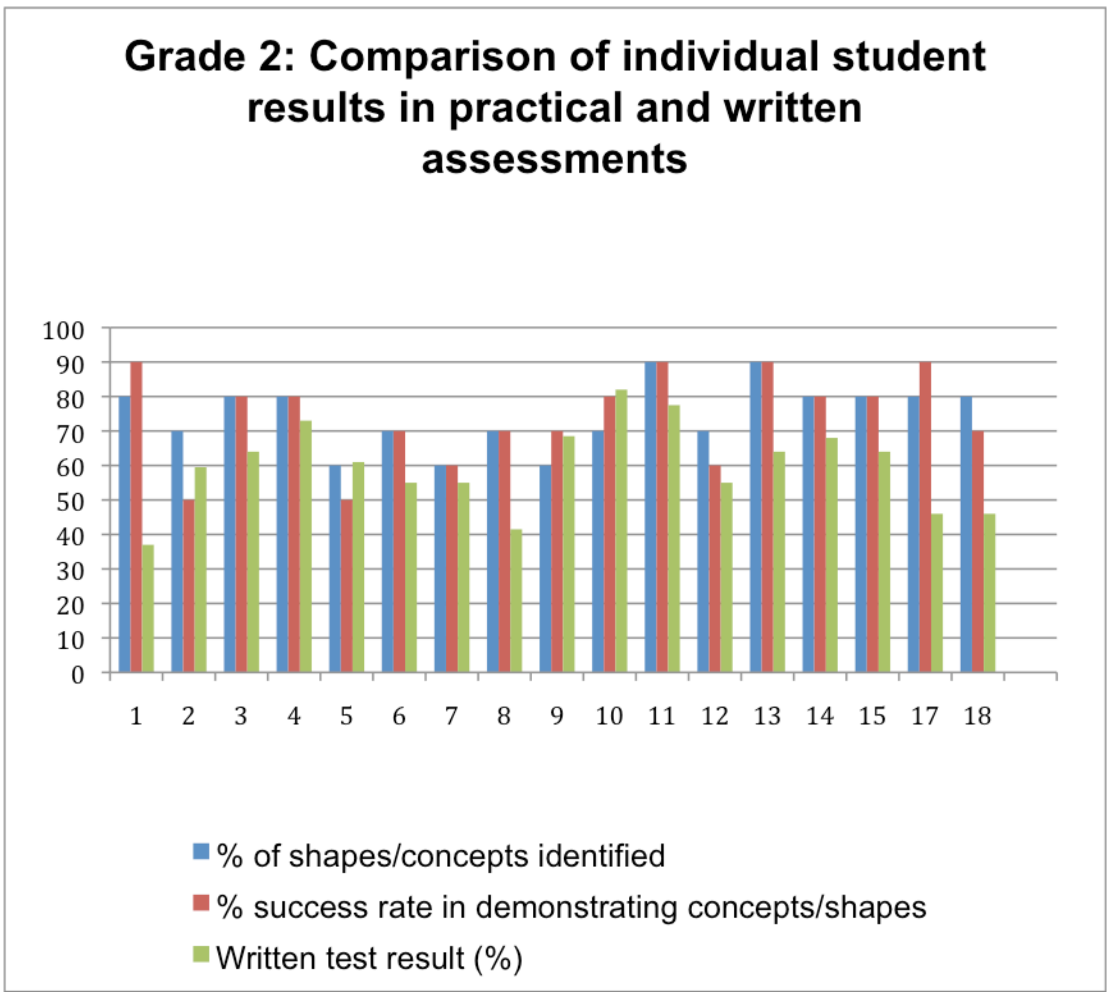


The graph above shows that there is, on the whole, a similar pattern of percentage increase within the two Grade 3 groups in the written test. The control group, who had done written work in their unit, generally showed a greater increase which could be expected due to the fact that the test used vocabulary and drawn images with which they were very familiar. The participant group had not worked with paper or written words/drawn shapes and so this was more of a challenge for them. Nevertheless, the results show that transfer of skills and knowledge do occur from kinesthetic learning, in the majority of cases, completely without written work.

The inclusion of a spelling test and the availability of unit vocabulary (within the classroom) during the control group test were not what I had anticipated or planned for. This gave them an advantage as some of the test might have been more like a multiple-choice exercise if students looked at the words and chose from the visible vocabulary. It is interesting that, despite the availability of the answer vocabulary and the greater amount of time spent on the unit by the control group (1/3 greater in total) the results are not widely different between the groups. This is especially relevant given that the starting points were also different; the participant group beginning the unit with less overall knowledge than the control group. I would anticipate, therefore, that the participant group, with extra time given to equal the control group class time, would show an even greater increase from their prior learning results.

The participant group contained students who exceeded the expectations of their class teacher, in some cases improving their score by over 100%. Around half of the students in the participant and control groups showed increases of between 40-75%. In both groups, there were increases for the majority of students. The average (mean) increase for the participant group was 45%, and the average increase for the control group was 98.5%. Also there were three who scored less than the prior learning test. In part, this may be due to the oral nature of the pre-test compared with the written nature of the post-test. It is, therefore, important to examine oral and kinesthetic responses. These are compared with the written test results in figures 7 and 8 below.

