Integrating Physical Activity with Academic Outcomes for Learning

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Abstract

Although it is widely accepted that physical activity (PA) can benefit our overall health, researchers are challenging the limitation of PA promotion primarily as energy expenditure. Growing evidence supports the positive effects of PA on children's cognitive growth and function which can enhance their learning. Concerns for the health of children alone has led to the realization of the need for more PA in schools. However, many educators recognize that PA has a positive impact on concentration, learning and academic success. A major barrier of increasing PA in schools is the current paradigm of thought that 'academics' takes priority over PA. The trend to reduce opportunities for PA during the school day in lieu of 'academic' instruction time is a growing concern. The problem is that "academic" instructional time predominately means students sitting in an often-congested classroom learning through mostly sedentary methods. Recent research focusing on the benefits of PA to children's cognitive growth and function attempts to overcome the barriers to increasing PA in schools through the integration of PA with curriculum outcomes traditionally taught in the classroom.

The current research study involved 86 grade four students from a public elementary school. The researcher developed a unit of lessons in mathematics in consultation with the grade four teachers and the curriculum guides set out by the school district. For each lesson, two formats were developed, one was based on traditional classroom methods and the other was integrated with physical activity. The physically active lessons constituted the intervention while the classroom lessons served as the control and a switched replication design was used. The learning outcomes taught for

each lesson, both the traditional and PA lessons, were evaluated immediately after the lesson through a short post-test/quiz administered by the classroom teacher to measure what was learned. The student scores for the post-test/quiz were similar in both conditions while PA was increased significantly during the intervention. This is consistent with the results of other studies in that there were no significant positive effects on the learning outcomes measured but neither were there negative effects when PA was increased. Such results demonstrate that lessons can be taught effectively while increasing the amount of PA in schools.

A unique component of this study was a qualitative focus group study following the intervention which examined students' perceptions of their learning experience during the intervention. The key benefits perceived by participants were increased enjoyment and enthusiasm for mathematics which promoted their engagement in the learning activities due to enhanced opportunities for physical activity and social interaction. These positive perceptions demonstrate potential for not only using a physically active or movement-based approach to teach mathematical concepts but the potential to increase student engagement and enjoyment in their learning experience.

The results of this study add to the limited research in this area. The traditional teaching approach of our current school system, which uses predominantly sedentary methods in a classroom setting, is challenged by the growing evidence that PA can be integrated effectively into the school day. This type of teaching strategy has the potential to increase PA for children during the school day, promote student engagement in learning and, as a result, increase academic achievement.

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LIST OF ABBREVIATIONS

BDNF	brain-derived neurotrophic factor
CBV	cerebral blood volume
EEG	electroencephalogram
EF	executive function
ERP	event related potential
fMRI	functional resonance imaging
MRI	magnetic resonance imaging
MVPA	moderate to vigorous physical activity
PA	physical activity
PE	Physical education
PET	positron emission tomography
SES	social economic status
TSMS	traditional, sedentary methods

Chapter 1: Introduction

It is generally accepted that physical activity (PA) benefits our overall health and the prevention of chronic diseases but there has been less recognition of continuing research that shows the cognitive benefits of PA particularly during growth and development. Growing evidence supports PA as being beneficial to children's cognitive growth and function, therefore, increasing the amount of PA for children during the school day has the potential to not only improve the health of children, but also their cognitive development and academic achievement. Unfortunately, the time provided for PA is inadequate (Vazou, Gavrilou, Mamalaki, Papanastasiou, & Sioumala, 2012). One of the major barriers to increasing physical activity during the school day is the current paradigm of thought that "academics" take priority over PA to cover curriculum content and increase standardized test performance. The trend appears to be reducing opportunities for PA during the school day in lieu of more academic instructional time (Ahamed et al., 2007; Erwin, Able, Beighle, & Beets, 2011; Koch, 2013; Sibley & Etnier, 2003; Tremblay, Inman, & Willms, 2000; Trudeau & Shephard, 2008).

Although many educators believe that PA has a positive impact on concentration, learning, and academic success, it is also recognized that scheduling even a few minutes for PA can be difficult in a standards-based education where teachers have little choice over what to cover in the curriculum (Bartholomew & Jowers, 2011; Sibley & Etnier, 2003). When teachers are forced to choose, academics get priority over PA. Therefore, it follows, that the integration of PA with classroom curriculum content in schools has the potential to solve this problem. This approach requires a paradigm shift in our current system that has the potential to both improve the health of our children and future society and enhance the cognitive development of children and improve academic achievement.

Concerns for the health of children have brought attention to the fact that many children are not acquiring the minimum recommended 60 minutes of moderate to vigorous physical activity (MVPA) a day (Public Health Agency of Canada, 2011a; Roberts, Sheilds, de Groh, Aziz, & Gilbert, 2012). Since most children spend the majority of their daily lives in school, it is the ideal place to work on increasing PA. During the school day, children learn mostly through traditional, sedentary methods (TSMs) which involve minimal movement as they sit in a classroom and are taught through predominantly verbal or written methods. Both inside and outside of school, modern technology and industry have resulted in many wonderful advances in our society that have minimized the daily physical challenges we need to survive. These advances have increased our quality of life in many ways; however, our more sedentary lifestyles have created new problems and diseases that prevent us from reaching our full potential. PA is been promoted to help prevent hypokinetic diseases such as chronic heart disease, high blood pressure, type 2 diabetes, and obesity, which are now rampant in our society. Globally, there is great concern about the health of children as obesity has been described as an epidemic among children and has put them at further risk for many chronic diseases (World Health Organization [WHO], 2016). Human beings evolved to move their bodies in complex ways, integrating physical challenges and activities can help our bodies function optimally as the amazing machines they are. This includes our cognitive growth and function. Therefore, increasing physical activity for children during the school day is especially important considering not only the benefits to children's physical health and well-being, but also their cognitive growth and function that may support and increase their learning. The purpose of this study was to explore the impact of PA on the learning of outcomes normally taught in the classroom through TSMs. The question is "does integrating physical activity with academic lessons traditionally taught in the classroom through sedentary methods have a positive impact on student learning?" This study may provide some valuable insights not only about the possible impact of PA on learning but also on the attitudes and behaviours of students towards their learning experience. As well, it may provide evidence for the need of a paradigm shift in the teaching and implementation of pedagogic practices.

Chapter 2: Literature Review

2.1 Need to Increase Physical Activity Levels in Children

Regular physical activity is promoted as an important component of a healthy lifestyle. National guidelines recommend at least 60 minutes of moderate to vigorous physical activity (MVPA) a day for children and youth, ages 5 to 17, to achieve measurable health benefits (PHAC, 2011b). However, the fact is that most students are not acquiring this goal each day as close to one third of 5- to 17-year-olds, an estimated 1.6 million, were classified as overweight or obese between 2009 and 2011 (Roberts, et al., 2012). We need to consider that most children spend much of their daily lives in school often sitting in their desks learning through the TSMs used in the classroom. This is also referred to as the "transmissive method" by Aiello, Di Tore, and Sibilio (2010) who describe it as the passive transmission of knowledge from teacher to students as in a classroom lecture using predominantly verbal or written methods. According to research, not only does this type of situation do nothing to address childhood obesity and promote physical activity, it does not maximize students' learning or cognitive development. Although growing evidence supports PA as being beneficial not only to children's physical health and well-being but also to cognitive growth and function, little has changed in classroom teaching methods and the training of teachers. In fact, minimal opportunities for PA are given to children during the school day. Unfortunately, the trend appears to reduce physical education (PE), recess and lunchtime play and other opportunities for PA during the school day in lieu of more academic time, even though it has been shown that more time spent in PE and other PA opportunities does not decrease academic performance in other subjects (Ahamed et al., 2007; Koch, 2013; Tremblay, Inman, & Willms, 2000; Trudeau & Shephard, 2008).

2.2 Increasing Opportunities for Physical Activity in School

The school setting is often portrayed as having the potential to influence children's physical activity levels. However this potential is not realized as the time provided for PE is inadequate and other opportunities for students to be physically active are limited (e.g. at recess, lunchtime). It seems that in general, schools have made little progress in helping children to be physically active during the school day (Vazou, et al., 2012). Considering the reported obesity epidemic and declines in the amount of physical activity across childhood – with the greatest declines occurring during elementary school –, one would expect school districts to increase the time spent in physical education (Bartholomew & Jowers, 2011). In recent years, major emphasis has been placed on children's standardized test performance and, consequently, have led to reductions of children's opportunities to engage in physical activities during the school day. Sibley and Etnier (2003) note that although the increased emphasis on standardized test performance has led many educators to believe that "non-academic" classes should be cut so more time can be spent in the classroom preparing for these tests, there are many educators who believe that PA and PE actually have a positive impact on concentration, learning, and academic success. Erwin, Able, Beighle, and Beets (2011) point out that the approach of cutting PA time in favour of increasing academic time is challenged by research reporting that PA may generate improved academic achievement, both directly and indirectly.

Proponents of PA have long argued for the necessity of school-affiliated PA. Researchers have provided evidence that participation in PA programs do not negatively impact children's academic performance and some suggest that the time spent in PA would not only benefit health but might contribute to academic performance (Sallis et al., 1999; Shephard, 1997; Sibley & Etnier, 2003; Trudeau and Shephard, 2008). Research that addresses the impact of physical activity on children's physical health, cognitive function, and psychological well-being is of critical importance. However, the extant literature in this area has been relatively modest until recent years. Research has been growing quickly due to new technology that allows more convenient and non-invasive means of measurement. Demonstrating the positive influence of PA on the cognitive function of children is important because it is a potential argument for increasing PE and/or other types of school PA without the risk of decreasing academic progress. Increased participation in PA at school may also offer a way to reduce disruptive behaviour, the drop out from the educational system, and, indubitably, an important benefit would be an enhanced level of physical fitness (Trudeau & Shephard, 2008).

Concerns mainly for the health of children have led to current attempts to increase PA in the school setting. This has resulted in different initiatives that have promoted activity breaks or "energizers" as a method to increase opportunities for students to accumulate additional physical activity minutes throughout the school day. Activity breaks are also recognized as having the potential to increase on-task behaviour and attention spans during academic instruction. However, scheduling even a few minutes for physical activity can be difficult for teachers who have little choice over what to cover in the curriculum. Bartholomew and Jowers (2011) noted that while teachers are generally supportive of physical activity interventions, they find it difficult to provide sufficient time to sustain implementation of any health-related, non-academic intervention.

The perceived importance of PE and its' contribution to children's academic success has varied considerably over the history of the modern educational system (Tomporowski, Lambourne, & Okumura, 2011). Traditionally, although insufficiently, the way of achieving PA and fitness in school has been considered PE class, but the time for PE has been reduced in favour of classroom instruction and cannot compensate for the predominantly sedentary environment in schools (Vazou et al., 2012). Evidence of the high priority given to certain content areas of the school curriculum can be seen in the inequality of the minutes devoted to each area. PE has one of the lowest time allocations in this province according to the recommended time allotments published by the Newfoundland and Labrador (NL) Department of Education and Early Childhood Development, Program of Studies, 2018-2019, with only six percent of instructional time recommended at the primary and elementary levels. This six percent is matched only in the allocations for music, art, and health, with math and English language arts receiving the most instructional time of 16% and 24% respectively (NL Department of Education, n.d.). But even though six percent has been recommended, as a PE Specialist in this province and a parent, this researcher can attest that most schools in the school district only receive four percent of the instructional time for PE which is shown in class schedules. This translates to three 30-minutes class periods or 90 minutes in a seven-day cycle (2100 minutes of instructional time). This results in students receiving only two

30-minute periods of PE weekly, on average, out of 1500 minutes of instructional time Monday to Friday. Finding ways to increase PA during the school day is important because it not only addresses the need to increase the health and fitness of children but because of the potential effects of PA on academic achievement.

2.3 PA, Fitness, Brain Function and Structure, Cognition, and Academic Achievement

Recently, researchers have proposed that children's cognitive functions (e.g., information processing, executive function [EF], and memory) are related positively to the level of physical fitness and/or PA participation (Howie & Pate, 2012). Donnelly et al., (2016) noted that the potential benefits of PA on cognitive performance, learning, brain structure, and brain function for children are important as they may be the foundation upon which more global improvements in academic achievement are attained. Support for these findings have important implications for educators, health professionals, and researchers.

In a recent systematic review, Donnelly et al., (2016) reported on the extant literature examining the effects of PA and fitness on the brain structure, function, cognition and academic achievement in children. They reported finding 137 (64 cognitive function and 73 academic achievement) studies using a variety of study designs, that provided evidence to suggest that there are associations among PA, fitness, brain function and structure, cognition, and academic achievement. They noted that the available literature contained numerous methodological shortcomings and inconsistencies among studies that made synthesis difficult, however, the assessment of the literature by

Donnelly et al. (2016) revealed two very important points related to the current study. First, studies that involved acute bouts of activity were found to be most frequently associated with improvements in both EF and academic achievement. Secondly, improvements in academic achievement were generally associated with studies that delivered physically active lessons as opposed to those that attempted to increase activity by increasing the amount of PE time that students participated in, or providing activity breaks. The current study uses acute bouts of activity to implement physically active integrated lessons.

2.31 PA and brain structure and function.

Research has yielded a great deal of evidence showing the positive impact of exercise on biochemical and physiological interactions in the brain. However, most of this research has been carried out on animals and results translated to the understanding of neuroplasticity in humans and its relationship to cognition. Initial evidence for the direct effects of exercise on the brain was obtained from research conducted with rodents where bouts of exercise elicited a cascade of neurological changes in the hippocampus that have been linked to memory consolidation and skilled actions (Gomez-Pinilla & Hillman, 2013). The evidence for benefits of exercise on human cognition have been mostly developed in research with older adults where experiments demonstrated that routine exercise alters specific brain structures and functions, and these changes were associated with cognitive performance (Colcombe et al., 2006; Colcombe et al., 2004; Kramer et al., 1999).

Physical exercise involves energy expenditure that intrinsically affects the energy status of the cell. Neuronal and cognitive plasticity in the brain relies on the body's management of cellular energy and emerging evidence indicates that energy balance can impact synaptic and cognitive function (Vaynman, Ying, Wu, & Gomez-Pinilla, 2006). Current findings of Vaynman et al. (2006) suggest that mechanisms central to hippocampal energy metabolism may play a role in modulating cognitive function. In 2004, Vaynman, Ying, and Gomez-Pinilla, concluded that exercise-enhanced learning and memory seem to be dependent on hippocampal brain-derived neurotrophic factor (BDNF), a central player found to mediate the effects of physical exercise. The neurotrophin BDNF is the most important factor upregulated by physical activity because it mediates the effects of physical exercise on synaptic and cognitive plasticity and has an important role in cell genesis, growth, and survival (van Praag, 2009). Ang and Gomez-Pinilla (2007) reported that voluntary exercise increases BDNF levels in the hippocampus, an area vital for learning and memory formation, which has provided insight about the molecular mechanisms responsible for the effects of exercise on cognition. It is in the hippocampus that exercise results in a robust increase in new neurons. Increased hippocampal neurogenesis could mediate the beneficial effects of running on cognition, specifically learning and memory. An increase in neurogenesis is associated with improved cognition and the strongest neurogenic stimulus is exercise (van Praag, 2009).

Kramer and Erickson (2007) note that Pereira et al. (2007) reported increases in cerebral blood volume (CBV) in the dentate gyrus of the hippocampus using magnetic resonance imaging (MRI) measures for a group of eleven middle-aged individuals who participated in a three-month aerobic exercise program. These CBV changes were related to both improvements in cardiorespiratory fitness and performance on a test of verbal learning and memory. Analysis in local brain energy metabolism has be studied in humans using positron emission tomography (PET) to monitor alterations in glucose utilization, oxygen consumption, and blood flow during activation of specific areas. These methods have clearly established a relationship between functional activity or "brain work" and energy metabolism (Magistretti, Pellerin, & Martin, 2000).

Relatively few studies have been conducted to examine exercise training influence on human brain structure and function. Kramer and Erickson (2007) report that a recent study by Colcombe et al. (2006) employed a semi-automated segmentation technique on high-resolution MRI data from older adults who were randomly assigned to either six months of an exercise intervention or stretching and toning non-aerobic control group. The older adults who walked three days a week for approximately one hour a day for six months displayed increases in gray matter volume in the frontal and temporal cortex, as well as increases in the volume of anterior white matter. There were no volumetric increases for the nonaerobic control group or in a group of college-student control participants. Overall, studies have shown that physical activity improves cognitive function. Physically fit aged individuals performed better on measures such as reasoning, working memory, vocabulary, and reaction time than their sedentary counterparts. This positive outcome is reflected in neurophysiological measures such as electroencephalogram (EEG), event related potential (ERP) and functional resonance imaging MRI (fMRI). MRI studies have also shown that pre-frontal and temporal gray matter volume was increased in active elderly subjects as compared with sedentary controls (van Praag, 2009).