Fig. 7: *Comparison of Grade 2 written and practical assessment results by student.*

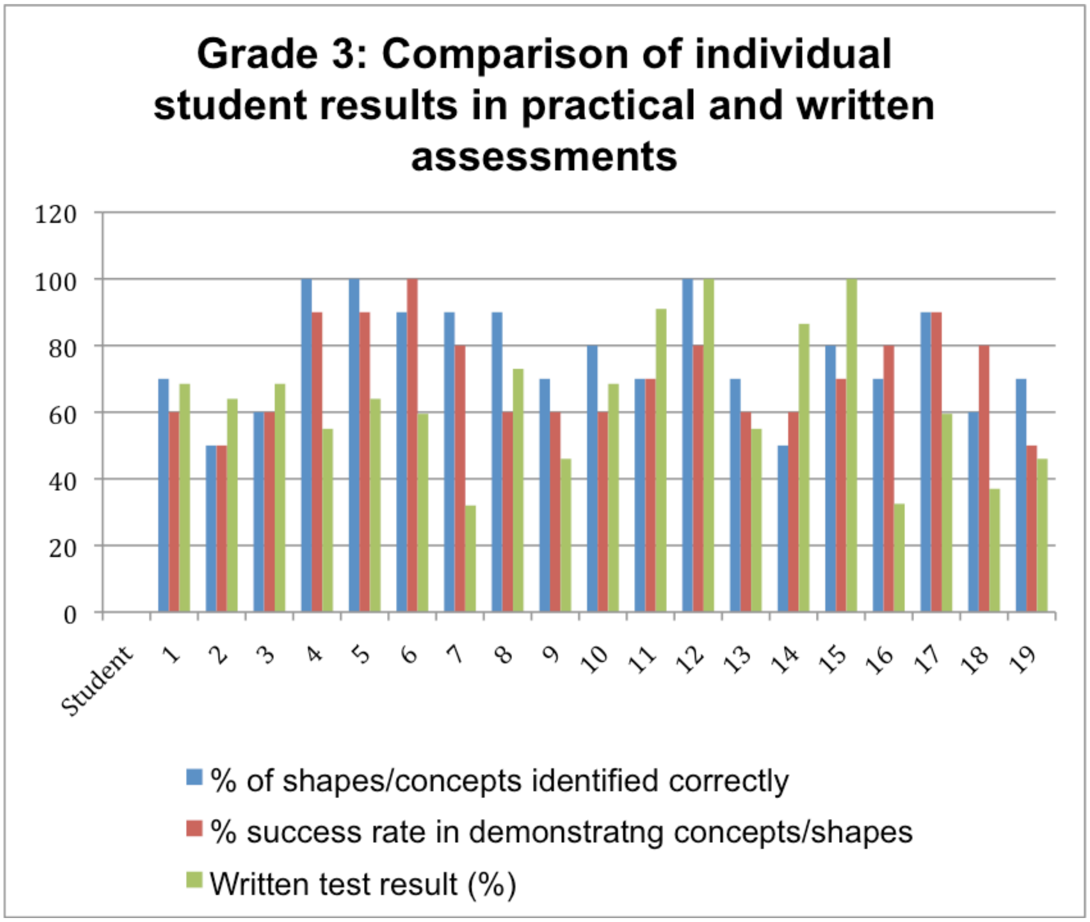


The graph above shows the percentage of shapes or concepts correctly identified verbally (blue), the approximate success rate in demonstrating concepts or shapes during the unit (red), and the written test result (green) for each student. For the identification of concepts/shapes, each student was asked ten questions during the unit. Those who were absent on certain days were graded on the number of questions they had been asked. Also, due to the nature of some of the projects, the demonstration of concepts was often done in small groups. For this reason, this element (red column) is an approximate grade from my observations during individual and small group work. Results in this area are varied because co-operation was necessary as well as a personal understanding of tasks and concepts. Students who found it difficult to co-operate with others, despite changes in the composition of the small groups, often did not complete work as well as they did in individual tasks. This meant that I had to assign a lower mark based on what was demonstrated as they did not co-operate sufficiently to perform group tasks well although it was possible that these students might *know* how to complete tasks. Students 2, 5, 12 and 18 fall into this category.

It can be seen that few students did better on the written test than in either the practical or verbal assessments, the majority performing better in demonstration and oral responses. Students 1, 2, 13, 17 and 18 had significantly better results in demonstration and oral responses than in the written test revealing that, for these students, their knowledge and understanding did not translate well to the formal test situation. This is especially relevant as students 1, 2 and 13 had been identified as having focus/behavioural issues, and students 17 and 18 have low reading skills.

A comparative analysis of the Grade 3 results follows.

Fig. 8: *Comparison of Grade 3 written and practical assessment results by student.*



In the Grade 3 participant group, the majority of students were able to identify shapes and concepts and demonstrate them well. In the last session, all students were able to identify any of the 3-D shapes presented which revealed that they had mastered this aspect of learning. A couple of students (2, 19) found it difficult to work with a group or individually in creating shapes and using concepts such as transforming nets into three dimensional forms. However, these students struggled generally with co-operating with a group, one due to emotional sensitivity, and the other because of behavioural difficulties. This participant group contained two students who scored 100% on the written exam. This was not achieved by any of the control group. Approximately half of the students showed positive results in the written test that were improved from one or both of the practical areas assessed, showing a good measure of transferred knowledge and understanding. This contrasted with the Grade 2 group who showed little transfer of knowledge. Teaching using solid manipulatives and props was clearly a more effective approach. As students were able to see, physically experience and explore the shapes, there was more opportunity for understanding and connecting knowledge with application. Almost half of the students did not perform well in the written test, however, even though they could identify shapes and concepts and use these in their practical work. In some cases (7, 16), the post-test score was considerably less than the one for practical work. For these children, the type of assessment used is clearly important in order to show their true knowledge and learning. I will address this issue in the following section.

In the Grade 3 class, the approach I used was more successful in providing for skills transfer which translated well to the written test. Around half of the students achieved similar results in the practical/oral and written assessments. While 5 out of 19 students performed relatively poorly (below 50%) in the written test, the majority of students scored well, including 21% achieving marks in the A grade range (letter grade assessments begin in Grade 4, but this is a useful indicator of standard test ability) or attaining “exceeds expectations” for the grade level. (See Appendix E for letter grade percentage ranges.) Some students performed considerably better in practical tasks and oral responses than in the written test. For such students, it is essential that assessment should not be limited to written work as they can clearly demonstrate their knowledge and understanding, but find it a challenge to put this in writing.

In terms of teacher expectations, the Grade 3 participant group students achieved the results expected by their class teacher in most cases. Of the four students who did not do as well as she had expected, one was experiencing emotional difficulties around the time of the test which might account for lower marks than anticipated. The control group achieved the expected results.