Some researchers hypothesize that given the high brain plasticity of childhood, changes seen in older brains as a result of PA may be even greater and more global in the developing brains of children (Hillman, Castelli, & Buck, 2005; Trudeau & Shephard, 2008). Donnelly et al. (2016) reports that studies that have assessed children's brain structure and function consistently show fitness-related differences but that there is a relatively small number of studies that have included measures of brain structure and function. This is not surprising given that the first neuroimaging investigation into the association of childhood fitness with brain function and cognition occurred only a little more than a decade ago (Hillman et al., 2005). Findings from two eight-month studies conducted by Krafft et al. (2014) and Schaeffer et al. (2014) using a MRI technique suggest that PA is related to brain structure via the integrity of white matter tracts that are a part of the neural network supporting EF and memory and that this relationship may be dependent on the amount of PA participation. No studies were found that examined the effects of acute PA on brain structure.

Two randomized control trials that used ERP to understand the effects of daily PA on preadolescent brain function and cognition found that effects were selective to aspects of cognition that required extensive amounts of EF. These trials also found the benefits of PA interventions followed a dose-response relationship with higher attendance rates associated with larger changes in neural indices of attention allocation, (i.e. P3 amplitude), faster cognitive processing speed (i.e. P3 latency), and improved behavioural performance during EF tasks (Hillman et al., 2014; Kamijo et al., 2011). Only two acute studies were found that measured the effects of single bouts of PA on the neuroelectric system on preadolescent children. These studies conducted by Drollette et al. (2014) and Hillman, Buck, et al. (2009) demonstrated short-term benefits to cognitive processes reflected in the P3 component often associated with the allocation of attentional resources during the updating of working memory (Polich, 2007).

2.32 The Executive Functions (EF) hypothesis.

The EF hypothesis proposes that exercise has a potential to induce vascularization and neural growth and to alter synaptic transmission in ways that alter thinking, decision-making, and behaviour in those regions of the brain tied to EF (Kopp, 2012). Since empirical evidence obtained from research conducted on adults confirm predictions derived from the executive function hypothesis (Colcombe & Kramer, 2003) it is reasonable to extend the EF hypothesis to predict exercise related improvements in children's cognitive function (Diamond, 2013).

Laboratory-based tests revealed a stage-like emergence of the components of EF in children and neuroscientists have linked behavioural test performance to brain development (Best, 2010). For example, working memory ability has correlated with math and reading scores in children, as well, processing speed and decision-making ability benefit performance in parts of standardized tests of academic achievement (St. Clair-Thompson & Gathercole, 2006). It is the development of components of EF that is thought to form the basis of learning and cognition and is associated with academic achievement (Donnelly et al., 2016).

In addition, classroom-based PA programs have been shown to be effective in improving on-task behaviour during instruction time (Mahar et al., 2006). This increase in on-task behaviour subsequently correlates with EF, which helps self-regulation and behavioural inhibition and the ability to inhibit off-task behaviour, which in turn, allows more attention to classroom material, a prerequisite for successful learning (Hofman, Schmeichel, & Baddeley, 2012). Therefore, PA affects cognitive skills such that learning and classroom behaviour are improved which in turn promotes academic achievement in school. Evidence of the positive effects of PA on learning and behaviour are especially valuable when considering several clinical disorders that are characterized by lack of behavioural control, attention, and judgement (e.g. attention deficit hyper disorder [ADHD] and autism) since these have been explained in terms of ineffective executive function (Lyon, 1996; Naglieri, 2003; Tomporowski, Davis, Miller, & Naglieri, 2008). A child who cannot effectively plan, update working memory, shift from one mental set to another and inhibit impulsive behaviour is unlikely to be able to stay on task in the classroom and excel academically (St. Clair-Thompson & Gathercole, 2006).

2.33 Physical Activity, fitness, cognition, and learning.

"Since the time of the ancient Greeks, there has been an implicit belief that PA is linked to intellectual abilities" (Tomporowski et al., 2008). Ironically, modern science has only recently, relatively speaking, sought to provide evidence of this link, particularly regarding the potential benefits of PA on the cognitive development of children and their education. In 1997, Etnier et al. reported that although relatively few studies pertaining to exercise and cognition had been carried out in children and young adults, studies testing the effects of acute PA on cognitive performance in children, 6 to 13 years old, had collectively shown a small positive effect. A meta-analysis by Sibley and Etnier in 2003 examined 44 studies involving children ages 6 to 13 years old that used a variety designs, including both chronic and acute PA paradigms, and reported a positive significant overall effect (Hedge's g = 0.32). A positive correlation between physical activity and learning and intelligence scores was also reported in a meta-analysis of school age children by van Praag in 2009. Since 2003, Donnelly et al. (2016) noted that there has been considerable growth in the field of kinesiological neuroscience which has resulted in substantial progress in linking PA to cognitive performance as well as brain structure and function. Further, researchers have recognized the importance of including both mechanistic and behavioural measures in studies on PA and cognitive performance and children. Donnelly et al. reported that most of the research findings support the view that physical fitness, single bouts of PA, and participation in PA interventions benefit children's cognitive functioning such that higher levels of fitness or increased PA are predictive of better cognitive performance. Studies examining the effects of acute PA on the cognitive task performance of children are especially of interest because they support a beneficial relationship that may be task specific, with benefits more consistently observed on measures reflecting higher order EF functions. Still, more evidence is needed (Donnelly et al., 2016).

2.331 The effects of acute and chronic physical activity on cognitive performance.

The relationship between physical activity and cognition has been explained according to numerous proposed mechanisms. Sibley and Etnier (2003) categorized these mechanisms into two broad categories-physiological mechanisms and learning/developmental mechanisms. Physiological mechanisms, the physical changes in the body brought about by exercise, include changes such as increased cerebral blood flow, alterations in brain neurotransmitters, structural changes in the central nervous system, and modified arousal levels. The learning/developmental mechanisms, the movement and physical activity learning experiences, contribute to, and may even be necessary for, proper cognitive development. Educators have suggested that movement, particularly in very young children, stimulates cognitive development (Sibley & Etnier, 2003). These authors also note that according to Piaget, skills learned during physical activity carryover to learning about concepts. This might suggest that the movement involved in activity is important rather than the actual physical exertion.

While some studies have examined the effects of chronic exercise on the cognitive functions of children, others have looked at the effects of acute exercise. A review by Tomporowski et al. (2008) evaluated the impact of chronic exercise or habitual exercise activity on measures of children's cognitive function. They reported clear evidence of the effect of aerobic exercise on children's executive function and overall, the results reviewed indicated that children who are physically fit perform cognitive tasks more rapidly than do less fit the children (Tomporowski et al., 2008).

Conversely, Chang, Labban, Gapin, and Etnier (2012) discuss the growing body of research designed to understand how a single bout of exercise (acute exercise) affects cognitive performance. This research is based upon the premise that physiological responses (heart rate, levels of BDNF, and changes in plasma catecholamines) to exercise have an impact on cognitive functioning that can be assessed using behavioural measures. Chang et al. (2012) reported a positive effect of acute exercise on cognitive performance. They felt that findings relevant to different moderators could provide insights as to the potential mechanisms of the effect and guidance for exercise recommendations to garner the largest cognitive benefits. They conducted a comprehensive review to explore the effects of acute exercise for both children and older adults.

Their consideration of different moderators yielded some notable outcomes. Chang et al. (2012) suggested that mechanisms underlying cognitive benefits are impacted by *exercise intensity* and that effect subsides very quickly following the cessation of exercise. This indicates that physiological responses to the exercise are themselves predictive of the impact on cognitive performance. They concluded that lower intensity exercise results in the appropriate level of the physiological responses immediately post exercise, but higher intensity exercise is necessary for effects to be maximized if there is a delay between exercise session and the cognitive test performance. This is corroborated by the finding that cognitive tests administered 11-20 minutes after exercise generally result in the biggest effects and that these effects subside following a longer (>20 minute) delay (Chang et al., 2012).

Regarding the *duration of exercise,* Chang et al. (2012) found that when the cognitive task was performed *during* a short duration of exercise it had no effect on cognitive performance. Exercising between 11 and 20 minutes resulted in a negative effect on cognitive performance but exercising for longer than 20 minutes had a positive impact. They noted that these findings were consistent with the conclusions drawn by Brisswalter, Collardeau, and Rene (2002) as well as Lambourne and Tomporowski (2010).

An important finding for the cognitive task types reported by Chang et al. (2012) is that measures of reaction time yielded non-significant effects but positive effects were reported for measures of EF. This is consistent with the findings of other researchers such as Colcombe and Kramer (2003) and Tomporowski et al. (2008). When effects relative to the particular cognitive task used were examined, Chang et al. (2012) found that the largest positive effects were observed from measures of visual search, Stroop color or word, choice reaction time [concentration, addition and subtraction,], verbal fluency, incompatible reaction time, Stroop interference [free recall,] and visual short-term memory. The Stroop effect is a demonstration of interference in the reaction time of a task, that is, the finding that naming the colors of color words such as 'green', 'red', 'blue' is easier and quicker if the actual observed colors of the words match the colors that the words denote than if they do not match (Chang et al., 2012).

Initial fitness levels have been reported to be a factor when considering the effects of exercise on cognitive performance. However, when cognitive performance was assessed following exercise, Chang et al. (2012) note that positive effects were generally observed for all *fitness levels*.

Type of exercise activity effected cognitive outcomes such that anaerobic forms of exercise and muscular resistance exercise resulted in negative effects. According to Chang et al. (2012) studies that combined aerobic and resistance exercises yielded the largest effects and were significantly higher than what was observed for aerobic exercise in isolation. This may indicate that stimulation of multiple physiological systems yielded the biggest gain for cognitive performance.

An additional finding of interest was that the effects were largest when testing occurred in the morning as compared to afternoon or evening/night. Chang et al. (2012) noted that this may have important implications for researchers interested in improving cognitive performance in the workplace or in school-aged children.

Overall, the research indicates that exercise benefits cognitive tasks performed during or following the exercise bout. The magnitude of the effect is dependent on a number of factors, but effects are larger with fit individuals who perform the PA for 20 minutes or longer (Chang et al., 2012). Future studies focusing on these mechanisms might enable researchers to prescribe a particular exercise dose to positively influence cognitive performance.

2.4 Physical Activity, Physical Education, Physical fitness, Academic Achievement, And Concentration/Attention

Few dispute that healthier children learn better (Best, 2010) as educators and scientists alike understand the importance of physical, cognitive, and brain health among school age children (Castelli, Centeio, Beighle, Carson, & Nicksic, 2014). Classroom studies that delivered physically active lesson seem to have the most consistent positive association for increased academic achievement while the results of quasi-experimental studies utilizing enriched PE/PA programs demonstrated that, although these programs required extra time resulting in a substantial reduction in time allocated for other academics, children still achieved, at least, equally in academic measures. Therefore, the evidence seems strong that the efficiency of learning is enhanced by increasing PA. A significant note is that groups taught by a professional PE teacher achieved greater fitness while maintaining academic scores (Trudeau & Shephard, 2008).

2.41 Physical activity, physical education, physical fitness and attention/concentration.

The impact of increased PA on attention, which is believed to be important for learning, would benefit from further investigation as few studies were found that measured this association and results were inconsistent. School-based PA studies that measured the effects of short bouts of PA on attention, concentration and time-on-task (TOT) for primary and elementary students varied in study design and testing method. However, a few studies did find positive results (Ma, Le Mare, & Gurd, 2015; Mahar et al., 2006; Tine & Butler, 2012). A study by Adsiz, Dorak, Ozsaker, and Vurgun (2012) examined the effect of a 12-week program that added sport activities three times per week on attention measured by the Bourdon Attention Test. They found that children who engaged in physical activities had 83% higher attention levels than sedentary children. There were no studies found that reported positive effects for PE class or physical fitness on concentration/attention.

2.42 Physical fitness and academic achievement.

Fitness was consistently positively associated with academic achievement in numerous studies. Although fitness measures varied, most studies used the FITNESSGRAM® to assess fitness but tests to assess academic achievement used a variety of standardized tests (Donnelly et al., 2016). Cross-sectional studies by Cottrell, Northrup and Wittberg (2007), Wittberg, Northrup and Cottrel (2009) and Wittberg, Cottrell, Davis and Northrup (2010) all focused on fifth grade students with sample sizes ranging from 968 – 1740 participants and used West Virginia standardized test scores. Consistent positive associations were shown among the number of physical fitness tests passed on the FITNESSGRAM® and academic achievement scores in the study by Cottrell et al. (2007). The studies by Wittberg et al. (2009; 2010) found that children who achieved the Healthy Fitness Zone® (HFZ; the gender- and age-specific fitness goals) designation from the FITNESSGRAM® also tended to score higher on tests of academic achievement. In a longitudinal study by Wittberg, Northrup, and Cottrell (2012) which assessed 1,725 fifth and seventh graders, fitness was also consistently associated with academic achievement. Students who increased their fitness or maintained fitness across time had higher academic achievement scores than students who did not achieve the HFZ on the FITNESSGRAM®

Interestingly, social economic status (SES) has been shown to moderate the relation between fitness and achievement. In a longitudinal study by London and Castrechini (2011) fifth and seventh graders showed that more advantaged students have a greater ability to maintain higher levels of academic achievement despite lower levels of fitness, whereas less advantaged students experience an even greater level of academic disadvantage when they are also physically unfit.

Telford et al. (2012) suggested that differences in school cultures or support for fitness programming and achievement might play a more meaningful role in the associations of fitness with academic achievement than the direct effects of children's individual fitness on academic achievement.

2.43 Physical education and academic achievement.

Donnelly et al. (2016) report that PA intervention studies that have investigated additional or enhanced PE and academic achievement generally did not show positive effect between PE programs and achievement scores. The exceptions were two-year intervention studies that notably compared PE led by specialists to common-practice PE lead by classroom teachers (Sallis et al., 1999; Telford et al., 2012). However, these studies had opposing findings, with one that showed improvements in math but not reading whereas the other found the reverse.

One of these studies was a two-year cluster randomized trial, project Spark, that followed 759 Californian children in fifth and six grades. Sub-groups of students were taught by either a professional physical educator, a trained classroom teacher, or through a program by the classroom teacher. It is important to note that the group taught by the professional PE teacher achieved greater fitness and groups taught by both the professional PE teacher and the trained teachers had smaller declines in academic performance despite allocating more time to PE. Improvements were found in reading, although there were decreases in language scores and no effects on composite or math scores. (Sallis et al. 1999). In the second study, Telford et al. (2012) randomly assigned 13 schools to a specialist-taught PE condition and 16 schools to the common-practice PE condition and followed third-graders' achievement scores for two years. Math scores during the two years were significantly higher in the specialist-taught PE condition, but no differences were observed in reading or writing scores. Although these studies found improvements in different areas, neither had negative effects despite the allocation more time to PE in the study by Sallis et al. (1999). The study by Telford et al. did not allocate more time but it is worth noting that in both studies the specialist-taught PE condition yielded better academic scores with the increased PE time in the study by Sallis et al. also producing higher fitness levels. These studies demonstrate that PE time can be increased without jeopardizing academic achievement and can have the added effect of increasing fitness levels if PE is taught in an effective manner by a qualified PE specialist.

Two earlier landmark studies that measured the association of additional or enhanced PE and academic achievement support these findings as well as improved classroom behaviour. In a well-known study which took place in the Trois-Rivières region (Quebec) between 1970 and 1977 and involved 546 primary school students, an experimental, extra five hours of PE per week was implemented, taught by a PE specialist. The students in the experimental condition showed higher academic performance than their control counterparts who were enrolled in a normal school program for 40 minutes per week. The extra 60 minutes per day of PE was necessarily taken from time for academic teaching but it is notable that despite this, during the last five years of primary school, the overall academic performance of the experimental students improved relative to the control with higher scores in math during standardized provincial exams although scores in English were lower (Shephard, 1996).

In South Australia, a 500 student SHAPE (School Health, Academic Performance and Exercise) trial added 1.25 hours per day of endurance PE to the curriculum of 10-year-old primary school students (Dwyer, Coonan, Leitch, Hetzel, & Baghurst, 1983). A control group maintained the status quo of three half hour periods of PE per week, a second group was taught the same program content but the allocated time was increased to 1.25 hours daily, the third group was allocated the same amount of increased time as the second group and the same content as both groups but emphasis was placed on the intensity at which the activities were executed with the aim to increase heart rate. This study was unable to show any significant improvement in academic performance in association with increased physical activity. However, as in the other studies reported, this study showed that arithmetic and reading scores were not adversely affected by the substantial reallocation of curricular time in favour of PE. A follow-up of 216 participants over the succeeding two years found that physical benefits were maintained although there were non-significant trends for better arithmetic and reading grades. A significant finding by Dwyer et al. (1983) was beneficial teacher ratings of classroom behaviour for both groups that received the extra 1.25 hours of daily PE as opposed to the control group. Their results also showed substantial health benefits to the 10-year-old children resulting from the daily physical education program described. An interesting point made by Dwyer et al. (1983) is that despite the potential health benefits, schools are unlikely to introduce an extra item into the curriculum if they believe that the academic performance of their students may suffer.