On the whole, I gained better results using visual aids in addition to exploring shapes and concepts kinesthetically rather than using dance and physical exploration of shapes and concepts alone. This may be due to different areas of the brain being engaged in learning when both visual and physical awareness and reinforcement were used thus creating a greater chance of learning and understanding. This was in line with Reed and Diamond's studies as discussed in my literature review (11-12). I was not able to verify this, however, within the scope of my study. Also, the majority of students in both participating classes were able to demonstrate their learning effectively through practical and oral means, with most students attaining percentages within ranges equating to pass marks in the written test. Of those not achieving 50% or above, there were a high proportion of students with low reading levels or focus/behavioural issues which provided an obstacle to written work.

Enjoyment of Mathematics and Attainment.

Earlier, I cited Humphrey, Reed and Sousa who posit that a correlation exists between enjoyment of a subject and the test scores. In order to discover if this was the case for my study, I recorded the students' perceptions of their usual mathematics classes (during the prior learning assessment) and those where I used dance (following the unit). Along with the written test, I also provided a space for students to write comments about their experience of the dance unit. I also recorded some of their responses during the study. I was not present during the test, which was administered by their class teachers, and the students were not told that I would view their responses. I felt that this encouraged them to be honest rather than saying what they thought would please me. The percentage responses are tabulated for each grade below (fig. 9). As there were no notable differences between results and responses of boys and girls, I have not included results by sex.

Fig. 9: *Student enjoyment of mathematics classes with and without dance, and the nature of comments regarding the dance unit.*

Grade 2

Perceptions of mathematics	***Using usual teaching methods (% of students)***	***Using Dance (% of students)***
Like	***65***	***55***
Sometimes like	***15***	***10***
Do not like	***20***	***30***
No response	***0***	***5***
Positive comment about dance unit	***n/a***	***75***
Negative comment about dance unit	***n/a***	***0***
No comment	***n/a***	***25***

Grade 3

Perceptions of mathematics	***Using usual teaching methods (% of students)***	***Using Dance (% of students)***
Like	***40***	***68***
Sometimes like	***45***	***32***
Do not like	***15***	***0***
No response	***0***	***0***
Positive comment about dance unit	***n/a***	***76***
Negative comment about dance unit	***n/a***	***0***
No comment	***n/a***	***24***

As the tables above show, three quarters of the students in each grade gave positive responses to the dance unit while no students made negative comments. A quarter of the students did not write a comment – this included the two students with low reading/writing levels. Written comments ranged between, “It was OK”, to “It was cool/good/fun”, and “I loved it”. However, these perceptions did not equate with how difficult the students found learning geometry through dance or with test results. For this reason, I have included a comparison of students’ perceptions and attainment below.

Fig. 10: *Student perceptions of level of difficulty in learning mathematics through dance compared with enjoyment reported and attainment-Grade 2.*

Grade 2 Participant Group

Student	Enjoyed dance unit	Enjoyed learning math through dance	Difficulty of learning math through dance	% in written paper	% in oral & practical combined	Student issues identified by class teacher
1	Yes	Yes	Easier	37	80	Focus/behaviour
2	Yes	No	Harder	59.5	60	Focus/behaviour
3	N/C	Yes	Harder	64	80	
4	Yes	No	Easier	73	80	
5	Yes	No	Easier	61	55	
6	N/C	N/C	N/C	55	60	
7	Yes	Yes	Easier	41.5	70	
8	Yes	Yes	Easier	68.5	65	
9	Yes	Yes	Harder	82	75	
10	Yes	Yes	Easier	77.5	90	
11	Yes	No	N/C	55	65	Focus/behaviour
12	Yes	No	Harder	64	90	
13	Yes	Yes	Easier	68	80	
14	Yes	Yes	Harder	64	80	
15	N/C	Yes	Easier	46	85	Low reading level
16	N/C	Yes	Easier	46	75	Low reading level

N/C = No comment/response

The results in the table above (fig. 10) show that all of the Grade 2 students who responded enjoyed the dance unit even though around a third did not enjoy learning geometry using dance. There was also no distinct correlation between enjoyment of dance or the dance geometry unit and whether students perceived it as easier or harder to learn mathematics using dance. Some students, for example, said that they found it easier to learn mathematics using dance and yet did not enjoy doing so (students 4 & 5), while others answered the opposite (students 3, 9 & 14). There was also no apparent effect on assessment results for those who, for example, said they enjoyed dance or found it easier. For this class, then, perceived enjoyment or level of difficulty in learning did not seem to bear any relation to outcomes achieved. It is clear, however, that the majority of students thought it was easier to learn mathematics using dance (64% of those who responded compared to 36% who found it harder). Those with low reading levels also found it easier to learn geometry using dance and achieved good practical results which contrasted with their lower marks in the written test.

Fig. 11: *Student perceptions of level of difficulty in learning mathematics through dance compared with enjoyment reported and attainment-Grade 3.*

Grade 3 Participant Group

Student	**Enjoyed dance unit**	**Enjoyed learning math through dance**	**Difficulty of learning math through dance**	**% in written paper**	**% in oral & practical**	**Student issues identified by class teacher**
1	Yes	Some	Harder	68.5	65	
2	Yes	Some	Same	64	50	Fragile Emotions
3	Yes	Yes	Easier	68.5	60	
4	Yes	Yes	Harder	55	95	
5	Yes	Yes	Easier	64	95	
6	Yes	Yes	Easier	59.5	95	
7	Yes	Yes	Same	32	85	Focus
8	N/C	Yes	Easier	73	75	Focus
9	N/C	Yes	Harder	46	65	
10	Yes	Some	Easier	68.5	70	
11	N/C	Yes	Easier	91	70	
12	Yes	Yes	Same	100	90	
13	Yes	Some	Easier	55	65	
14	Yes	Yes	Harder	86.5	55	
15	Yes	Some	Same	100	75	
16	Yes	Yes	Same	32.5	75	
17	Yes	Yes	Easier	59.5	90	
18	Yes	Yes	Harder	37	70	Low reading level

19	N/C	Some	Harder	46	60

N/C = No comment/response

All of the Grade 3 students who responded enjoyed the dance unit and enjoyed learning geometry through dance some or all of the time. Slightly more students found it easier to learn using dance (42%) than harder (31%) while 26% felt it was as easy or hard as learning using their normal class methods. As with the Grade 2 class, there was no correlation between the amount of enjoyment and how easy or hard it was to learn geometry using dance. Similarly, there appears to be no correlation between enjoyment, level of difficulty perceived and attainment. This is contrary to the views I explored in the literature review expressed by Humphrey, Reed and Sousa who relate achievement to pleasure. It is possible that, in a larger sample size or different environment these results would be at variance. However, it is significant that the achievement of my students seemed to bear little relation to their level of enjoyment or to how difficult they found learning mathematics through dance.

Conclusions

From the results of this study, there is no evidence to suggest any relationship between enjoyment of dance or of learning through dance and attainment, these findings being contrary to the views of researchers as I expressed above. Although pleasure may be a motivation for learning, as the research of Maslow and Elton suggests (Lit. Review, 11), actual acquisition of knowledge, learning and achievement seem, according to my data, to be unaffected by levels of enjoyment. Furthermore, students' perceptions of how easy it was to learn geometry using dance have no obvious bearing upon assessment results. Students were able to differentiate between enjoying the dance unit and their enjoyment of learning mathematics through dance. They were also able to express whether this style of learning was easier, harder or as easy/hard as their usual classroom learning methods.

More students enjoyed mathematics than had done so before the study and felt that it was easier to learn the subject using dance. For example, every student in the Grade 3 participating class enjoyed the dance unit some or all of the time. Interestingly, several teachers in the school assumed that girls would enjoy the dance more than boys but this was not the case. As I chose music and dance styles that I thought would have a broad appeal (Research Design, 28), I expected that students would prefer different styles and, therefore, enjoy their learning as a result. My findings suggest that the preferences of students were not important. If theories such as Gardner's *Multiple Intelligences Theory* and Sousa's work on memory being affected by motivations and emotional states are valid (Lit. Review 12, 15), then learning preferences and enjoyment would have had a greater impact on achievement than was evident in my findings. As it was, neither the preferred learning style, nor emotional responses to music, nor enjoyment had any noticeable effect on the outcomes.

The approach I used for the Grade 3 class was more successful than that used for the Grade 2 class in providing for skills transfer which translated well to the written test, however, using dance alone showed a similar pattern of improvement in standard written test scores to strategies normally used such as paper-based and manipulative exploration. Including visual aids as part of the dance unit proved more effective in helping children understand shapes and concepts. A higher percentage of students were able to identify and demonstrate understanding of the geometry unit practically and/or in the written test when visual aids and more detailed explanations were included. Both approaches, however, were successful in creating an overall improved understanding of geometry in demonstration, and the test results showed that the use of dance without any written work translated into reasonable overall written test results and, in the case of the Grade 3 class, mostly good to excellent results. This skills transfer is an indication that learning and motor skills may be interrelated as the research of Diamond (2000) suggests. All students in this class were verbally able to identify all solids in the IRPs by their last class and some could also work out the names of other solids using knowledge gained of terms and 2-D shapes (e.g. octagon becomes an octagonal prism in 3-D). Such use of higher thinking skills was encouraged by the use of frequent problem-solving in the assigned tasks which probably contributed to the successful application of these skills. For some students, using the dance unit alone was sufficient to provide all of the knowledge and understanding required to gain full marks, while other students would probably have benefited from an approach which included some written or visual-based work.

For those with focus issues or low reading ability, the written test was not well done, whereas the majority of these students were able to display their knowledge in practice and in oral response to questions. Standard style written tests are, according to my research, not sufficient to show learning for those struggling with writing or reading comprehension. Catterall's suggestion that experiential reinforcement is required for deep learning, as I explored in my literature review (8), certainly seems to apply to my students, most of whom were successful in increasing their knowledge and applying it kinaesthetically. If all of them are to do well in future written tests, though, several children need to be schooled in how to translate this knowledge into written form. Of course, this only requires attention if written forms of assessment remain mandatory. This issue is addressed below.

ISSUES ARISING

The main issues arising during my research fall into the following categories:

- Unexpected deviation from the agreed schedule
- Altered test conditions between control and participating groups
- Differences between the oral nature of the prior learning assessment and the written one of the post-test
- Questions regarding the effectiveness and value of written testing

Unexpected deviation from the agreed schedule.

Prior to commencing the research project, the class teachers and I agreed upon a schedule which would work for all of the teachers and myself. This included a four week period in which 7 x 30 minute lessons would be taught. At the end of this period, the students would then be given a unit test developed collaboratively with all the teachers concerned directly after the end of the unit.

Although the participant class schedules went as planned (apart from one interruption due to a fire drill), the control group teacher found it necessary to start the unit later and to do three consecutive days (Tuesday-Thursday) for three weeks with the test on the ninth day. Also, the lessons were 40 minutes long providing the control class with 33.3% more tuition than the participant classes. This condensed time period along with a greater amount of time spent on the unit gave the control group a probable advantage causing a greater margin of improvement from prior learning to post-test results.

<u>Altered test conditions between control and participating groups.</u>

The test was due to take place immediately after the dance unit. However, due to the altered control group schedule, the participating groups had a 1½ week wait before the test whereas the control group took the test the day after completing the unit. The test was taken by all of the students on the same day. In the classroom, the control group were able to see the vocabulary for shapes and concepts around the room (without pictures) whereas the participant groups had none. This could make the first section of questions easier to answer because the words were readily available, thus giving a multiple-choice effect rather than testing what was remembered and known. There was no advantage, however, for showing understanding in other parts of the test and some of these questions were less well answered by the control group.