A more recent intervention study involving sixth grade (11-year-old) students over a single school term included 55 minutes per day of PE in the curriculum versus the same allocation of time for arts and computer sciences. Coe, Pivarnik, Womack, Reeves, and Malina (2006) reported students enrolled in PE class did not perform better academically than those who had an extra 55 min of classroom time. They did note that decreased classroom time, however, did not translate into a lesser academic performance, either. The two groups performed equally well in mathematics, science, and English despite the reduction in other academic time. Previous research where additional time during the school day was allocated to PE programs showed similar results, demonstrating that decreased time spent in academic programs did not adversely affect the academic performance of the students (Coe et al., 2006; Shephard, 1997). As a result, Coe et al. (2006) suggested that a threshold of activity intensity may be needed to bring about the changes needed to contribute to increased academic achievement. Their study found an average of only 19 minutes of the 55-minute class period was spend in moderate to vigorous activity and this low level of activity may not have provided sufficient stimulation to influence academic achievement.

A valuable consideration is that increased PA during the school day may induce arousal and reduce boredom, which can lead to increased attention span and concentration (Shephard, 1997). Shephard also suggested that increased activity levels might be related to increased self-esteem, which would improve classroom behavior as well as performance.

2.44 Physical activity and academic achievement.

Researchers have explored the relationship between participation in PA and academic achievement through the implementation of both chronic or acute PA. PA interventions studies designed to have an impact on academic achievement included physically active classroom lessons, classroom PA breaks, additional school PA, and afterschool fitness program, or specialized programs. In a their review, Donnelly et al. (2016) reported that the results of cross-sectional studies were mixed but that in intervention studies designed to increase participants' PA levels positive effects were seen on both mathematics scores and reading except for those intervention studies that used classroom PA breaks. Notably, the benefits of PA in the classroom appear to be more effective when the PA is integrated into the curriculum rather than being implemented as a break from academic content. It is also important to note that even the studies that failed to find a positive relationship between PA and grade point average (GPA) generally found no decrease in academic achievement because of increased participation in PA. Trudeau and Shephard (2008) point out that the absence of an increase in GPA should not be interpreted as a negative outcome because if academic achievement can be maintained while spending less time on a specific discipline, this means the intervention must have an increased academic efficacy.

2.441 Classroom PA breaks.

Only two studies were found that examined the use of PA “breaks” in the classroom and neither showed positive results on academic achievement but as in other PA or PE interventions neither were there negative effects. A 16-month intervention, Action school BC!, involved 287 primary school students in fourth and fifth grades (aged 9-11 years old) in British Columbia. PA was delivered by classroom teachers with 47 minutes more per week in the intervention. There were no differences in mathematics, reading, or language scores among children attending schools that received the intervention but despite the corresponding decrease in academic time, the academic performance of the experimental group, as measured by the Canadian achievement test, remained unchanged (Ahamed et al., 2007). Similarly, no significant differences among the intervention and control groups were observed in reading and mathematics scores after an 8-month intervention, ABC (Activity Bursts in the Classroom) for Fitness, by Katz et al. (2010).

2.442 Physically active classroom lessons.

Studies that measured academic achievement after the implementation of physically active academic lessons did show significant improvements particularly in mathematics scores and reading fluency. For example, in a three-year cluster randomized trial, significant improvements were observed not only in math but also in reading, spelling, and composite scores (Donnelly et al., 2009). For this study, Donnelly et al. (2009) designed and implemented an intervention model in partnership with TAKE 10!, a program of the International Life Sciences Institute Research Foundation/Center for Health Promotion, that increased PA in the classroom. The intervention provided training for classroom teachers to deliver existing academic lessons taught thorough PA and was termed “Physical Activity Across the Curriculum,” or “PAAC.” PAAC was used to promote ninety minutes per week of moderate to vigorous intensity physically active academic lessons (Donnelly et al., 2009). Another 20-week intervention providing more than 20 minutes a day of curricular-based physical activity resulted in significantly higher mathematics scores and reading fluency on a validated curriculum-based measure, but no differences were seen on standardized test scores (Erwin, Fedewa, & Ahn, 2013). In a study by Reed et al. (2010), a random sample of 3rd grade teachers integrated PA into their core curricula approximately 30 minutes a day, 3 days a week for four months. Children in the Experimental Group performed significantly better on the Standard Progressive Matrices (SPM) Fluid Intelligence Test and on the Social Studies State mandated academic achievement test. The SPM Fluid Intelligence Test consists of given sets or series of diagrammatic puzzles exhibiting a serial change in two dimensions simultaneously. Each puzzle has a part missing, which the person taking the test needs to find among the options provided (Reed et al., 2010; Raven, Raven, & Court, 1998). Experimental Group children also received higher scores on the English/language arts, math and science achievements tests, but were not statistically significant compared with Control Group children.

2.443 Additional school PA.

Studies that examined additional PA throughout the day found favourable effects on mathematics achievement similar to studies involving physically active academic lessons (Donnelly et al., 2016). A study by Gao, Hannan, Xiang, Stodden, and Valdez (2013) incorporated extra PA in the school day, for one year, using the "Dance Dance Revolution" (DDR) program (a music video game series produced by Konami). The intervention for the children involved participating in a 30-minute, DDR-based exercise program three times per week. Greater improvements were found for mathematics scores but not reading scores for the intervention group in comparison to the control group. The exer-gaming based intervention was also found to influence children's cardiorespiratory fitness over time which is consistent with other school-based intervention studies (Gao et al., 2013).

2.5 Need to Integrate Physical Activity

Unfortunately, the use of standardized testing to evaluate schools and teachers has placed pressure on districts to maximize instructional time at the expense of PE and recess (Center for Education Policy, 2007; Trost & van Der Mars, 2010). As a result, school-based PA interventions need to target the regular education classroom Although, initiatives often promote the use of PA breaks to increase the amount of PA during the school day, scheduling even a few minutes can be difficult in standards-based education where teachers have little flexibility in covering certain aspects of the curriculum (Koch, 2013). With time as a major factor, many researchers are working to combine physical activity interventions with academic content (Donnelly et al., 2009; Mahar et al., 2006;

Stewart et al., 2004). These are generally teacher-implemented academic lessons that utilize MVPA in the review or teaching of core academic content (Bartholomew & Jowers, 2011). Strategies for effective implementation of PA-integrated lessons has become an important consideration. The main purpose for such lessons is often, simply, to increase the amount of PA. However, Koch (2013) states that when students are engaged in "sedentary learning" teachers are not only negatively impacting their overall health but limiting student comprehension through a single dimensional learning style. Integrating physical activity within their lessons is a way to maximize academic learning while helping to meet physical activity recommendations. Further, incorporating physical activity within academic curricula has been shown to increase the attention and interest of students, as well as increase academic intrinsic motivation and achievement (Vazou et al., 2012). PA has also been linked to simple functions such as memory and the ability to concentrate (Koch, 2013). Considering all these factors, integrating PA may also help teachers to deal with the many challenging student behaviours and needs thereby maximizing use of time and therefore academic benefits.

The integration of PA within a standard curriculum can create a more conducive learning environment in which students become truly *active* participants instead of just participating in the common method of interactive teaching (Koch, 2013). PA can be specifically integrated with academic lessons by adding movement to learning such as performing jumping jacks during math problem or using purposeful movement when students expressively use their bodies to grasp intangible academic concepts such as using their bodies to make letters or act out a word problem (Koch, 2013).

2.51 Interdisciplinary education versus PA integration.

Cone, Werner, and Cone (2009) define “Interdisciplinary Education” as a “process in which two or more subject areas are integrated with the goal of fostering enhanced learning in each subject area” (p. 4). Kitchen and Kitchen (2013) promote using an “Interdisciplinary Education” approach as a means to increase student time in PE, particularly in public elementary schools where it is often significantly reduced or cut from the curriculum due to increased pressure related to academic performance standards. They suggest PE could share some of the abundant minutes of English or math without compromising any of the content.

Notably, Kitchen and Kitchen (2013) acknowledge that one of the most common criticisms of physical educators is that integrating other subject content with PE may compromise or jeopardize the PE content. To address this concern, they suggest that a “content linkage approach” can be utilized to present content without compromising or affecting the integrity of either of the objectives of the content areas integrated (Graham, Holt-Hale, & Parker, 2009). Kitchen and Kitchen describe developing a link between what is currently being taught in PE and what is being taught in other content areas through a combined theme, movement, or fitness activity that is taught in a PE lesson. As an example, they suggest that it requires very little effort to include the utilization of bar graphs to chart the resting, activity, and recovery heart rate before, during, and after exercise and it should serve to highlight important concepts in both math and PE.

However, in defining why other subjects should integrate content with PE their justification is based on the physiological benefits of PA as described earlier in this paper. Kitchen and Kitchen (2013) refer to "movement-based" learning enhancing student recall and teaching effectiveness through active engagement of students in the learning process (Blaydes-Madigan, 2004). They also note that content integration uses a combination of modalities, as described by Cone et al. (2009), that increase the likelihood for all students to successfully learn the content presented. Cone et al. refer to Gardner's (1983) Frames of Mind: The theory of Multiple Intelligences to support interdisciplinary learning as being sensitive to children's varying learning-style differences by often combining the modalities of seeing (visual), hearing (auditory) and doing (tactile-kinesthetic), allowing children the opportunity to use their strengths to learn. They also note that according to Piaget (1969) children benefit from concrete, practical, active learning experiences that bridge the gap between abstract concepts and the hands-on real world. However, in support of an interdisciplinary teaching approach to learning, Cone et al. emphasize a movement orientation as follows:

1. Using movement promotes active involvement in learning versus passive learning that leads to increased understanding.
2. For young children movement is a natural medium for learning. As children learn fundamental concepts such as height, distance, time, weight, size, position, and shape, movement gives meaning to an abstract system of language symbols.
3. Movement stimulates development of the motor and neurological systems.
4. Movement can be experienced as a means of expression and communication.
5. Movement activities motivate children and capture their interest.

(Cone, et al., 2009, p.6)

Kitchen and Kitchen (2013) propose what they call "Interdisciplinary Education" to combine PE content with other subject areas but the support they offer weighs heavily on the benefits of integrating PA or physical movement with other subject content as opposed to PE. This is evident in their reference to many of the same benefits proposed by the current study of integrating PA into subject content normally taught through sedentary methods in the classroom.

Although Kitchen and Kitchen's (2013) proposed use of "Interdisciplinary Education" is based on the definitions and benefits described by Cone et al. (2009), there appears to be some fundamental differences in their interpretations of integrating PE versus PA or movement. In reviewing the literature, there appears to be a serious need for researchers to differentiate between what is PE and what is PA. Cone et al. offer some clarity in stating that it is through the PE program that students gain the essential kinesthetic learning experiences that will enhance their ability to learn both movement and other subject areas through movement. This statement and the PA/movement approach described earlier by Cone et al. support the PA integration approach of the current research.

2.6 Implementing Physical Activity Integrated Lessons

A successful integration of PA with classroom academics requires collaboration between classroom teachers and physical education specialists (Bartholomew & Jowers, 2011; Koch, 2013). In order to be more effective, classroom teachers need to develop a generalized understanding of locomotor, non-locomotor and manipulative skills such as jumping, galloping, sliding, throwing, dribbling, among others. This understanding of movement concepts can help teachers create content specific lessons with movement. As an example, teachers can teach first-grade students specific academic concepts while also working on their balance and hopping skills (Koch, 2013).

With physical movement as a beneficial factor for both cognition and motor development, as well as students being more engaged, on task, and generally preferring lessons using kinaesthetic and tactile components, integrating PA into academic content may be the solution to a few problems. Such engaging lessons would allow teachers to maximize learning while helping students meet daily physical activity recommendations and reduce sedentary time. The impact on both learning and health outcomes provide strong arguments that support integrating PA into daily academic lessons.

2.7 Combining Physical Activity with Learning Outcomes.

Given the benefits of physical activity on cognitive outcomes as well as health, particularly regarding the prevention of chronic diseases and childhood obesity, it seems reasonable to integrate PA with curriculum content in schools to potentially improve academic outcomes as well as the health of future generations of citizens. Erwin, et al. (2011) refer to the Ecological Model that stipulates individuals affect and are affected by their physical and social environments. Children are influenced by family and school environments. In addition, access to programs and facilities affect their behaviours, e. g. physical activity. Within the context of the school, the ecological model suggests that teachers have the opportunity to engage students in additional physical activity while focusing on academic outcomes (Erwin, et al., 2013).

Although research on the impact of integrating PA in the classroom on students' school day PA levels is scarce, preliminary findings are positive (Erwin et al., 2011). However, much of this research does not measure the impact of PA on improving academic outcomes.

Erwin, et al. (2011) conducted an 18-day study examining the effects of integrating PA with mathematics in 75 students, aged 8 to 12 years, from the classrooms of four participating teachers. PA was measured using pedometers with a subgroup of 11 participants wearing an Actigraph during the entire day throughout the study. The Actigraph measured frequency and magnitude of vertical accelerations related to levels of PA such as running. Before the data collection, researchers met with teachers to develop lesson plans that included a component of PA that was specifically integrated into math core content.

The authors found that participants averaged significantly more steps per minute during PA integrated math classes compared to baseline math classes, thus producing higher levels of PA. The additional school day step counts taken during the intervention account for approximately 5% of the daily recommendation for children. Erwin, et al. (2011) note that their findings were supported by other investigations reporting increased student school day PA through increased classroom-based PA (Mahar et al., 2006).

Erwin et al. (2011) concluded that their findings demonstrated the potential for using teachers as facilitators of PA in the classroom, thus increasing students overall PA levels and promoting healthy lifestyles. They did not, however, measure the effects of the increase of PA on learning.

Aiello et al. (2010) describe

> "the motor laboratory as a methodological teaching strategy alternative to the traditional learning methods, that is in favour of the cognitive mechanisms, being as well an effective way to achieve a more balanced energy expenditure during the school time." (p.37)

Their research analyzed the relationship between teaching methods based on motor and sports activity and caloric expenditure to determine the difference in energy expenditure between traditional approaches adopted by teachers and teaching methods based on "laboratory" activities using the body and movement.

Aiello et al., (2010) conducted a study on 50 students from three classes of a primary school in Italy using an integrated model of action research and experimental research that required collaboration between primary school teachers and researchers of the University. Teachers first delivered a 45-minute lesson to students on a common pre-established topic using the "transmissive method" (the passive transmission of knowledge from teacher to students as in a classroom lecture using predominantly verbal or written methods), then a 45-minute lesson was given by teachers on the same common topic using the "motor laboratory" and methodologies which involved teaching through motor and sport activities. Students' energy expenditure during the lesson was measured using a calorimeter, a Multi SenseWear Armband sensor, put on their right arm before the lesson. The authors found greater energy expenditure during the "motor laboratory" compared to "transmissive method". More importantly, they state that the learning outcomes showed the possibility to use effective forms of teaching not necessarily focused on oral communication, graphs or images. Aiello et al. note that the research model they proposed was aimed to encourage awareness in teachers that movement activities can be as effective as other forms of teaching but they can also have a positive effect on physiological parameters traditionally not involved in the teaching of the disciplines in the educational field. Despite their consideration of the effectiveness of using motor activities to teach learning outcomes, unfortunately Aiello et al. did not measure or compare the actual effects of motor activity on learning or the learning experience of the students.

Although teachers often recognize the importance of promoting PA-integrated lessons, many are not familiar with activities or ways to implement PA with academic content (Koch, 2013). Koch (2013) gives several examples integrating physical activity into different academic subject areas. One such example includes using various movements for solving math problems that allows students to create their own math-bo type (refers to Tae-bo, a cardio-boxing fitness program) work out. To do this, teachers assign a math function to a physical activity such as “addition, punching”; “subtraction, knee lifts”; “multiplication, uppercut”; “division, hook”. Teachers can then provide simple PowerPoint slides with a different equation on each slide and have students bounce in place (like a boxer) and for each function have the students perform the equation. For example, the mathematical operation “$3 \times 3 = 9$” leads students to perform three uppercuts, show the “X” sign with their arms, perform three more uppercuts, show the equals sign using their arms, and perform nine more uppercuts for the answer.

Koch (2013) agrees that linking PA with academics is a viable method for increasing student learning and promoting additional amounts of PA among K-12 students. Koch particularly stresses the importance of PE teachers assisting classroom teachers with the development and guidance needed to provide movement within the classroom. Effectively implementing movement into classroom lessons can not only increase the amount of PA a child receives each day, but also foster creativity, cognitive development, and motivation for student learning.

Bartholomew and Jowers (2011) used the Texas I-CAN! (Initiative for Children's Activity and Nutrition) as part of their original approach to integrate PA with classroom lessons. They began by training teachers to modify their lesson plans to incorporate PA during academic time. However, in their initial approach, few teachers implemented the lessons daily as was intended. Their evaluation indicated that while teachers strongly supported the concept, a lack of planning time and available resources (model lesson plans/equipment) was cited as a significant barrier to implementation. To minimize these barriers, the authors tried another approach (Take 10; Stewart, Dennison, Kohl & Doyle, 2004) that provides a series of 10-minute active lessons, using repetitive activity to reinforce existing knowledge. However, there were still issues. In fact, focus groups revealed the teachers considered the lessons as lacking integration within the academic curriculum and felt the activity was merely "tacked on" to an overly basic lesson. To address this issue, the authors formed a committee of teachers to develop a novel set of active lessons across kindergarten to grade 5 as well as across subjects. The committee included teachers from each of the elementary school grades and specialist teachers including PE. The lesson development involved creating two types of lessons. Bartholomew and Jowers describe the first set of lessons as incorporating the teaching of new information with physically active games. For example, one activity consisted of a "Cardiac Relay" for which children are divided into relay teams. The first child is given a blue-coloured rubber disc representing a deoxygenated red blood cell. The child begins in the "muscle" and runs through the "heart" to the "lungs" where he "picks up oxygen" by exchanging the blue disc for a red disk. He then returns through the "heart" to the "muscle" where the next child begins. Through this activity children learn the basic structure of the circulatory system. The second set of lessons emphasized drill and practice of factual information. One example is called "Spelling Freeze Tag". In this activity children are released to run within a designated area and when tagged they "freeze" in place with their hands raised. Another student with a list of spelling words quizzes the "frozen" student. If correct, the student is released to continue running, if not, a second word is presented (Bartholomew and Jowers, 2011).

Despite minimal training, Bartholomew and Jowers (2011) reported that teachers were able to implement the newly developed lessons and produce a significant increase in PA. However, curriculum outcomes were not measured for this study as for above-mentioned studies, but in a more recent pilot study Bartholomew and Jowers used the Texas I-CAN! active academic lessons to measure the effects on proximal spelling scores. Using a sample of six 4th grade classes, teachers were randomly assigned to complete either a week of normal spelling instruction or to use the I-CAN! active lessons. In an example of an active lesson the children would be asked to compete in relay teams in which each team member would race, in turn, to the board to write one letter of the word. The next then child adds to the word or corrects an earlier error by a teammate. The first team to correctly spell the word wins that relay. For a sedentary lesson, the children might create a spelling diamond in which the child would write the full word, and then move down a line and write all but the last letter. They then would move down a line and write all but the last two letters and so on until there was one letter and the process was reversed. The process in both the active and sedentary lessons was continued for all words on that week's spelling list. To assess spelling, a pre-test was provided on Monday, the intervention or control lessons occurred on Tuesday, Wednesday and Thursday and a post-test on Friday. Bartholomew and Jowers found mixed results. For their initial post-test, the authors found the traditional lesson provided a small, but non-significant benefit relative to the intervention (*Cohen's d* = -.22; p = .11). For the follow-up retention test, the authors reported that the active lessons provided a moderate, significant benefit (*Cohen's d* = .63; $p < .05$). Bartholomew and Jowers noted due to the small sample of mixed results their data needs to be replicated but the results are intriguing. Once again, the research provides a strong support for use active lessons as an approach to school-based promotion of physical activity.

2.8 Rationale and for the Study

Despite the widely-recognized beneficial effects of PA on children's health, growth, and development and the potential of PA to help prevent chronic diseases and childhood obesity, efforts to increase PA in schools have not been as effective as they could be (WHO, 2016; Vazou, et al., 2012). This is true even though increasing PA has been congruent with school health mandates and public policy initiatives. The primary focus of schools is to educate students and this is measured by various forms of academic achievement. Unfortunately, the approach of the public-school system to foster academic achievement traditionally occurs in a sedentary environment as most learning takes place in a classroom where students sit and receive instruction.

Concerns mainly for the health of children, especially since it is reported many children are not acquiring the minimum recommended amounts of PA each day, have led to current attempts to increase PA in the school setting (PHAC, 2011a; Roberts, et al., 2012). Since most children spend most of their daily lives in school, and because schools have the structure and influence on their communities, it is considered the ideal place to work on increasing PA opportunities for young people. But the trend has been to reduce opportunities for PA during the school day, including physical education (PE), recess and lunchtime play, in lieu of more academic instructional time (Ahamed et al., 2007; Erwin, Able, Beighle, & Beets, 2011; Koch, 2013; Sibley & Etnier, 2003; Tremblay, Inman, & Willms, 2000; Trudeau & Shephard, 2008). A major barrier to increasing physical activity during the school day is the current paradigm of thought that "academics" take priority over PA to cover curriculum content and increase standardized test performance. Other barriers include a crowded curriculum, lack of teacher confidence and expertise, and restrictive school policies (Hills, Dengal, & Lubans, 2015; Morgan & Hansen, 2008).

Beyond concerns for the general health, increasing PA for children addresses their innate need to move. Many educators believe that PA has a positive impact on concentration, learning, and academic success, but recognize that scheduling even a few minutes for PA can be difficult in a standards-based education where teachers have little time or flexibility (Bartholomew & Jowers, 2011; Sibley & Etnier, 2003). Administrators are reluctant to give up time to increase PA opportunities despite the potential health benefits if they believe that the academic performance of their students may suffer (Dwyer et al., 1983). Attention needs be given to experimental studies have demonstrated that enriched PE/PA programs that required extra time resulting in a substantial reduction in time allocated for other academics, did not have negative effects on academic achievement (Coe et al., 2006; Sallis et al., 1999; Shephard, 1997; Sibley & Etnier, 2003; Trudeau and Shephard, 2008). This evidence suggests that the efficiency of learning is enhanced by increasing PA.

Growing research challenges the approach of cutting PA time in favour of increasing academic time to improve academic achievement. Evidence supports PA as being beneficial to children's cognitive growth and function, therefore increasing PA may generate improved academic achievement, both directly and indirectly (Erwin et al., 2011; Sallis et al., 1999; Shephard, 1997; Sibley & Etnier, 2003; Trudeau and Shephard, 2008). Demonstrating the positive influence of PA on the learning experience of children is important because it is a potential argument for increasing PE and/or other types of school PA without the risk of decreasing academic progress.

Finding ways to increase PA during the school day is important because it not only addresses the need to increase the health and fitness of children but because of the potential effects of PA on cognitive performance, learning, brain structure, and brain function in children that may improve academic achievement. But in the current paradigm, when teachers are forced to choose, academics get priority over PA. Therefore, new and innovative strategies are needed to provide adequate PA.

Integration of PA with classroom curriculum content in schools has the potential to solve this problem. Teachers are more likely to be persuaded to embed movement across the curriculum if evidence can be shared on how PA can enhance student engagement and or at least not detract from academic performance (Riley et al., 2016). Integrating PA within the existing curriculum is a potentially time and cost effective strategy that is currently under researched (Erwin et al. 2012). In addition, much of this research does not measure the impact of PA on improving academic outcomes. Still, these research models can encourage awareness in teachers that movement activities can be as effective as other forms of teaching in addition to having a positive effect on physiological parameters traditionally not involved in the teaching of 'academic' content. Effectively implementing movement into classroom lessons can also foster creativity and motivation for student learning. Sadly, when students are engaged in "sedentary learning" teachers are limiting student comprehension through a single dimensional learning style (Koch (2013).

The existing research reveals that acute bouts of physical activity have been found to be most frequently associated with improvements in both EF and academic achievement. Further, improvements in academic achievement were generally associated with studies that delivered physically active lessons as opposed to those that attempted to increase activity by increasing the amount of PE time that students participated in, or providing activity breaks (Donnelly et al. 2016). The research supports the attempt of the current study to use acute bouts of activity to implement physically active integrated lessons in a school setting.

The purpose of this study was to explore the impact of integrating physical activity with the learning of math outcomes normally taught in the classroom through traditionally sedentary methods. The amount of student PA was measured in concert with academic achievement based directly on the learning outcomes taught during the intervention lessons. A complementary qualitative study was carried out immediately following the intervention lessons with student focus groups to provide insights on how students felt about their learning experience during the intervention. It is the belief of the researcher that integrating PA with student learning across different subject areas can make students' learning experiences more enjoyable and engaging which is likely to result in improved academic achievement.

Chapter 3: Quantitative Methodology

The benefits of this study are its practical application. However, the real-world setting has constraints and limitations which challenge internal validity. This is because in ecologically valid settings not everything can be controlled the same way as in the controlled laboratory context. It is unreasonable to expect any single experiment to meet all research design considerations therefore limitations need to be acknowledged. One of the limitations was controlling teaching style. Due to the number of classroom groups (four) involved, scheduling constraints, and the fact that classes are taught most subjects by their individual classroom teacher at the elementary level, it was difficult for the same teacher to deliver all lessons to all classes for this study. Although the different teaching styles of teachers may be of some concern it was less disruptive to have the assigned classroom teacher deliver the math lesson in the classroom as it would normally occur. This kept the learning environment consistent and avoided any novelty effects. All teachers followed the same lesson plan to keep things consistent and an independent observer was present in the classroom to indicate any teaching styles or factors that may have affected the delivery of the lesson.

For the lesson integrated with physical activity, the routine also remained consistent with the students' regular physical education teacher leading the lesson in the gymnasium setting at the regular time. As a result, the only difference in routine involved the actual intervention of having physical activity combined with the classroom curriculum outcomes, the effects of which were being evaluated. In the case of the intervention, any difference in teaching style was not an issue as the same teacher delivered all physically active lessons to all classes. It should also be noted that the physical education teacher delivering the intervention, the PA lesson, was also the researcher for this study.

It was necessary to conduct the physically active lesson in the gymnasium as most classrooms tend to be small and were not set up for, or conducive to, moderate-vigorous physical activity or movement of students. Any physical activity in the classroom would have required movement of furniture which, at the very least, would be time-consuming and even then, space would be restrictive. The physically active lessons in the gymnasium also coincided with the students' regular lesson in the gymnasium to maintain routine and work within the constraints of the school schedule. As well, the physical education teacher delivered the physically active lesson because of their expertise in teaching through movement, as well as supervising and organizing physical activity as part of a lesson. Many classroom teachers lack the experience needed to integrate physical activity into a lesson safely and effectively and some may be uncomfortable using physical activity as part of their lesson. Similarly, the classroom teacher may be more effective in the classroom using regular classroom methods that do not normally integrate significant PA. Consequently, both types of lessons were taught in an effective manner so that the effect of interest can be measured.

Due to the focus of this research the external validity of a true experimental design was difficult to achieve. As a result, this research employed a quasi-experimental design that better fit the real-world setting while still controlling as many of the threats to internal validity as possible. The switched replication design was used as the classroom groups in this study were taken intact, that is, the groups were not randomly chosen by the researcher. A strong feature of this design resided in the replication of the treatment several times. Since there is no standard statistical analysis for this design, various T-tests were used to determine the significance of the results.

Table 1: Treatment Trials

Groups	trials					
	1	2	3	4	5	6
1	O_1, T	O_2	O_3	O_4, T	O_5	O_6
2	O_7	O_8, T	O_9	O_{10}	O_{11}, T	O_{12}

Notes:

GROUP 1 = class A + class B

GROUP 2 = class C + class D

O = test

T = treatment applied

Timeline: lessons consisted of six consecutive math periods of 30 minutes each.

- Lessons plans followed were developed in consultation with all classroom teachers and physical education teacher based on the outcomes to be taught.
- There were two versions of each lesson, a physically active version and a traditional classroom version meeting the same outcomes.
- Class groups alternated doing the physically active lesson for one lesson.

- A short post-test measuring the outcomes was administered at the end of each lesson by the classroom teachers for both the classroom lesson and the physically active gym lesson.
- Amount of physical activity (PA) achieved during every lesson was measured by a pedometer worn by each student.
- Each class was taught the prescribed lesson by their regular teacher in the classroom and their regular physical education teacher in the gym.

3.1 Participants

Ethics approval was obtained from Interdisciplinary Committee on Ethics in Human Research at Memorial University of Newfoundland (ICEHR approval # 20162065-HK) prior to the recruitment of participants. The research study involved 86 grade four students (boys and girls) from both English and French immersion streams of a public elementary school. For each experimental group, two classes were combined, one from each stream to balance out each group. Permission for this research was obtained from the school district and the administration of the school and was conducted in cooperation with the grade four teachers. Prior to the study, all students had consent forms signed by their parents allowing them to participate.

3.2 Procedures

Through consultation with the grade four teachers and the curriculum guides set out by the school district, a unit or block of four 30-minute lessons in mathematics was planned which coincided with their curriculum outcomes. There were two corresponding plans for each lesson, one plan was based on traditional classroom methods and taught in the classroom by the assigned classroom teacher, as they would normally occur. The second set was based on the same curricular outcomes but planned with physical activity integrated into the lesson. All physically active lessons, which constitute the intervention or treatment, the independent variable, were taught by the same teacher in the gymnasium. The classroom lessons served as the control and were taught by the classroom teacher for each class. Groups alternated doing the physically active lesson and the classroom lesson according to Table 1: Treatment Trials. The learning outcomes taught for each lesson, both the classroom and PA lessons, were evaluated immediately after the lesson through a short post-test/quiz administered by the classroom teacher to measure what was learned, the dependent variable. The math lessons implemented for each condition and the assessment quizzes can be viewed in Appendices 3, 4, and 5 respectfully.

At the beginning of each math lesson for this study, both the classroom lesson and PA lesson, all participants put on a pedometer to measure the amount of PA achieved during every lesson. Pedometers were collected at the end of each lesson and steps were recorded for each student.

3.3 Data Collection and Measurement

The amount of physical activity (PA) achieved by each participant during each lesson was measured objectively using a pedometer. All students participating in this study were asked to wear a pedometer during each intervention and control class for a total of 4 times. Prior to the study, during a physical education class, the researcher instructed the children on how to use the pedometers and gave them an opportunity to test them and understand how they work. The researcher did this to prepare the children for the research classes and to reduce the novelty effect of using the pedometers. Teachers involved in the study were shown how to use the pedometers individually. Students were instructed to wear the pedometer by clipping it onto their waistband on the dominant hip directly above the knee.

At the beginning of each class that was part of the intervention study, the teacher was instructed to pass out the pedometers as labelled for each participant. At the end of each intervention class the teacher collected the pedometers and the researcher recorded the number of steps taken.

The average number of steps counts for each group during each intervention class was used in the analysis to account for possible differences in the physically active math classes versus the traditional classroom math classes. In this research study, more than one type of pedometer was used due to limited availability of pedometers from the university for the number of students in the study. For consistency, a combination of the available pedometers was used for each group. As a strength of the research design each group acted as their own control group using the same pedometer for each condition so data was comparable.

Approximately 20 pedometers were obtained from the university, specifically the Yamax Digi-walker SW-200 electronic pedometer (Yamasa Tokei Keiki Co. Ltd., Tokyo, Japan). The remainder of the pedometers were part of the school equipment, approximately 30 Piezo® Step MV piezoelectric pedometers (StepsCount, Deep River, ON) and approximately 39 "Crystal Light" promotional pedometers that had been donated to the school. Before initiating the study, all pedometers were verified to be in working order with pilot testing which detected a ±2 step error on 15-step test. Manually counted steps were used as the criterion measure.

No information was available regarding “Crystal Light” promotional pedometers but Bassett (2000) reported that the Yamax Digi-walker SW-200 performed accurately in laboratory testing and has been validated against the energy cost of physical activity in children (Eston, Rowlands, & Ingledew, 1998) as well as observed physical activity in children (Kilanowski et al., 1999). The Piezo® Step MV pedometer was reported by Webber, Magill, Schafer, and Wilson (2014) to have recorded step-counts accurately in older community-dwellers. Bassett (2000) reported correlation coefficients of 0.80-0.90 between the Yamax Digi-walker SW-200 pedometer and outputs for moderate intensity activities (carried out under laboratory conditions) obtained from different brands of accelerometers, suggesting that these devices essentially measure the same thing. Therefore, the simple pedometer was adequate for a summary statistic of physical activity (Tudor-Locke, 2001).

The electronic pedometer is a uniaxial motion sensor worn on the body that measure steps and/or distance traveled. Advantages to using steps as a metric for assessing physical activity is that they are intuitive, easy to measure, and they represent a fundamental unit of human ambulatory activity. Step counts are easily interpreted by researchers, clinicians, and participants alike (Tudor-Locke, Bassett, Shipe, & McClain, 2011).

Although some studies used accelerometers as opposed to pedometers, both these measures, as well as measures of behavioural observation, have shown strong correlation which makes the pedometer useful in studies to provide an objective measure of physical activity in children, particularly because of its unobtrusive size and economical cost (Kilanowski, Consalvi, & Epstein, 1999). In addition, pedometers do not require any synchronization to a computer which can be a source of error. Pedometers have provided a valid measure of PA when measuring children engaged in a variety of moderate to high intensity recreational activities as well as less intense classroom activities. They have also been shown as a valid method for assessing levels of physical activity for large samples in intervention studies. (Kilanowski et al., 1999).

Heart rate monitors were worn by a subgroup of eight students, which included two from each class group, to measure PA intensity. These were distributed to the selected students in each class in the same manner as the pedometers. The researcher showed each of the students and their teachers how to wear these monitors and often checked with students at the beginning of class to ensure they were set up properly. Unfortunately, data from the heart rate monitors had to be omitted from the results due to inconsistent or absent data which was both a result of equipment and/or technology issues and human error.