<u>Differences between the oral nature of the prior learning assessment and the written one of the post-test.</u>

In order to carry out research in a public school, I was required to keep testing to a minimum, ensuring that students were not put in stressful circumstances. In order to assess prior learning as well as analysing results after the unit, I carried out an informal prior learning assessment orally. For more authentic quantifiable results, it would have been better to have a similar format pre- and post-test rather than one being oral and the other written. To help address this problem, I used some oral-based assessment strategies during the unit lessons. This involved asking questions about shapes and concepts. This, naturally, could not give a totally accurate picture of the transferability of skills from practical dance work to the written test.

Questions regarding the effectiveness and value of written testing.

Although teachers use a combination of methods to assess students, the Ministry of Education in Canada uses written tests to rate student, school and province-wide progress in meeting targets for mathematics and other subjects. This is exemplified in the *Foundation Skills Assessment* (FSA) papers that Grade 4 and 7 students sit. Evidence from the results provided to the provincial and federal governments is based purely on these written papers and does not consider other types of assessment despite the recognition that the FSA "is only one measure of student learning" (25) and that teachers hold an important role in classroom assessment. As these FSA assessments are held as indicators of how well individual schools, districts and provinces are teaching foundation skills of mathematics, it is a concern that some students who take the test, or their schools, may be perceived as failing. My research, for example, shows students whose knowledge apparently decreased or who did not show progress in their written test answers. Although none of the students are officially recognized as having special educational or behavioural needs (which would mean they could be eligible for exemption from, or have help in, the FSA and other tests), there are problems with merely taking this as a final result.

As there is often a marked difference between attainment in written and practical/oral forms of assessment as indicated by my study, it brings into question the validity of such measures and the weight which the results carry in educational policies and practices. The Grade 2 participant class teacher, for example, identified two students who find reading a challenge and whose written work was also not strong. Although these students were able to answer questions verbally and could demonstrate their learning physically, they were not able to translate this to the written part of the test.

EVALUATION OF THE IMPACT OF THE RESEARCH

The results of this study were mixed. Most students achieved good results overall in the written and practical assessments, while some students struggled to translate practical learning into written test responses. None of the participating students had been drilled to perform well in the test, a practice which many teachers feel pressured to do prior to national (and other) tests so that school results are acceptable (Volante 2004). I believe that a combination of written and practical assessments gives a more accurate picture of what students have learned. Knowledge demonstrated rather than memorised facts regurgitated surely provides a better representation of authentic learning and understanding. For example, all of the Grade 3 students and most of the Grade 2 students were able to display their learning clearly during their final lesson by forming shapes named, describing and demonstrating concepts and identifying solids. If the assessment had been solely based on *applied* understanding (measured during the last lesson), the results would have been very good and, in some cases, exceptional, with the majority of students performing well. This contrasts with the written test results. Using a more holistic, all-embracing learning assessment which includes verbal and practical elements would be beneficial for students and would, as the results of my research show, provide a better measure of achievement than written tests alone.

More students said that they enjoyed learning mathematics using dance than had done so in their normal classroom experience, but enjoyment of dance or learning mathematics through dance did not appear to correlate with attainment. Although the control group showed greater improvement in results from prior learning to post-test, this group also had one third extra class time. The participant group may have shown the same improvement given the same time as the control group as the pattern of improvement was similar. The class teachers are keen to incorporate dance into the teaching of mathematics as the majority of students found the unit enjoyable and teachers feel that the majority of students will achieve better results than using their normal methods alone.

As I stressed in my literature review, I agree, in part, with Eisner that the arts should not be justified instrumentally. I used choreography which the children performed and successfully included mathematical concepts in my lesson therefore I conclude that dance can be used as a teaching tool *and* maintain its unique aesthetic and artistic qualities. In this way, it is not a justification, but rather an added benefit that mathematics can be taught while teaching dance. This was illustrated by my students' enjoyment of dance, including their enthusiasm in sharing (performing) their work, and, in addition, many found it useful for learning. My research also helps to show that there is an important role for a dance specialist and, likewise, of other dance specialists. I liken this to music education where a generalist classroom teacher may help the children with making basic rhythms on small percussion, but the skilful beauty of melody-making, phrasing and dynamics is taught by specialist teachers.

Additional Findings and Conclusions Beyond the Research Questions

From my study, it is clear that the use of standard written tests as measures of attainment are not an accurate indication of how well students understand tasks or can achieve learning outcomes. In life situations this is also the case. It would, for example, be unreasonable to expect a person to drive a car safely with only the written test and without practice and demonstration of skills in a test. Why should educational bodies and the public, then, expect that written examinations and tests provide an accurate assessment of learning or a school's, district's or province's success in reaching targets for learning and teaching? Perhaps it is because quantitative data is easier to measure, having exact calculable results. Such tests also reduce the variation and subjectivity possible in teacher assessments but the possibility of teaching to the test increases. If teachers are trained well to teach and measure using a variety of assessment methods, they should be trusted to accurately report this learning. The responsibility for training teachers in assessment methods could be taken up by districts or provinces and used as a focus for professional development days. In addition, end of unit tests, usually taken only once, are open to results being affected by the emotional, physical or mental state of the student. In my study, this was true in the case of at least one student who had known emotional struggles in the week of the test and who, subsequently, performed more poorly than was normally expected. As there was no opportunity to retake the test at a more appropriate time for the individual, the results could not be improved upon. This could be detrimental to the student's progress as she could equate lower marks with being unable to do well in the subject if no other assessment was done to counteract this.

Physical demonstration, oral responses and practical tasks are necessary to gain a fuller picture of a student's knowledge and understanding as not all students are able to express their understanding effectively in written responses. As I expressed above, the application of learning is, I believe, more important than mere head knowledge. This is especially true for those who have low reading ability or have other medical, emotional or social issues which affect the ability to focus when seated at a desk writing. Some in the control group also had test anxiety in spite of only being seven or eight years old. Previous poor results or other reasons may have triggered this anxiety although I would need to establish the cause in order to help these students overcome this. It is unlikely that these children would thrive in a written test. Oral assessment or physical demonstration would probably be less threatening for them and would give a truer indication of applied knowledge and learning. Indeed, if students' learning preferences are catered for, as promoted by Gardner and his followers, why not also include different government assessment structures?