Learning or academic outcomes were measured by a short quiz administered immediately following the lessons involved in the study. Each quiz was matched directly with the concepts taught in the preceding lesson and designed to measure the student's comprehension of these concepts. All quizzes can be found in Appendix 5. All quizzes and lessons were prepared by the researcher based on the prescribed math curriculum and were reviewed by the classroom teachers. The quiz was administered by the classroom teachers. The classroom teacher also evaluated the quiz for each student in their class and scores for all quizzes were submitted to the researcher as a percentage. Teachers could use these quizzes for their own evaluation of students as well.

In most of the related literature, studies examining the relationship between PA and academic outcomes used standardized measures of academic achievement. Few used results/scores from school curriculum-based tests or school evaluation results. Only a handful of studies measured academic achievement using physically active classroom lessons and only one acute study was found that directly measured the academic concepts taught. Bartholomew and Jowers (2011) measured the effects of integrating PA with spelling lessons in the classroom over a one week period. To assess spelling, a pre-test was provided on Monday, intervention or control lessons occurred on Tuesday, Wednesday and Thursday, and a post-test was administered on Friday. Bartholomew and Jowers suggested that teachers are likely to be more sensitive to academic outcomes that follow a standard elementary schedule of one week of instruction followed by testing. This is the approach of the current study which was designed to measure the immediate and direct effects of PA on student learning of math curriculum outcomes in an authentic school environment.

3.4 Data Analysis

All data, in the form of steps recorded from the pedometers and percentage scores for the quizzes were collated for each student from all intervention lessons according to condition, PA math lessons and TSMs math lessons. These statistics were then summarized and averages calculated for each class and their experimental group (Group

1 and Group 2). Summary statistics were then processed using "Graphpad Prism 8 Software." Paired t-tests were conducted for each class individually in each experimental group and for all participants combined. Values were produced for both PA (step) results and learning outcomes (quiz results) and significance was evaluated for t-test results. Tables 2, 3 and Figures 1, 2 in the results section show the final statistical results for both the dependent variable, outcomes learned, and the independent variable, PA, respectively.

Chapter 4. Quantitative Results

The specific purpose of this study was to explore the impact of PA on the learning of outcomes normally taught in the classroom through TSMs. Scores from the lesson quizzes designed to measure the learning outcomes were recorded as a percentage for each participant while PA was recorded as the number of steps measured using pedometers worn by the participants. Data from the heart rate monitors which were worn by a small subgroup of participants was omitted due to inconsistent or absent results which was both a result of equipment/technology issues and human error.

The physical activity outcomes of the statistical analyses show that the number of steps for the physically active (PA) lesson condition in the gym was significantly increased for both groups that participated [$t(84)= 11.6$. $p<0.001$]. That is the children in each group were significantly more active during the PA math lesson in the gym ($M= 566.4\pm241.4$), compared with the math lessons taught in the classroom ($M= 272.2\pm142.5$). In fact, all groups showed the same trend in step counts (Table 3). Figure 2 displays the overall step counts differences between conditions though there was some overlap with the classroom steps count (PA CI = 514.4 to 618.5; Classroom CI= 241.5 to 302.9).

The learning outcomes for the math lesson, as measured by the quiz scores, did not show significant differences [$t(86)= 0.51$, $p= 0.60$] in both conditions, the PA math lesson and the classroom math lesson. Notably though, the mean difference between conditions was small (see Table 2), being less than 1 point. Note that the *p*-values for each class are significantly different between conditions however not in the same direction (Table 2). As displayed in Table 2, the overall mean difference of Class A (PA M= 85.75; Classroom M= 92.42) and Class B (PA M= 71.96; Classroom M= 83.91) both in **Group 1** showed that children did perform better in the classroom math while children in Class C (PA M= 83.68; Classroom M= 74.44) and Class D (PA M= 87.79; Classroom M= 79.62) who together formed **Group 2** did perform better in the PA math. Interestingly, the opposing results for **Group 1** cancel out the results for **Group 2** netting in an overall non-significant result with the overall means not being significantly different in classroom lessons (Grand M= 82.34) and in the PA lessons (Grand M= 81.52). This can be seen in Figure 1 which shows the quiz scores for both conditions are similarly grouped. The statistical analysis showed that the learning outcomes for all classes were not different $t(86) = 0.521$, $p=0.60$. A closer glance to the individual class data demonstrated that the first two classes scored better in the learning outcomes for in-class lesson compared to PA lesson. For the step count analysis, the outcomes showed that children were significantly more active during in-PA lesson compared to in-class lesson [$t(84)= 11.6$, $p<0.001$. All groups showed the same trend.

Table 2. The Statistical Analyses of Quiz Scores/Learning Outcomes

Group	Class	t-value	*p*-value	DF	ΔMean	ΔSD
1	Class A	2.31	*P*=0.035	15	-6.67	11.53
1	Class B	6.65	*p*<0.001	27	-11.95	9.51
2	Class C	2.19	*p*=0.043	16	9.24	17.36
2	Class D	5.19	*p*<0.001	25	8.17	8.03
	Grand Total	0.52	*p=0.600*	86	-0.82	14.75

Table 3. The Statistical Analyses of Step Counts

Group		t-value	*p*-value	DF	ΔMean	ΔSD
1	Class A	6.51	*P*<0.001	15	379	233
1	Class B	9.57	*p*<0.001	27	385	209
2	Class C	4.57	*p*<0.001	16	235	212
2	Class D	4.06	*P*<0.001	24	182	225
	Grand Total	11.60	*P*<0.001	84	294	234

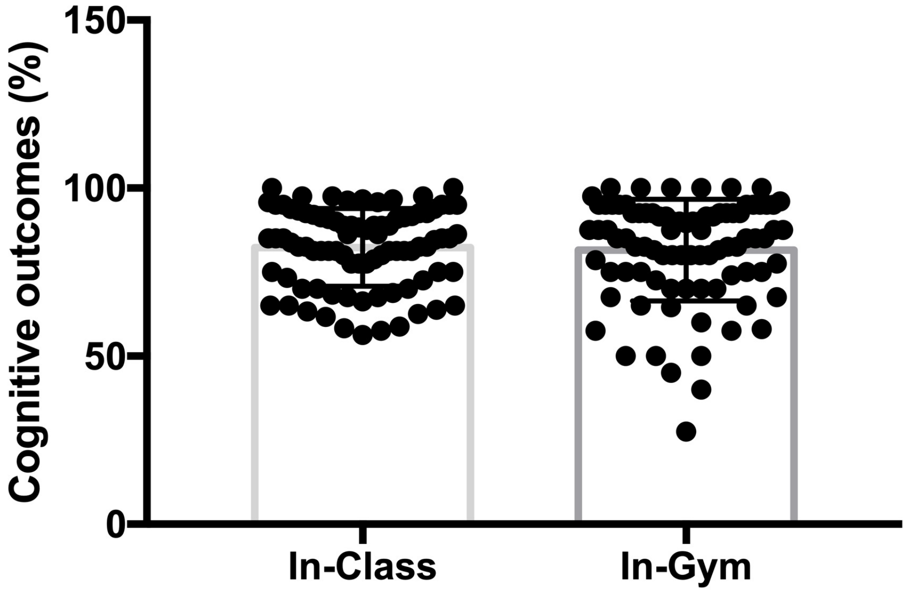


Figure 1: Learning Outcomes (% grade) as a function of conditions (In Class vs In-Gym)

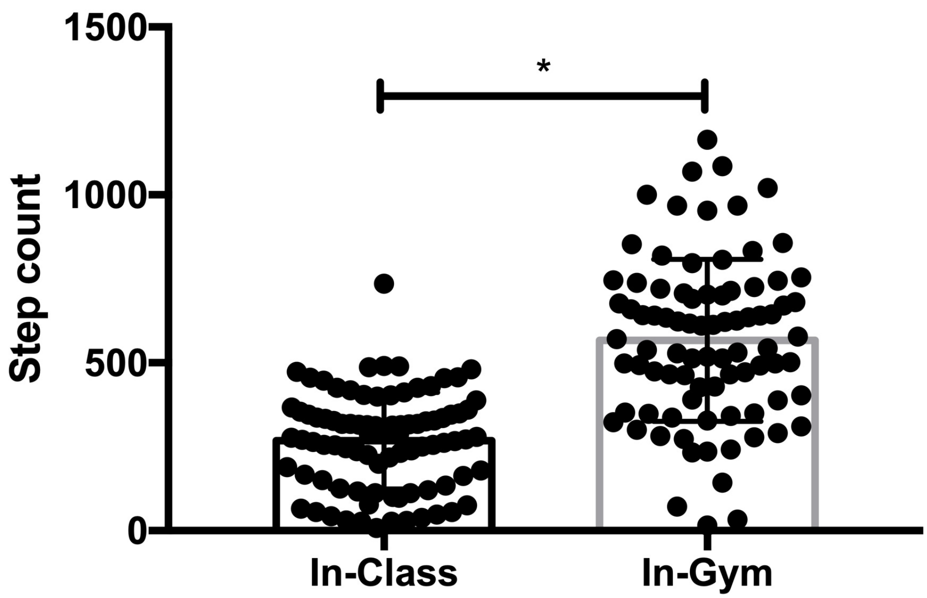


Figure 2 Step Counts as a function of conditions (In Class vs In-Gym)

**denotes statistical significant difference between conditions (p<0.05)*

Chapter 5: Qualitative Methodology

This study used a combined methods approach following the dominant-less dominant design model (Creswell, 1994). This complementary qualitative analysis will help provide insight or interpretation of the results from the quantitative analysis. Morgan (1997) notes that the benefits of focus groups include interpreting discrepancies between anticipated and actual effects. Focus groups have evaluation applications even when a program/study is a clear success, as an investigation of the sources of the study's success by hearing the perspective of the study's participants is wiser than simply assuming the program/study works for the reasons intended by the researcher (Morgan, 1997).

The qualitative section of this study employed an explorative qualitative research design (Creswell & Poth, 2017; Denzin & Lincoln, 2005; Lichtman, 2010; Patton, 2015; Ritchie & Lewis, 2003). The goal of this methodology was to gain new insights from and understand the perspectives of the young students who participated in this study, whose voices are limited in current empirical research (Lichtman, 2010; Ritchie & Lewis, 2003). This design helps to explore the concepts being examined in this study more comprehensively and thoroughly, to fully understand the participants' experience and viewpoint for further consideration and investigations (Lichtman, 2010; Ritchie & Lewis, 2003).

5.1 Researcher's Lens

The researcher of this study has completed a Bachelor of Physical Education and a Bachelor of Education (Secondary) and is enrolled in a Master of Science in

Kinesiology program. She currently works as a permanent fulltime teacher in the public school system and is currently teaching PE at the kindergarten to grade six levels but has taught classroom subjects (particularly sciences) and PE at all grade levels in the past. Additionally, she has coached all ages in various sports (cross-country running, track and field, soccer, basketball, volleyball), taught swimming skills to all ages, and continues to be a lifelong player of soccer.

The researcher views PE as an important course in the school system and that the skills acquired can be applied to all aspects of a student's education and life in general. As she has worked as a teacher over the years, she became more interested in primary/elementary PE as she felt that the foundational skills taught were acquired more readily and enthusiastically in the students' early school years and that these skills are important building blocks for more complex skills as the students' progress. She also believes that the skills taught in PE go beyond the direct teaching of physical skills and many inherent skills or intrinsic learning takes place. She admires young students natural love of movement and believes it should be a part of a holistic approach to learning.

The co-investigator for the qualitative portion of this study has completed a Bachelor of Physical Education and a Bachelor of Education (Primary/Elementary), and is enrolled in a Master of Physical Education program. As a graduate student, he has completed a thesis using qualitative research methods in inclusive PHE (physical and health education) and hopes to contribute to the assurance of a quality PHE that caters to all students with diverse backgrounds, needs, and aspirations in PHE.

He currently works as a substitute teacher in the public school system, teaching both classroom and PHE at all grade levels. He also works within a youth corrections facility where he has observed the role that PHE can play in a troubled youths' life. Additionally, he is involved in the sport of freestyle wrestling at a provincial level and after years of competing, has stepped into a leadership role in this sport as a coach and administrator.

The co-investigator views PHE as an important component of anyone's life. He became more interested in primary/elementary PHE as he felt that the foundational skills acquired in the early years of PHE are important building blocks, for more complex skills in a students' later life. In addition, he believes PHE can have an important role in shaping students' attitude, thoughts, and feelings toward healthy and active living, which can last throughout students' life-course.

5.2 Participants

The participants in focus groups for this study was a subset of the total 86 students participating in the overall study. Asbury (1995) suggests that a focus group consists of 6 to 12 individuals who are similar in some way and that three to four groups is usually sufficient. A total of eight participants were chosen in a semi-randomized manner from each experimental group (four students from each of the two classes which comprised each experimental group) to form two focus groups for the interview process.

Although there appears to be some debate on whether to recruit participants based on homogeneity and heterogeneity, Barbour (2005) suggests considering the primary purpose the focus groups. Ideally the researcher should aim for enough diversity within groups to stimulate discussion and sufficient homogeneity to facilitate comparison between groups (Barbour, 2005). Barbour further suggests using 'purposive' or 'theoretical sampling', that is, the researcher speculates as to which groups of people are likely to have different views or experiences to guide recruitment and group composition. In a study by Pawlowski, Tjørnhøj-Thomsen, Schipperijn, & Troelsen (2014), which used focus groups to explore barriers for recess physical activity and included children from the fourth grade, the principal, or designated teacher, was asked to identify three boys and three girls who would represent differing levels of physical activity for each focus group.

The researcher, in consultation with the teachers, chose individuals in a similar manner but selected students representing different levels of achievement on the quiz portion measuring learned outcomes and were interested in participating in an interview. Therefore, the students were chosen in a semi-randomized manner.

5.3 Data Collection/Procedure

Focus group interview sessions took place on the first day following the intervention. The interviews took place during school hours with each focus group sitting around a table in a quiet classroom. In this study, focus group interviews lasted approximately 30 minutes, which had been deemed by the researcher (based on experience teaching students at this grade level and knowing their attention levels) sufficient time for the discussion. This time period also fit logistically within the school day schedule as school periods are 30 minutes long. For the purpose of data collection, the researcher prepared a semi-structured interview guide to help focus the discussion (see Appendix 1). The session was audio-recorded and, as suggested by Asbury (1995), a co-investigator was present to help take field notes of nonverbal behaviours or other dynamics that could not be audio-recorded as well as note any ideas and insights that might present themselves. Field notes were also taken immediately after each interview and reflective journal entries were used to summarize the researcher's personal thoughts, insights and feelings during the research process (Creswell & Poth, 2017; Patton, 2015). Participants were asked opened-ended questions such as "How did you feel about learning math using physical activity?" and "How would you compare learning math in the classroom, as you normally do, to your experience of learning math using physical activity in the gym?" During the focus group session, the researcher moderated the discussion as the investigator, posing the questions, encouraging the input of all participants, and keeping the discussion on track as much as was appropriate (Asbury, 1995). Both the researcher and the co-investigator were free to explore, probe, and ask questions that would elucidate and illuminate the comments, ideas, and insights of the participants regarding their experience of combining math outcomes with PA (Creswell & Poth, 2017; Fontana & Frey, 2005; Patton, 2015).

Each of the two focus group interview sessions were audio-recorded and transcribed verbatim for analysis although the analytical process began during the interview sessions whereby initial insights of the investigator and co-investigator were used to refine the guide used for structuring the focus groups (Pawlowski, et al.,2014). Focus group transcripts were then used to identify comments made by participants which reflect a positive or negative experience. The overall experience of the participants was then described in a narrative report by the researcher.

All interviews maintained empathic neutrality throughout the entire duration (e.g., showing openness, sensitivity, respect, awareness, and responsiveness to participant in body language and response) (Pedersen, 2008). For the process of the interview the background of both the researcher and the co-investigator should be noted. As a teacher for more than 20 years, the investigator is quite familiar with the school setting, particularly at the elementary level. The researcher's experience and current position as one of the physical education teachers of the students/participants in this study meant that she had an ease and expertise that allowed both the researcher and the students/participants to be comfortable during the group discussions. The co-investigator, though not familiar with the particular school and students/participants involved in the study, also had a teaching background in same the public school system, teaching both in the classroom and PHE at all grade levels.

5.4 Data Analysis

A thematic analysis technique employing a data analysis spiral (Creswell & Poth, 2017) was used to identify, analyze, and report themes within data (Braun & Clarke, 2006). The five steps of the data analysis processes were: (1) managing and organizing the data, (2) reading and memoing emergent ideas, (3) describing and classifying codes into themes, (4) developing and assessing interpretations, and (5) representing and visualizing the data (Creswell & Poth, 2017). To begin both interviews were transcribed from the audio recordings and were reviewed for accuracy. Following the initial organization of data participants' identifiers were anonymized and thorough readings of the transcriptions commenced. 'Memoing' of relevant ideas occurred during this initial phase of data analysis. Codes were identified through the repeated readings, and continually modified and revised to ensure that there was no overlap or redundancies. Finally, codes were grouped into themes. Each theme or key concept was organized relevant to each of the research questions and acted as the voices of the participants on PA integration into math curriculum.