The Future: Implications for the school, district and my own teaching

As the majority of schools that I have worked in have rarely or never used dance or arts to teach mathematics, as encouraged in the IRPs (*Mathematics Grade 2*, 33), I have opened up a new approach in the local area. It is certainly a new way of interdisciplinary learning in that I used choreographed dances as well as exploration of concepts through movement tasks in order to teach geometry rather than focusing on more static representations and use of floor patterns that I mentioned have often been employed (Lit. Review, 16). In this way, I feel that dance is not reduced to movement for the sake of teaching mathematical concepts, but holds an equal status in the interdisciplinary partnership. Due to the constraints of this study, I did not assess learning in the field of dance although it is clear that students learned dance concepts related to mathematical ones such as the use of patterns, shapes and space. I would, therefore, be interested in comparing learning and achievement in dance as well as mathematics using a similar study. I also think it would be useful to adopt this interdisciplinary approach for other areas of mathematics. I found that the children and school staff responded well to the project and would be willing to embrace more collaborative teaching involving dance. This could lead to further work with this and other schools in the district. I have shared some of the findings informally with the school and class teachers involved and will be recommending further dance integration work to the district following the results of my research as well as encouraging further studies as outlined below. I will provide a report on my findings and a copy of my dissertation to the school district and school. They will be able, therefore, to see the results and recommendations and my hope is that they will be encouraged to use dance to enhance the learning experience of all elementary school students.

AREAS FOR FURTHER STUDY

As my study was on a small scale, it would be valuable to do a larger scale study involving more schools in the district, using whole grade classes for experimental and control groups. In a longer study it would also be possible to use switching replication design where participant and control groups are switched following the unit, thereby giving a more accurate picture of each group's ability to learn and demonstrate their learning by using dance and usual teaching methods.

Further research needs to be done to assess the success of combining regular classroom teaching methods, including some written/drawing work in addition to using dance as a teaching tool. In my study, I focused on using dance as a tool without usual class teaching. However, it would be useful to measure the success of using dance with visual aids and explanation (as I used with the Grade 3 class) versus using dance alongside regular class teaching methods.

I would also like to see collaborative research involving neuroscientists, mathematicians and dance teachers. With my research, for example, it would have been interesting to engage in the prior learning assessment using scientific measures such as the *Quantile Framework* (Metametrics 2001, n.p.). The imaging of brain activity through an advanced transportable form of positron emission tomography (PET) or another imaging technique would also be interesting to explore, if technology develops sufficiently to do this, in order to establish which areas of the brain are engaged in learning when using dance or mathematics individually compared with studying them together as in my research. In this way, educational and dance practitioners might be able to develop more effective teaching strategies through a greater understanding of brain functions in dance, mathematical and integrated activities. Ethical and financial considerations for these types of study would need to be examined as such testing and imaging would be costly and potentially invasive.

In addition, I would value having more in depth input from students and teachers to establish a more complete knowledge of each student's prior learning. If we could more accurately measure and take account of learning preferences, emotional states and other factors that can affect learning, strategies could be developed to help each child learn effectively. Again, ethical standards would need to be considered in gathering this information.

APPENDICES

Appendix A: Prior Learning Assessment. Student responses

Key

Questions 1-7 (identification/understanding of 2-D & 3-D shapes and concepts)

√ = response totally correct
Pop = recognized but not understood
√x = 1 response correct, 1 incorrect
pt = partly correct
x = responses incorrect

Question G1 (whether the student likes math)

N = no
Y = yes
S = sometimes/some topics

Question G2 (how students prefer to work) & G3 (how students try and remember things)

Write/paper = using paper/writing
Head = thinking through/solving "in my head" (without writing down)
Hands/do = using hands-on methods, body or manipulative materials

Grade 2 students

Grade 2	Q1	Q2	Q3	Q4	Q5	Q6	G1	G2	G3
Participant group									
2AB1	Pop	√	√	**√x**	x	x	N	write	head
2AB2	"	√	√	√	x	√	Y	write	head
2AB3	"	√	x	√	**√x**	√	S	hands	write
2AB4	"	x	x	x	x	√	N	paper	write
2AB5	Ab								
2AB6	"	√	x	**√x**	√	√	**Y**	head	head

2AB7	√	√x	x	√x	√x	√	Y	hands	head
2AB8	√	√x	x	√	√x	√	S	hands	head
2AB9	pop	√x	√x	√	√x	√	Y		
2AB10	“	√	x	√	√x	√	N	head	Write/do
2AG1	“	√	x	√	√	√	Y	head	write
2AG2	x	X	√x	√	x	x	Y	Hands/head	head
2AG3	Ab								
2AG4	x	√x	√x	√x	√	√	N	paper	write
2AG5	pop	√	√	√	√x	√	Y	head	head
2AG6	√	√	√	√	√	√	Y	head	head
2AG7	x	√	√	√	√x	√	Y	head	head
2AG8	x	√	√	√	√x	√	Y	head	head
2AG9	Ab								
2AG10	x	√x	x	√	√x	√	Y	hands	head
Control group									
2BB1	√	√	√x	√	√	√	Y	all	head
2BB2	X	√x	x	√	√	√	Y	head	do
2BB3	Pop	√x	x	√	√	√	S	hands	Head/do
2BG1	“	√x	x	√	√	x	S	write	write
2BG2	“	√x	x	√	x	√	S	head	head
2BG3	“	√x	√x	√x	√	x	N	hands	do
2BG4	“	√x	x	√	√	√	N	hands	head
2BG5	Ab								