5.5 Trustworthiness

To increase and maintain the trustworthiness, the following criteria were considered: transferability, reflexivity, credibility, resonance, significant contribution, ethics, and coherence (Zitomer & Goodwin, 2014). To increase transferability of research findings, that is, the idea that the diversity of the participants would be representative of all participants in this study, four students were chosen from each of four classes participating in the study. The selected participants represented different levels of achievement on the quiz portion measuring learned outcomes. (The details regarding the participants are noted in section 5.2 of this paper). The investigator's and co-investigator's own critical reflections on experiences, assumptions, and reactions throughout the research process were referred to throughout the data analysis for reflexivity. To promote the credibility or strength of research findings data triangulations (i.e., using multiple data sources) multiple data sources were used and member checking was performed (Creswell & Poth, 2017; Patton, 2015). Resonance (i.e., impacts of the study on readers) was achieved by presenting the research participants' quotes verbatim in the results. To make a significant contribution and generate insights to the field of study research questions were developed to understand how the integration of PA into math outcomes traditionally taught using more sedentary methods affected the learning process from students' perspectives. Ethics (i.e., values and moral principles in research process) were maintained by making the participants aware of all stages and procedures of the research process. An open and respectful line of communication was maintained between the participants and the investigators. Coherence (i.e., following a consistent, clear, and concise research paradigm) was established by carefully attending the underpinning philosophies and processes of explorative qualitative research design and this process was reviewed by an expert (i.e., the researcher's supervisor for their master's program) (Creswell & Poth, 2017; Patton, 2015).

Chapter 6: Qualitative Results

Participants were young students in grade 4 but they were very happy and capable of discussing their experience during this study. The students that participated in the focus groups expressed profound insights both directly and indirectly, regarding their experience participating in this PA intervention in their math lessons. Participants described their perception on how it affected their learning and why and suggested how similar practices could affect student' learning and well-being in general. Although they were delighted to use the study equipment, especially the pedometers, the selected (8) participants wearing the heart rate monitors shared how they found wearing them to be "pretty uncomfortable". Overall, they found the study equipment both novel and interesting, which might explain some inaccuracies in the readings. Participants communicated their enjoyment of the lessons which combined math with physical activity stating emphatically that's "my kind of math!" They even developed their own term to concisely describe their experience of learning math outcomes combined with PA calling it "smart learning". It should be noted that the names used for the participants in the following section are not their real names.

6.1 "Pretty uncomfortable"

During this study students were asked to wear equipment for measuring their number of steps to indicate their level of activity while learning the math curriculum. All students wore pedometers while only four students for each of the two groups wore heart rate monitors to assess intensity. The pedometers were simply clipped to their waist band above their hip while the few students that wore the heart rate equipment wore a wrist monitor and a transmitter? strapped around their chest. Students found the equipment to be novel and interesting to use but those wearing heart rate equipment found those pieces somewhat uncomfortable.

The pedometers were new to students and they were excited to use them. Marley said, referring to the pedometers, "It felt kind of cool because I never learned about like… I never used one of those…I never used it for math anyways!" Oliver expressed a keen interest in the use of the pedometers "Amazing when you get to use the steps, when you calculate your steps and that." Unfortunately, in their excitement, students tended to look at their pedometers often, over handling them, and as a result sometimes reset them. This is evident in a statement from Perry who states, "Yeah, cause everyone one was looking at theirs every second, like 5 seconds."

Similarly, the few select students who wore the heart rate monitors found them interesting as Danielle noted "…since I like put on the heart thing, I never knew you had to put on like all that stuff to see your umm, your heartbeat." Martin who also wore the heart rate monitor agrees "I found it interesting too, the heart rate and the fitbit!" Some chatter that erupted within the group on this topic during the focus group, indicated that other students found the heart rate monitors uncomfortable as well. Perry, a student who wore the heart rate bracelet and chest strap confirms this stating, "it's uncomfortable… it's a bit uncomfortable…" and Danielle clearly reveals that "It's really uncomfortable!" when referring to wearing the heart rate monitor.

Generally, students found using the research equipment interesting and were excited to use it. This was particularly true regarding the pedometers which were simple and easy to use. The heart rate monitors with both the chest strap and bracelet was more difficult to set up and wear, making it, according to the students, uncomfortable to wear. Both the excitement and difficulty of wearing some of the equipment may explain why sometimes the results were absent or unreliable.

6.2 "My kind of math!"

Students seemed surprised to be learning math content in a gym environment combined with PA, but they very clearly expressed their enjoyment of the combination. They felt the space in the gym was conducive to PA learning and created a more interactive environment with their peers. They also alluded to the fact that they felt more engaged in learning and immersed in the content. The participants compared their experience of learning math combined with PA to learning math in the classroom where they felt more confined in their desks and bored with the math indicating a clear preference for the PA math. They also felt their enjoyment of physical activity made the math content more palatable and easier to learn.

Almost all the students, at one point or another throughout our interview, expressed their agreement that the PA math presented in this study was enjoyable. Simply put, Martin says "That's how I would describe it - fun math." Cady keenly translates it to "Fun learning", while Cindy says, "I thought it was really fun" and Dana concurs, "It was really fun, I liked it a lot!". Numerous comments and nods from other students attending the focus groups indicated that most students agreed that doing the math content through PA in the gym was "fun" and that they "liked it" or "enjoyed it" that way. Sadie went as far as to say that it was "awesome." When asked by one of the investigators how many participants would be ‘really happy’ to have math combined with PA, the group responses seemed unanimous with nods, raised hands and several “yeahs”. Among the positive responses, Perry expresses himself in a unique way saying “Yeah, ‘Mudder’ (Mother) Goose! I’d be happy as ‘Mudder’ Goose!” Although the students enjoyed it, they were initially surprised to be doing math in the gym combined with PA. Perry expresses both his surprise and interest when he says: “I found it interesting because normally you go to gym you’re like ‘oh yes today we’re going to run laps or something’ and then, but then, when you go in it’s like ‘Geometry what!!!’” Olivia also states that she found it to be a “surprise that we were doing math in gym.” Some students were disappointed, fearing not only that it was meant to replace their regular gym time for PE but that because they were doing math it wouldn’t be fun. Danielle says:

> “At first I was kinda just like ‘aww we are doing math in the gym it’s not going to be fun because we’re wasting all of our gym time’ and then I said to myself ‘well, we’re still doing gym and we’re still also learning’ so that was really fun!”

Martin felt it was “A lot different from the other gym classes that we did!” However, Perry very quickly expressed how pleased he was to do PA math in the gym saying “Yeah, that’s my kind of math!” His positive reaction was echoed by others within the group.

Many students expressed how they felt engaged in the content while still having fun. Marley states “I found that like when we were like doing the relay races that was really fun. You were learning math and having fun the same time!” Sadie gives the following example, “And we actually got to get up and bring the lines of symmetry over onto a giant sheet of paper while trying to do it like a relay race! It's fun. I love relay races!" The activities combining math with PA were new to the students and they seemed to enjoy them. As Cindy says, "We did more activities that we really haven't done in the gym that I really like!" Some students expressed that math was not their favourite subject but when it was combined with physical activity in the gym it made them like math more or become more engaged. Danielle says "Yeah, because I love doing sports and math isn't my favourite subject but I'm really good in it but it's not my favourite (laughter) so I think it helped me like math better." Some students were initially not happy about it at all because they shared Alicia's sentiment when she states, "I don't like math." But when Alicia was later asked if she liked math better when she did it in the gymnasium with physical activity she confirmed, yes "in the gym." After engaging in the PA math class students indicated that it made math more likeable and enjoyable for them. When asked by the co-investigator if doing math in the gym made students like it more, a count of hands indicated that all students in the focus group liked math more when it was combined with PA in the gym. When Oliver was asked if he would like it if he could have physical activity in his math classes on an ongoing basis he said "Yeah, I love it!"

Students compared how they felt about learning math combined with PA against how they felt about traditional classroom math, and it was clear that the preference was PA math in the gym. Gary states that "It was better to have it in the gym." And Martin agrees, "Yeah, I enjoyed it that way!" Sadie does not feel positive about doing math in the classroom, she says "Yeah, much more interesting than sitting down in a room, sweating…" Most students related that they were bored during sedentary math in the classroom and felt a need to move. Sadie goes on to plainly state that "The classroom math is boring because you're just in this room with a gray pencil writing down 80 +…" Alicia concurs with Sadie but clearly compares the two as follows "Umm, math in the classroom is really boring and then math in the gym is fun!" Students indicated that they find it difficult to sit still in the classroom. Perry describes how he feels. "I liked walking around like I don't like sitting down for a long time! I budge a lot!" He continues to elaborate about his restlessness in the classroom, "I'm usually acting like this, like come on get it over with!" Many of the students indicated that they found math in the classroom was "boring" and that math in the gym was not only more interesting and fun but also easier. Danielle expresses this when she says, "Umm, well I think it was pretty cool to do math in the gym because it was really like easier than doing math in the classroom, it was really fun…" Qualitatively speaking, it was apparent throughout both focus groups that students preferred PA math Hunter exemplifies this when he says, "Oh yes, better than just math in the class!' Students stated that integrating math and PA made the learning fun and preferably to sedentary learning in the classroom. Oliver states, "I found it was cool that you could combine math and gym together and do really fun activities than sitting in class and writing it down and that." Several students felt that "doing" the activities in the PA math kept them active but sitting as in the classroom learning makes your legs "sore" and can be "painful". They pointed out that you can be active and still learn. Cindy tells us:

> Sometimes, like your legs get like really sore if you're just sitting down but when you're in gym and you're doing it you're keeping yourself active so you won't get sore from sitting down but you're still…umm, learning. So, it's better.

For classroom math, students are generally sitting in their desks and students immediately clarify why the PA math is better. Marley puts it simply. "You're not sitting…" Sadie points this out as well saying, "Yeah… it's because in the classroom you don't really get to do activities and most of the time my legs are, are, are, feel like pins and needles!"

Students in the focus groups were clear that they found PA math in the gym to not only be more enjoyable than sedentary math in the classroom but that it was fun. This fun was a result of the fact that the PA lessons were both physically and mentally challenging for students. This is supported by Danielle who says:

> Umm when we were… when we did the relay races like there was a paper, a piece of paper on the wall and you had to draw the… the… lines of symmetry on the sides and stuff. Well, it was really fun because, like for me, it was like who's going to be the fastest and the smartest (laugh)!

This integration of physical activity in the lesson, by all indications of the participants, increased the students' involvement in their learning because it was fun! Students felt that when the lesson isn't fun, they feel disengaged with the material. Martin relates the following, "Doing the thing when you're...when you're umm...if you're not having fun, you'd just be like…when's this gonna be over? I'm getting bored!"

Generally, educators believe that when students are engaged in the learning content, they learn better. Therefore, if integrating PA into subject content makes the lesson fun or more enjoyable, and if when students are having fun they are more engaged, then, it follows that integrating PA into subject content can improve learning! When asked by the co-investigator if they thought adding PA to lessons in other subject areas would increase their involvement and improve learning their responses were definitively positive with immediate nods, 'mm-hums', and 'yeahs' from the group.

Students gave numerous examples from the PA math lessons where they enjoyed how physical activity was integrated with the math content. One example is given by Gary, "Umm, a, I liked when we got to like make a shape, like run around and make the shape." Another example shows that learning is implicit in the activity. Danielle who appreciated being active while learning gives the following example:

> Umm, well, I felt I did actually learn a lot because when we did the thing where you got the skipping ropes and you had to do the shape it was really cool because you did math and you exercised at the same time. So, you were active while learning.

Students particularly enjoyed the running component and the speed that went with it. As Kyle says, "I liked it because you have to like run quick and try to put it on symmetry or not symmetry."

Another aspect of the PA activities appreciated by the students was the interaction with their classmates. When asked to give an example Hunter responds, "Ahh… doing the thing with your partner…the race thing."

The students give numerous examples of why they enjoyed the physical activity during math and how it affected their learning. The physical activity they felt increased their enjoyment of learning math and helped them to stay focused on what they were learning. This, in turn, helped them to remember the learning content and actual made them want to remember it.

Students continued to describe how during math in the classroom they are just sitting down in their desks and that they find this to be physically painful. They find that in the classroom their mind wanders but when they are having fun by moving and doing math in the gym "the only thing in your mind is the math" and that makes learning easier. Cindy describes it as follows:

> Math in the classroom it's just like, it physically hurts because it's umm, your muscle gets sore like you're hunched over, over your desk, and like there's a bunch of stuff on your mind, like, except for math, then it's just really hard. But when you're having fun in the gym, umm, it's like, it's a game so you don't really have to, you're not thinking of anything because you're having fun so the only thing in your mind is the math. But otherwise in the class, you're not really doing anything so, umm, it's… a, not, you're like you're… everything else is in your mind and you just feel the need to... like…move around because your muscles get sore and stuff so…

Students describe how in the classroom they are just sitting and, as a result, just want it to be over but that during the PA math in the gym they didn't want it to be over. Cindy describes how she felt:

> Umm, just sitting down, like, you, you read the math and it just gets all confusing cause, umm, it's like you're hunched over and it's painful so you're thinking…,

> like you're looking back at the clock like oh when's it going to be over, I wonder, umm, like, if I'm going to get this right! But in gym, you're just running around having fun, there's really…, you don't want it to be over so you don't really have to be thinking when is it gonna be over so you just…

Students clearly indicate that when the learning is "fun" then you want to remember it and that PA made learning "fun" so therefore helped them remember it. Cindy says, "Because if you're enjoying it then you'll remember it a lot more because you only really want to remember things that you like. So, it'll help a lot if you wanted to remember it." Cady supports Cindy's statement:

> Adding on to what Cindy said about like remembering…, like when you go…, like I'm sure you like remember like last Christmas because it was so fun and like that, like it's a memory to you, well like gym's like that because when something's like super fun you'll always remember it!

All indications from students were that if you don't enjoy learning the content you won't be focused and want to remember it. According to the students, PA can make you enjoy learning math so it helps you to remember it, which in turn helps you learn. Cindy expresses this when she says:

> Because if you don't enjoy it, like you don't want to remember things that aren't, that you don't like, like if you didn't like math then you wouldn't want to remember it because you don't really like it. But if you really like gym (PA) then you're gonna wanna remember it because you liked it, so…

It seems that the reason PA helps students focus and learn is because these young students feel the need to move. When asked directly by one of the investigators if they feel like they physically need to move during class time, there was a unanimous response from students indicating that this is true with multiple voices in unison responding. "Yeah! Yeah!" Even students that enjoyed math in the classroom appreciated the physical movement during the PA math in the gym and felt it satisfied their need to move. Dean states, "Like math in class I find is fun, but like math in the gym gets you a bit more active so like…" (Oliver adds "Sweatin' harder…") Dean continues, "You're not getting all squirmy cause like you need to move and stuff."

As noted, the PA math lessons which covered the same learning outcomes as the classroom math lessons took place in the gym. This is because the space in the gym was conducive to moderate physical activity while the classroom is not. The classroom space is generally small and cluttered with desks, tables, bookcases and other obstructions that make it difficult to employ physical activity safely and efficiently. Several students indicated that they would like to see math continue in the gym space, as Gary says, "I wish every math class was in the gym!" Students also felt that learning math in a bigger environment made learning more comfortable and less loud. Estelle says, "I found that if, when you were in the gym doing it, it was a bigger environment, so it wasn't as like… loud!" Perry continues with, "Yeah and uncomfortable!" When asked by an investigator if the students liked having the space and if it was more exciting the group replied in unison, "Yeah!" Gary and a few other students stated more specifically that it wasn't "as cramped!"

The responses from students made it clear that students enjoyed the math lessons combined with PA in the gym because they found it "fun". The physical activities did not only increase the fun factor but engaged students both physically and mentally in the learning process. Students revealed that they found math lessons in the classroom "boring" and as a result they tended to be restless and lose focus. The PA satisfied the need students felt to move and as a result kept them focused. The faster pace created in the PA math lesson challenged students not only physically but mentally as it required quick thinking. Students also related that because they liked doing the PA math, it made them want to remember it more. The space in the gym was needed to facilitate the physically active math lessons as classrooms do not have adequate space. Besides obvious safety factors, students felt more comfortable doing physical activity in the bigger space of the gym and found it was less "cramped" and not as "loud'.

6.3 "Smart learning"

When students discussed how PA math affected their learning, they described being active not only physically but also mentally. Being active and learning at the same time was keenly described by one of the students as "smart learning". Student made some insightful reflections on their experience. Some students alluded to the fact that the act of physically doing the learning activities and having fun while they did it made learning the math outcomes easier. They also found that the learning environment created during the PA math lesson in the gym space made learning more interactive.

During these focus groups students reflected on how PA affected their learning. One student even thought back to when they started school in kindergarten and noted that as they have progressed in school, math has become more sedentary and less fun. But when math was combined with PA in the gym during this study, they were able to "play" which made learning math more "fun" again! Cindy explains it like this:

> Also, I liked it because I don't really like math because it's like (*another student in background "boring"*) …yeah, we don't, like in kindergarten 'n stuff we got to play like little games to do the math, now it's like just on a paper and you have equations so it's not very fun. But math, when we do gym it's more fun because, (*student in background "you get up to move")* yeah, you get to play a game which would, which is my favourite part of school. And you also can get your least favourite part done while you're doing your favourite part so it makes…

When the investigator asks if students think that if they are happy, they learn better, the group responds with a collective "yes". To be definitive the investigator confirms by asking if everyone felt that they learned a little bit better during the PA math, the response included multiple voices from the group saying "Yeah…definitely…yep…" Students felt that learning with PA not only increased engagement but understanding. According to Perry, "Because you can interpret it better." Students also felt that it helped them both mentally and physically. Marley states, "And it makes you more smart!' and Danielle says, "Yeah... and more strong!" Students clearly feel that having fun when they are learning increases engagement. When asked why it was important to have fun when learning Gary responds, "So you don't die of boredom!' Students indicate that during sedentary learning in the classroom they become disengaged and distracted. Danielle and Martin conjointly express this in the following exchange:

> (*Danielle*) Ah so it's kinda like Martin said, umm, but like when sometimes when, when, umm, people are showing me math I kinda look for something to just like do while umm, 'cause I'm really bored so I'm just like…
>
> *(Martin) "*Playing with your desk stuff like this, like...'
>
> (*Danielle*) "And I don't pay attention but when, but when, it's more fun I pay attention and I learn better."

Throughout the interview process, students described their experience during the PA math as fun. They felt the movement allowed them to interact more with the material and their classmates. The higher paced movement made the learning of the math outcome more challenging and didn't allow them to get bored. Some of the students give examples which demonstrate implicit learning. Cady relates to an earlier experience she compares to her experience in this study with the PA Math. Cady says:

> When we do French umm…when we play, when we umm, when we learn, when we do French in class we play this game called 'Dix' where you have to say the numbers, sort of like a game, like whoever's left standing wins.
>
> …And I, we, our whole class get really excited and like we love it so much and, but a… we're learning the, the numbers in French and umm…
>
> …so…it's learning!

When Gary describes how the moving or doing aspect of the PA math helped him learn the content, it is what we call tacit learning. Gary relates the following:

> I liked it that…because it actually helps, like you, umm, a, when you do the running around it actually helps with the quiz that we do at the end of the lesson! Yeah! It helped me with the quiz there in the classroom.

It appears that physical activity as part of the math lesson involved the students in a more varied or complete way that helped them remember. Cady supports this when she describes how she liked the challenge of the relay races and working with her partner and how it kept her brain "active". Cady even comes up with a term to describe it, "Um, well my favourite part was the relay races with your partner and the word- …my brain was really active and the word I would describe it was 'smart learning'!" It was clear that the students enjoyed the PA math and found the classroom math sedentary with some students calling it "boring". Cindy puts out a theory that schools would be better if kids liked the way they were learning and they would want to keep doing it! Cindy says:

> Other schools should take notes because umm, more schools would um… would probably umm, be a better school if they, if the kids liked the way that they were learning then they would probably want to um, keep doing it and then their teacher would, like, teach them more of what they originally wouldn't want to learn about because it's boring. It's, umm, like making you want to do it more often!

Students seem to feel that the overall learning environment provided in this study for the PA math to be more conducive to learning. This included the more immediate nature or faster pace of the activity which helped students to stay focused. Cindy offers the following comparison bet the classroom math and the PA math in the gym:

> Cause regular classroom, umm, people, umm, they just tell you what to do and then you're sitting there and you completely forget what to do but in gym like you get… told what to do and then like, you don't… there's not like you are told what to do and then you forget because you have to start doing it immediately, cause…, for example, you say like you have to do one lap of the gym and then you have to do like… calculate something and then do two laps and calc.., like double that, like umm, you're told, you start doing it immediately but if you're told, umm, like, if you're told, okay you have to do like for the first page this and then like you have a bunch of pages.

The social side of the learning also seemed to be a positive factor for the students. In the gym, there was increased discussion and/or interaction with partners as opposed to working in the classroom alone in your desk. Cady talks about this:

> Okay, umm so when we did math in the gym we have like partners and we can like talk about what we're doing and all that stuff but in, in, umm, math class you kinda have to like sit in your desk and just think about it yourself, like you can't share it with anybody or just you can't really…, can't really discuss it.

The bigger environment of the gym used for the PA math helped increase the physical size of visuals making concepts easier for students to visualize and remember. Perry tells us:

> I liked the bigger shapes, like you could picture them better in your head so that when I came to the quiz, like you could like, like I found like I didn't need the Miras because like I could see the shapes like bigger.

… Cause I imagined it like as big as the gym shape.

Reflections by students on their learning experience during this study were insightful. A reflection on a much earlier student experience showed that satisfying a child's need to move, interact, and have fun is conducive to learning. It can make learning something that may be less appealing more enjoyable. When learning is fun it increases student engagement and helps them focus on the material and therefore learn. The physically active engagement in the lesson provides a tacit learning experience that helps students in the remembering of material. The overall learning environment provided by the bigger space of the gymnasium for the PA math lesson was found more conducive to learning by the students. This was due to the space available for students to move and not having to sit in desk. In turn, the physical movement made students engaged immediately in the learning activity and did not allow time for their thoughts to wander. The nature of the space and activities increased student interaction with each other as opposed to being confined in a classroom space in a desk. The bigger space also allowed the use of bigger equipment to manipulate and as a result provided larger visual stimulation to students to help them to remember.

Chapter 7: Discussion

The purpose of this research was to integrate moderate physical activity with the outcomes normally taught in a classroom situation using more sedentary methods. The expected result was that the achievement in the learning outcomes for the physically active lesson would the same or better than the outcomes for the similar lesson taught through the transmissive method used traditionally in the classroom setting but that the amount of physical activity for students would be increased.

7.1 Quantitative Analysis

After an examination of the results from this study we can say that the number of steps for the physically active (PA) math lesson condition in the gym was significantly increased for all classes that participated [t(84)= 11.6. $p<0.001$). That is, the children in each class were significantly more active during the PA math lessons taught in the gym compared to the traditional math lessons taught in the classroom. Each individual class showed the same trend (refer to Table 3). These results support the hypothesis of the researcher that integrating PA with lessons traditionally taught in the classroom through sedentary methods would significantly increase the amount of PA for students. While these results were significant the researcher notes after some review that they may have been even more significant. The reason is that one of the traditional classroom lessons involved students moving around the corridors of the school looking for examples of symmetry. As a result, students' steps were greatly increased with this movement which was atypical for a traditional lesson which is normally contained within the classroom. Another relevant note is that many of the students who were excited to use the pedometers were also quite competitive and took advantage of the any opportunity, especially outside the classroom to greatly increase their number of steps. This particular opportunity may have brought the number of steps achieved by students closer to the PA math lesson condition reducing the difference in the number of steps between conditions. Nevertheless, the increase in steps for the PA math lessons were still significant compared to the classroom math lessons.

This result is supported by similar studies in the literature. A study conducted by Erwin et al. (2011) involving students aged 8-12 and four teachers found that participants averaged significantly more steps during PA integrated math classes compared to baseline math classes, thus also producing higher levels of PA. Aiello et al. (2010) also conducted a study which did not use pedometers but compared the energy expenditure, measured using calorimeters, of students taught using what the authors called the “transmissive method” to that of students taught using the “motor laboratory” and methodologies which involved teaching through motor and sport activities. This study involved primary students in Italy and, not surprisingly, Aiello et al (2010) found a greater energy expenditure during the “motor lab” compared to the “transmissive method”. Neither of the aforementioned studies measured the effects of the increase of PA on learning which is examined in the current study. Nor did these studies measure heart rate. Erwin et al. (2011) did use accelerometers to measure higher levels of physical activity on a subsample of eleven students but due to “lack of participant compliance” and accelerometer malfunction they were only able to use data from seven of the eleven participants. The current study also used a subsample of students to measure physical activity intensity but with heart rate (HR) monitors. As with Erwin et al. (2011), there were malfunctions of the equipment and student error which prevented the use of the data. Results from the HR monitors were inconsistent or absent and therefore excluded from the data analysis completely.

In the current study, the impact of the increase in PA on learning was measured. After each lesson for both the control and the intervention a quiz was administered to students by the classroom teacher designed to measure the level of achievement in learning the math outcomes taught in each lesson. In comparing both the PA lesson and the traditional lesson the quiz scores did not show an overall significant difference. Notably though, the mean of the differences was relatively small (-0.82) which indicates scores were close in value for each condition. This is shown in Figure 1 where we can see most of the scores are similarly grouped. A closer examination of the individual groups reveals that the *p*-values for each individual class are statistical significant. Reviewing the overall differences in the means for individual classes, we can see that for Class 1(ΔMean = -6.67) and Class 2 (ΔMean = -11.95) the scores for the physically active math classes are *significantly lower* than the mean scores for the classroom math. But for Class 3 (ΔMean = 9.24) and Class 4 (ΔMean = 8.17) the scores for the physically active math classes are *significantly higher* than the mean scores for the classroom math. As a result, the scores for Class 1 and Class 2 effectively cancel out the scores for Class 3 and Class 4 causing an overall non-significant result (*p*=0.600) as seen in Table 2. These inconsistent results may be attributed to some of the limitations of this study.

One recent study which is similar to the current study was conducted by Bartholomew and Jowers (2011) after several previous attempts of integrating PA with traditional classroom lessons. They also involved grade four students and compared a week of normal spelling instruction to spelling instruction using the Texas I-CAN! active academic lessons. To assess spelling outcomes, they conducted a pretest on Monday, implemented the interventions and control lessons on Tuesday, Wednesday, and Thursday, and a post-test on Friday. Bartholomew and Jowers (2011) found mixed results like the current study. Their initial post-test found the traditional lesson provided a small but non-significant benefit relative to the intervention (Cohen's d=-.22; p=.11). It is interesting to note that in their study, Bartholomew and Jowers performed a follow-up retention test and reported that the active lessons provided a moderate significant benefit (Cohen's d =-.63; p< .05). Unlike Bartholomew and Jowers (2011), the current study did not perform a follow-up retention test but it may have been interesting to do so.

A qualitative study was conducted to examine the students' reflections on their overall learning experience throughout the lessons implemented to measure the effects of PA integration with math lessons. After a thorough review of the literature by the researcher, no studies were found initially that employed a follow-up qualitative study to examine the experience of the participants involved.

7.2 The Equipment

Initially, participants in the focus group interviews expressed their interest in using the equipment in this study for measuring physical activity. Participants wore pedometers to measure physical activity through steps and a small subgroup of participants additionally wore heart rate monitors which included the use of a strap and an associated bracelet monitor. Although they found the chest strap to be uncomfortable, they still found using it to be interesting. The novelty of the equipment and the natural curiosity of participants may explain some absent or unreliable results during this study. It should be noted that the data for the HR monitors was not used because data was missing and insufficient. For example, students sometimes reset their pedometers while checking their steps throughout the lesson. In future studies, the researcher recommends that participants be given more experience with equipment prior to use in the study. Another drawback to be avoided would be chest straps which were uncomfortable an cumbersome. Equipment can be costly, but if resources are available the researcher would recommend using more up-to-date fitness bracelets that monitor both heart rate and steps for future studies.

7.3 Qualitative Analysis

In the qualitative portion of this study participants described how they felt about their learning experience and reflected on the differences in both lesson conditions, giving specific examples. Eight grade four students were chosen from each of the two experimental groups to form two focus groups for the interview process. The perspectives of participants revealed some interesting and valuable insights about their learning experience during this research. In this study, each experimental group participated in both traditional classroom math lessons and math classes purposefully combined with physical activity in the larger space of the gymnasium on an alternate basis (switched replication design). We will discuss below their reflections and insights in relation to the current knowledge base in this field of study.

Previous studies have integrated physical activity across the curriculum and reported on PA levels and various academic measures (Bartholomew& Jowers, 2011; Donnelly & Lambourne, 2011; Mahar et al., 2006; Riley et al., 2016). However, none were found during the research, planning, and early implementation phases of the current study to have qualitatively examined students' perceptions of PA integration strategies on their learning experience with curriculum outcomes normally taught in the classroom using sedentary methods. That is, until a recent paper by Riley et al. (2017) which was published during the processing of the current study. Riley et al. confirmed the lack of similar research, since they were unable to find any other studies that had focussed on students' and teachers' perceptions of PA integration strategies. The findings of this current study add to this literature examining the use of PA in the teaching of core academic content.

The paper published by Riley et al. in 2017, focussed on the outcomes of a program called the "Encouraging Activity to Stimulate Young Minds (EASY Minds) program that integrated PA into mathematics lessons as a novel pedagogical strategy for teachers to improve engagement levels of students in math while increasing their physical activity. The methodology as well as primary and secondary outcomes of the EASY Minds cluster randomized control trial were previously reported by Riley et al. (2014; 2016). However, the focus of the paper by Riley et al. (2017) was to discuss both students' and teachers' perceptions of the physically active program of mathematics lessons (EASY Minds) in the primary school. Although the current study explores only the students' perception, the results obtained by Riley et al. (2017) for students are strikingly similar to the current study.

It is notable that the methodology of the qualitative portion of the current study and that of Riley et al. (2017) are also very similar. For example, at the completion of the original intervention, classroom teachers were asked to nominate children of differing abilities to take part in the focus groups in both studies. Riley et al. (2017) noted that a focus group methodology was utilized partly due to group interaction being capable of eliciting information and insights that are less accessible during individual interviews. Similarly, questions were asked designed to explore the students' perceptions of the mathematical lessons integrated with PA and how they related their experience with math lessons in the classroom. Riley et al. (2017) also used a thematic analysis of the student data and found many of the same themes highlighted in the current study. Interestingly, a key theme that emerged from both studies was that of increased enjoyment and engagement in mathematics lessons. The similarity of the results and feedback obtained by Riley et al. (2017) from the students in their study and that obtained from the participants in the current study about their experience was remarkable, especially considering that these students attended school in a country located in the opposite side of the world!

7.31 "Fun learning."

Participants express their clear enjoyment of combining PA with math lessons. They described it as "fun math" or "fun learning". Although participants were surprised initially about combining PA with math lessons in the gym, they clearly had a positive reaction as one student enthusiastically put it, “that’s my kind a math!” This sentiment was echoed by the other students. Having fun while doing math may seem to be a happy bonus but the participants were quick to qualify why having fun was important to their learning experience. Participants expressed how having “fun” while doing math made it more likeable, or perhaps palatable, for the students. As one student put it: “…because I love doing sports and math isn’t my favourite subject… so I think it helped me like math better.” Students’ felt that when PA activities were integrated with their math lesson they were “learning math and having fun the same time!”

It is very interesting to compare the comments and reactions of the participants in the current study to those of the students in the study conducted by Riley et al. (2017). They noted that most the students in the EASY Minds program reported that they enjoyed learning math in a different way. Their students used strikingly similar phrases such as, “I like doing sports and being active and when you combine that with maths it makes it much more enjoyable”, and described their experience as “having fun” which they felt helped them learn mathematics better.

Participants in this study compared how they felt about learning math combined with PA with how they felt about learning math through traditional classroom methods: “…more interesting than sitting down in a room, sweating…”; “the classroom math is boring because you’re just in this room with a gray pencil writing down 80 +…”; “…math in the gym is fun!” One participant related to her earlier learning experience in kindergarten when they played games to learn math. She noted that as they have progressed in school, math has become more sedentary and less fun – "…now it's like just on a paper…" But when math was combined with PA in the space of the gymnasium during this study, they could "play a game" which made learning math "fun" again! And as one of the participants put it "you also can get your least favourite part done while you're doing your favourite part…" Participants described being disengaged and distracted during sedentary math in the classroom. One participant states that when they are being "shown" math in the classroom they get bored and stop paying attention but when the math lesson was combined with PA it was "fun" and they paid attention. When asked why it was important to have fun when learning one student candidly responds, "So you don't die of boredom!"

Similarly, Riley et al (2017) reported that students described their classroom mathematics lessons as "it was boring, …it's very boring.." They described didactic teaching methods that predominantly involve writing things on paper and worksheet-based activities which they perceived were dull, boring, repetitive, and uninteresting. Students also reported not learning well because they will get distracted, and drift off.

Participants in the current study also indicated that for math lessons in the classroom they were mostly sitting which was more than just boring but physically painful. They shared their feelings: "…I don't like sitting down for a long time! I budge a lot!" and "…your legs get …really sore if you're just sitting down but when you're in the gym and you're doing it you're keeping yourself active … but you're still …learning. So it's better." and "…in the classroom you don't really get to do activities and most of the time my legs …feel like pins and needles!" Even participants who enjoyed math in the classroom appreciated the increased activity in the PA math lessons which made them feel less “squirmy”. The following statement describes how students felt not only physically but mentally in the classroom:

> “Math in the classroom …physically hurts because …your muscles get sore, …you’re hunched over, ... and like there’s a bunch of stuff on your mind …except for math, then it’s just really hard. But when you’re having fun in the gym …it’s a game …so the only thing in your mind is the math. But otherwise in the class, you’re not really doing anything so ...you just feel the need to …move around…”

Other participant statements described math in the classroom as:

> “…just sitting down, …you read the math and it just gets all confusing cause …you’re hunched over and it’s painful so …you’re looking back at the clock like ‘oh when’s it going to be over’, ‘I wonder, …if I’m going to get this right!’ But in gym, you’re just running around having fun …you don’t want it to be over…”

Clearly, participants find themselves pre-occupied with their need to move while learning math in the traditional classroom. The sedentary nature of the classroom makes them feel physically uncomfortable, restless, and distracted. They state that this makes the math “just really hard” and that it “just gets all confusing”. In contrast, participants describe the PA math as “fun” because it is like a “game” and you are “running”. During the classroom math, participants wonder “when is it going to be over” but for the PA math they “don’t want it to be over”! This was also a common theme in the Easy Minds program as students felt that expending energy helped them learn. They reported being able to concentrate and focus better and felt that it the program reduced talking, off-task time and other distractions (Riley et al., 2017).