Grade 3 Students

Grade 3	Q1	Q2	Q3	Q4	Q5	Q6	Q7	G1	G2	G3
Participant group										
3AB1	pop	x	√	√	√	√	pt	N	hands	depends
3AB2	pop	x	√	√x	x	x	x	Y	paper	Do/write
3AB3	√	x	/x	x	/x	x	pt	S	hands	write
3AB4	√	x	√	√	√	x	pt	Y	head	head
3AB5	√	x	x	√	x	√	pt	N	write	head
3AB6	pop	x	√x	√	√	√	x	Y	Paper/hands	head
3AB7	pop	x	√x	√	x	√	x	Y	head	head

3AB8	√	x	√	√	√	√	x	Y	head	head
3AB9	√	x	√x	√	x	x	x	S	head	head
3AB10	√	x	x	√	x	x	x	S	head	head
3AG1	√	√	√	√	√	√	x	Y	hands	depends
3AG2	pop	√	√	√x	√	√x	x	Y	paper	planner
3AG3	pop	√	√	√	x	√x	x	Y	head	write
3AG4	√	x	x	√	√	√	x	S	hands	write
3AG5	√	x	√	√	√	√	x	S	paper	Head/write
3AG6	pop	x	√x	√	√	√	x	S	hands	head
3AG7	pop	√	√	√	√	√	x	S	paper	head
3AG8	pop	x	x	√	x	x	x	S	paper	write
3AG9	pop	x	√	√	√	x	√x	N	head	write
3AG10	pop	x	x	√	x	x	x	S	write	write
Control group										
3BB1	pop	x	x	√	√	x	x	N	hands	head
3BB2	pop	x	√	√	√x	√	x	Y	paper	head
3BB3	spe	x	√	√	√x	√x	x	Y	paper	head
3BB4	√	√x	√	√	√	x	x	N	hands	Write/do
3BB5	pop	√x	√x	√	√	x	x	Y	Head/hands	head
3BB6	pop	√x	√x	x	x	√	x	Y	hands	do
3BG1	pop	x	√x	√	x	√	x	S	hands	head
3BG2	pop	√x	√x	x	x	x	x	S	hands	head
3BG3	pop	√x	√x	√	√	√	x	S	hands	head
3BG4	pop	√x	√x	√	√	√	x	S	paper	head
3BG5	√	x	√x	√	x	√	x	N	paper	head
3BG6	pop	x	x	√x	√	√	x	Y	paper	head
3BG7	pop	x	x	√x	√	√x	x	Y	paper	write

Appendix B: Grade 2 and 3 first lesson plans

Lesson Title: Making shapes Grade 2: Cubes

Date: 28.03.11

Concept: Identify & make shapes in groups and as individuals

Learning outcomes (BC IRPs): Shape & Space 2D & 3D – square, cube

General Goal(s):

- Identifying and making cubes and squares
- Counting, estimation & calculation

Specific Objectives:

- Counting sides, calculating pupils needed to make shape
- Making human cubes in groups

Required Materials: 8 dice, square dance music: *Cotton-eyed Joe*

Introduction: Cubes; what are they?

Warm-up: In a square, 'follow the leader' warm up: students follow teacher

Lesson activities:
Ice cube game (variation of freeze dance): getting into cubes when music stops.
Trying to make a cube with number of pupils rolled on dice (in groups)
Square dance: teaching a choreographed dance based on squares & cubes.

Cool down & Reflection: Questions about sides of cubes/squares and reflections on what worked best to make shapes. Any other cubes identified in everyday life.

Dance, P.E, Mathematics concepts/skills covered:

Dance	*P.E.*	*Mathematics*
Pattern, direction	Pattern, direction	Pattern, shape
Control, choreography	Locomotor/non-locomotor	Cube, square
Shape, group work	Co-operation, leadership	Estimation
Dance style, rhythm	Use of space, safety	Calculation, vertex
		Edge, face, side

Lesson Title: Making shapes Grade 3: Quadrilaterals & Prisms

Date: 28.03.11

Concept: Identify & make shapes in groups and as individuals

Learning outcomes (BC IRPs): Shape & Space 2D & 3D – quadrilateral, rectangular prism

General Goal(s):

- Identifying and making quadrilaterals, prisms
- Counting, estimation & calculation

Specific Objectives:

- Counting sides, calculating pupils needed to make shape
- Problem-solving to create rectangular prisms in groups

Required Materials: CD *The Quadrilateral Dance,* solid shapes, elastic

Introduction: From rectangle to quadrilateral to rectangular prism

Warm-up: Forming rectangles – taking them up, down with levels and body. And 'find the shape' game using shapes and blocks.

Lesson activities:
How can we make it a prism? Group work problem solving with bodies: building from flat (on floor) rectangle, to make a human prism. Elastic quadrilaterals.
Quadrilateral dance – teaching choreographed dance.

Cool down & Reflection: Questions about sides of shapes and reflections on what worked best to make shapes. Vertices, sides.

Adaptations/extensions needed: pupils divided themselves equally on 4 sides

Dance, P.E, Mathematics concepts/skills covered:

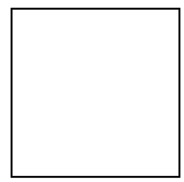
Dance	*P.E.*	*Mathematics*

Pattern, direction	Pattern, direction	Patterns, shape, vertex
Control, choreography	Locomotor/non-locomotor	Quadrilateral
Shape, group work	Co-operation, leadership	Rectangular prism
Dance style, rhythm	Use of space, safety	Problem-solving
division		Edge, face, side

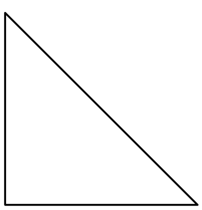
Appendix C: Geometry Unit Tests

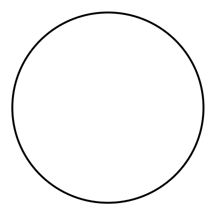
Geometry
Grade 2

Name these shapes:



1._________________________ 2.____________________________





3.__________________________ 4._____________________________

5. I have 6 faces, 8 vertices and am sometimes used for building blocks or dice. What am I?

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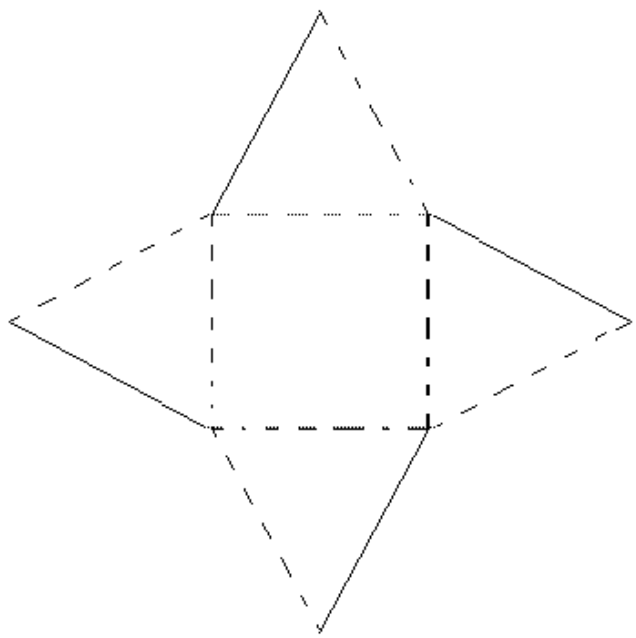
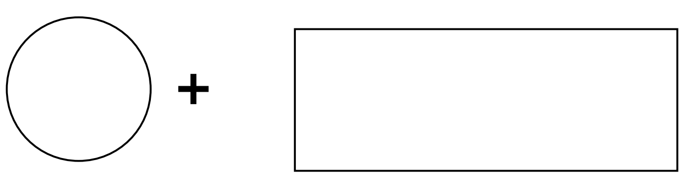
6. You can roll me any way you like, but you can never stack me. What am I?

7. What 3D shape will this net make?



____

8. Which 3D solid is made up of the following shapes:



____

9. Draw a circle around the solids which have MORE THAN 4 vertices.

CONE CYLINDER RECTANGULAR PRISM PYRAMID SPHERE

10. Describe the difference between the meaning of two-dimensional (2-D) and three-dimensional (3-D).

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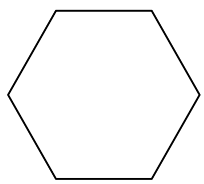
____

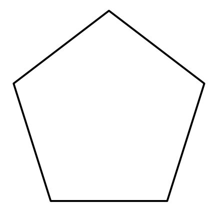
11. Build a cube using the mini marshmallows and cocktail sticks.

Geometry

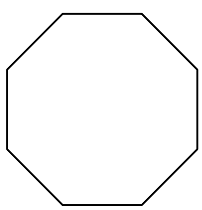
Grade 3

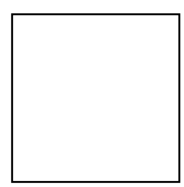
Name these shapes:





1.______________________ 2.______________________





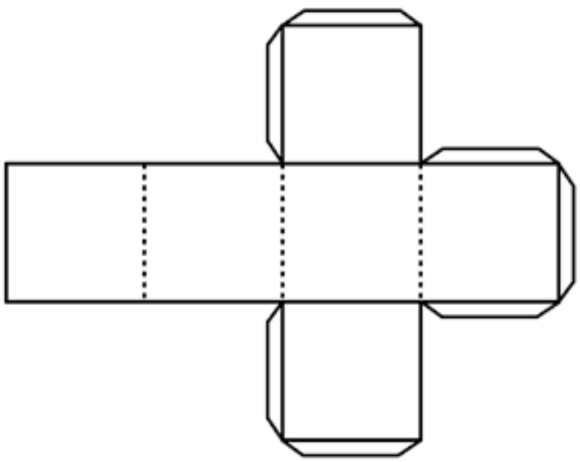
3.______________________ 4.______________________

5. I have 5 faces, 5 vertices and am made of a square and triangles. What am I?

____

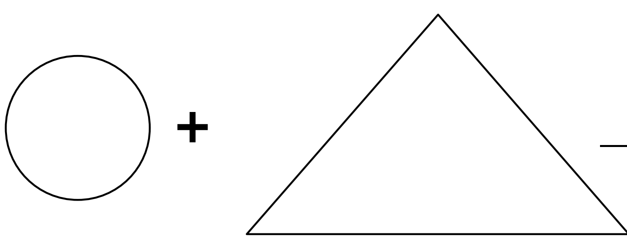
6. You can roll me any way you like, but you can never stack me. What am I?

7. What 3D shape will this net make?



____

8. Which 3D solid is made up of the following shapes:



____

9. Draw a circle around the solids that have MORE THAN 6 vertices.

CONE HEXAGONAL PRISM RECTANGULAR PRISM PYRAMID

10. Describe the difference between the meaning of two-dimensional (2-D) and three-dimensional (3-D).

11. Build a cube using the mini marshmallows and cocktail sticks.

Appendix D: Prior Learning Questions

Prior learning Questions

1. **What does 3D mean?**
2. **Can you tell me what this shape is?**
3. **What would this shape be as a solid?**
4. **Can you tell me something that is this shape (e.g. octagon = stop sign)?**
5. **Can you tell me how many sides this shape has (naming shape appropriate to grade)?**
6. **Can you show me which side is the length/width/height of this shape/solid?**
7. **What does perimeter mean (G3)?**

General Questions

1. **Do you like mathematics?**

2. **How do you like to work? (Give examples such as: "Do you like to work things out on paper?" or "Do you like to use objects/do or make something to work things out?")**
3. **How do you remember things? (Examples such as: repeating facts, writing down, doing something active that uses the knowledge…)**

Appendix E: B.C. Ministry of Education Grade Percentage Table

Letter Grade	**Percentage Range**
A	86-100
B	73-85
C+	67-72
C	60-66
C-	50-59
F	0-49

Based on *Provincial Letter Grades Order* (2009, 4) accessed at:

http://www.bced.gov.bc.ca/legislation/schoollaw/e/m192-94.pdf

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