The focus group participants commented on how they perceived PA math impacted their learning. Once their need to move was satisfied they were better able to focus and their learning experience became more enjoyable, positive, and therefore easier. When participants were asked if enjoying their learning experience helped them learn better, the group gave a collective and definitive positive response. Participants clearly felt that the lesson was "fun" or more enjoyable because they were physically "active while learning". They also appreciated the fact that they were getting exercise while learning. Participants stated that it helped them both mentally- making them "smart" and physically- making them "strong".

Riley et al. (2017) also reported that students liked that two subjects were combined in one class, "getting fit and active while learning" was considered a double benefit by students. Many of their students reported "getting fit" as a second but equally important outcome of the program, and this appeared to be an important motivator for some of them.

In the classroom math, the participants felt that they easily forgot what they were told to do because they were just sitting. In contrast, in the PA math lesson, they didn't forget the instructions as they had to start doing it immediately. The more immediate nature or faster pace of the physical activity stimulated students and helped them stay focused. A participant offers the following comparison:

> Cause regular classroom …people …just tell you what to do and then you're sitting there and you completely forget what to do but in gym like you get told what to do and then …you start doing it immediately…

The higher paced movement also made the learning of the math outcome both physically and mentally more challenging and didn't allow participants to get bored. As one student says: "…it was really fun because …it was like who's going to be the fastest and the smartest!" Participants enjoyed the relay race format in some of the PA math lessons which appealed to their competitive nature. One participant describes how the challenge of the relay races and working with her partner kept her brain "active" as it required not only quick physical movements but quick thinking and responses. Therefore, the PA kept them engaged. Participants insightfully called this "*smart learning".*

Again, Riley et al. (2017) reported a similar response from many students who commented on "multi-tasking" (doing mathematical and physical activities) and noted that being presented with an additional challenge aided in their learning. They also felt that the benefits included making it more exciting.

Overall, it seems the mental and physical challenge of the PA math lessons, the immediate nature of the physical movement, the physical engagement in the activities itself, not only increased the interest and enjoyment of students but engaged them both physically and mentally in their learning! It is commonly supported by educators that when students are engaged in learning content they learn better. Therefore, if integrating PA into math content engages students in their learning and when they are engaged they learn better, then it follows that integrating PA into curriculum content can increase students' academic achievement.

Participants further recognized that the physical activity not only increased their enjoyment and engagement in the math lesson but felt that it made them "want" remember it. All indications from students were that if you don't enjoy learning the content you won't be focused and want to remember it. As one student states: "Because if you're enjoying it then you'll remember it a lot more because you only really want to remember things that you like". The research shows that PA has been linked to cognitive tasks such as memory and the ability to concentrate (Koch, 2013). A participant in this study related how the moving or doing aspect of the PA math helped him learn the content, saying it helped him remember it when he wrote the quiz at the end of the lesson. Another participant stated that learning with PA increased their understanding by helping them "interpret it better." It appears that physical activity as part of the math lesson involved the students in a more varied or complete way that helped them to understand and remember. This is an example of tacit learning**.** Koch (2013) describes how specifically integrating PA with academic lessons such as performing jumping jacks during a math problem or using purposeful movement when students expressively use their bodies can help to grasp intangible academic concepts. As noted earlier in this paper, this is supported by Sibley and Etnier (2003) who proposed that the relationship between physical activity and cognition can be categorized into both learning/developmental mechanisms and physiological mechanisms. The learning/developmental mechanisms include the movement and physical activity learning experiences which contribute to, and may even be necessary for, proper cognitive development. Piaget also notes skills learned during physical activity carryover to learning about concepts (as cited by Sibley & Etnier, 2003). This may suggest that the physical movement alone involved in activity is important and is not contingent on the actual physical exertion. However, the effects of the PA math lessons on the participants' learning and/or experience may also be due in part to physiological mechanisms, such increased cerebral blood flow, alterations in brain neurotransmitters, structural changes in in the central nervous system, and modified arousal levels (Sibley & Etnier, 2003).

The findings of Riley et al., (2017) also support both learning/developmental mechanisms and physiological mechanisms. The students from their study used different ways to explain these benefits; "the exercise makes the brain work clearer"; because your mind has been doing exercise, it kind of gets ready for mathematics." Riley et al. reported students felt that their improved learning was due to having had the material presented in a way that allowed them to analyze and interpret (higher order thinking) with activities aiding verbal explanations, which sometimes were not easily understood. For example:

> "… I tend to drift off into my own little world because I don't always understand it when it's just on the sheet. But after doing the stuff in person, and her explaining to us what it is, I've learned about averages and all that."

Koch (2013) notes that incorporating PA within academic curricula has been shown to increase both the attention and interest of students, thereby increasing motivation and achievement. These observations can be attributed to both learning/developmental and physiological mechanisms but may also be due to a social/emotional component. Another aspect of the PA math that was appreciated by the students was the increased interaction with their partners/classmates. The larger open space of the gym gave them the opportunity to discuss what they were doing as opposed to working in the classroom alone in their desk. This social side of the learning was a positive factor for the participants. This is illustrated in the following statement:

> …so, when we did math in the gym we had like partners and we can like talk about what we're doing and all that stuff but in …math class you kinda' have to like sit in your desk and just think about it yourself, like you can't share it with anybody or …can't really discuss it.

Students from the EASY Minds program similarly mentioned that the social aspect of integrating PA activities with math content was particularly positive. They liked talking to their peers about their work and working together on group-based activities (Riley et al., 2017)

In addition, the bigger space of the gymnasium where the PA math lessons took place also helped increase the physical size of visuals making concepts easier for students to visualize and remember. A participant described it like this: "I liked the bigger shapes, like you could picture them better in your head so that when I came to the quiz, …I imagined it like as big as the gym shape." This experience is supported by the research. Chang et al. (2012) reported on the effects of exercise on different types of cognitive tasks and found positive effects for measures of executive function with some of the largest positive effects being observed for visual short-term memory. Students also felt that learning math in a bigger gym space made their learning experience more "comfortable" and "less loud", and not "as cramped!" Similarly, many of students in the EASY Minds program described being outside and away from the confines of the classroom as being conducive to learning and used phrases such as "being free", "having fun", and "freedom to learn" (Riley et al., 2017).

Overall, the feedback from the participants in the current study indicated that they enjoyed the math lesson when it was combined with PA because they liked to move. They reported that the PA made it fun which made them more interested and engaged in lesson. Research supports the positive effects of aerobic exercise in particular on cognition and therefore learning. Best (2010) points out that acute aerobic exercise induces immediate neurochemical changes that may prime the central nervous system for either concurrent or subsequent skill acquisition. Best noted a study conducted by Winter et al., (2007) which found that learning was superior following a short, intense running effort as compared to a longer, moderately-intense run or period of relaxation. Winter et al. reported that the behavioural effect was complemented by increases in peripheral levels of BDNF and monoamines (dopamine, norepinephrine, and epinephrine) that predicted retention of the learned material. Another study examined by Best considered whether the simultaneous engagement in exercise and a cognitive task leads to an interaction between the central and peripheral biochemical response. There was evidence that the greater the norepinephrine response to the simultaneous engagement in exercise and a cognitive task, the greater benefit to EF task performance (McMorris, Collard, Corbett, Dicks, & Swain, 2008). It appears these immediate neurochemical boosts may transiently enhance the neural response to challenging tasks (Best, 2010). Therefore, research is consistent with the reports of participants in this study that the PA math lesson helped them interpret, visualize and remember the concepts taught.

Best (2010) notes that generally children's exercise comes through participation in group PA activities or sports that require complex cognition to cooperate with teammates, anticipate the behaviour of teammates and opponents, employ strategies, and adapt to ever-changing task demands. These tasks place demands on children's executive processes require them to create, monitor, and modify a cognitive plan in response (Best, 2010). The author of the current study, who has many years of experience teaching children a variety of physical skills, activities, and sports as both a teacher and coach, supports this idea as she has observed how students/players are able to "think" the game or activity, anticipating and understanding strategic movements and positioning.

Best (2010) suggests that the 'contextual interference' that is created when components are presented in a complex and quasi-random manner, may explain how participation in engaging games transfers and results in enhanced EF. He states that the more effortful and elaborative the processing of pertinent information is, the greater the learning. For example, a fMRI study showed that this more effortful processing imposed demands on EF-related circuitry in the brain, as seen in greater frontal activation, compared to more widespread parietal, premotor, and cerebellar activation in the absence of contextual interference (Cross, Schmitt & Grafton, 2007). Researchers have suggested that this cognitive engagement inherent in exercise may help explain how exercise impacts cognition (Sibley & Etnier, 2003, Tomporowski et al., 2008).

Participants from the focus group indicated that the increased social interaction due to the nature of PA lessons helped them become more involved their learning. In addition, they felt that when the math learning tasks were combined with PA they felt challenged, both physically and mentally, which appealed to their competitive nature. There is evidence that supports social interaction as a factor that induces a more specific cognitive activation that enhances immediate recall. This is demonstrated in a study by Pesce, Crova, Cereatti, Casella, and Bellucci (2009) which examined acute aerobic exercise and cognition by comparing two forms of aerobic exercise of equivalent aerobic intensity. During one session children (aged 11-12) completed one hour of individual circuit training and during another session completed one hour of aerobic group games. Pesce et al. reported that the circuit training contained more opportunities to learn motor skills while the group games provided more opportunities to apply those motor skills in a competitive and strategic manner. Notably, the circuit training consisted solely of individual activity but the group games consisted roughly of equal parts individual activity and group activity. Although these activities were not combined with other learning tasks, after each session both immediate and delayed word recall were assessed. For immediate word recall, only the acute bout of group aerobic games enhanced memory relative to baseline memory performance. Pesce et al. concluded that specific cognitive activation likely occurred through the greater opportunity for social interaction and the need to apply motor skills in a strategic fashion. The benefits of social interaction are also supported in animal models which are often predictive of the effects on humans. Stranahan, Khalil, and Gould (2006) reported that rats in social isolation do not garner the same benefits from exercise as rats that are housed together.

Similar to the ‘contextual interference’ proposed by Best (2010), Tomporowski, McCullick, and Pesce (2015) proposed ‘variability of practice’ to provide a continuous stimulation of the pathways of executive function. Pesce et al. (2019) point out that his concept is also consistent with propositions by Best (2010) and Pesce (2012) that children should learn coordinating movements which lack automaticity and engage in movement actions in variable environments which require cognitive engagement and control to maximally benefit development. Both these concepts promote novelty, diversity, effort, and successfulness as key ingredients that can make learning experiences more meaningful and improve brain plasticity and cognitive development (Carey, Bhatt, & Nagpal, 2005; Pesce et al., 2019; Shors, 2014).

One of the most prominent comments about their learning experience from the focus group participants in the current study was how they found the PA math lessons “fun” and “enjoyable” mostly because of the PA activities in the lesson. Pesce et al. (2019) proposed that training executive attention in enjoyable problem solving and creativity tasks embedded in PA games can be exploited as a powerful means for promoting motor skills and executive function development jointly (Tomporowski et al., 2015). They note the importance of enjoyment citing attention, emotional regulation, and response-produced feedback as strictly intertwined with bodily motion (Pesce & Ben-Soussan, 2016). Pesce et al. (2019) proposed that cognitive challenges embedded into emotionally loaded playful activities and child-appropriate interventions can promote executive function development (Diamond & Lee, 2011). Pesce et al. (2019) emphasized that not only the mental effort generated by novelty and diversification, but also the success of the learning experience contributes to the impact at different system levels, such as the neurogenic level, the behavioural skill level and the more psychological level of interest, motivation, and well-being (Schmidt & Wrisberg, 2008; Shors, 2014; Sylvester, Standage, Ark, et al., 2014; Sylvester, Standage, Dowd, et al., 2014).

The aim of this portion of the current study was to examine students' perceptions of their learning experience and gain insight into the potential, the challenges and impact of integrating physical activity in elementary school mathematics lessons. The key benefits perceived by students was increased enjoyment and enthusiasm for mathematics which promoted their engagement in the learning activities due to enhanced opportunities physical movement/activity and social interaction. An insightful statement from one the participants clearly promotes her learning experience during the PA intervention as a positive one:

> Other schools should take notes because …more schools …would probably …be a better school …if the kids liked the way that they were learning then they would probably want to …keep doing it and then their teacher would like teach them more of what they originally wouldn't want to learn about because it's boring. It's …like making you want to do it more often!

These positive perceptions demonstrate potential for using a movement-based approach to teach mathematical concepts. Quality learning experiences have the potential to develop learners not only cognitively but also socially, emotionally and physically.

7.4 Transferability

The participants give numerous examples of why they enjoyed the physical activity during math and how it affected their learning. The physical activity they felt increased their enjoyment of learning math and helped them to stay focused on what they were learning. It also helped them to remember the learning content and actual made them want to remember it.

Participants described being active not only physically but also mentally. Being active and learning at the same time was keenly described by one of the students as “smart learning”. Student made many insightful and enlighten reflections on their experience. Finally, when asked by the co-investigator if they thought adding PA to lessons in other subject areas would increase their involvement and improve learning their responses were definitively positive. One of the participants in the current study, keenly suggests that schools should follow the example of the PA math lesson from this study because it would make them better schools. It would mean students liking the way they learn and as a result they would want to keep learning, participate in lessons more often and teachers would be able to teach students more content.

7.5 Limitations

This study was applied in the real-world setting in which not everything can be controlled in the same way as a controlled laboratory context. An ecologically valid setting has constraints and limitations which may affect the results.

One factor that may have affected the results of this study is teaching style. Due to the number of different class groups (4) and other limitations such as scheduling constraints within the structure of the school day, and classroom size, it would be difficult for the same teacher to deliver all lessons to all classes. Using the same teacher would also mean a longer time frame for all lessons to be delivered and altering the regular schedule to a greater extend. For this study, there was some minor alterations to the schedule to ensure all lessons were delivered in the morning within a certain time frame as research has shown that time of day can have an impact on results. As well, classes not involved in the experimental condition needed to participate in the classroom math class before attending their regular physical education class to avoid post-exercise effects on the outcomes. To work within the schedule and time frame as well as maintain as normal a routine for the participants and avoid novel effects from a new face or different teacher, classes were taught the math lesson in the classroom by their individual classroom teacher as would normally occur. This was considered less disruptive for students and teachers. To maintain as much consistency as possible all teachers followed the same prepared lesson plan and an independent observer was present in the classroom to note teaching style or factors that may affect the delivery of the lesson.

For the lesson integrated with physical activity, the schedule remained consistent with the students' regular physical education class time with their regular PE teacher leading the lesson in the gym setting. The teacher for the experimental condition, the PA math lesson remained the same for all classes. Therefore, in the case of the intervention, any difference in teaching style will not be an issue as the same teacher delivered all physically active math lessons to all groups.

Teaching style and lesson plans were controlled in the study due to previous concerns in the literature. Bartholomew and Jowers (2011) made several attempts to integrate PA with classroom lessons. During their initial approach, they trained teachers using the Texas I-CAN lessons to incorporate PA during academic time but few teachers implemented the lessons as intended. After a second ineffective attempt to integrate PA with academic curriculum they formed a committee of teachers to develop a set of active lessons. Notably, physical education specialists were included. Bartholomew and Jowers reported that the teachers were then able to successfully implement these lessons and produce a significant increase in PA. Koch (2013) stresses the importance of PE teachers assisting classroom teachers with the development and guidance needed to provide movement within the classroom.

Due to the real-world nature of this study the experimental groups are taken as is, as the class groups that already exist and are not chosen by the researcher. Some of the differences of the scores may be attributed to the existing dynamics within individual classes which include level of general ability or performance of the group as well as the behaviour of the group which includes their listening skills and organization of the class. In addition, some of the teachers participated in and supported this study more enthusiastically than others.

Another limiting factor was the time available within the school schedule to implement the lessons in the current study. The researcher had to conform to the rigid schedule of 30-minute periods with no transition time between classes, including the movement time between the space in the gym and classroom. To avoid any disruption to schedules was quite challenging, the current study strived to cause the least interference with the normal schedule, structure and teacher assignments, as well as minimize any demands on classroom teachers' time and workload.

The researcher believes that if the current study was to be repeated with a more focused, accommodating and collaborative approach, the effects of PA on learning would be more significant and would continue to improve if conducted over a longer time span. If the frequency, duration and intensity of such an intervention was increased it could improve fitness levels of students which in turn could have not only an increased effect on learning but health. When Chang et al. (2012) assessed cognitive performance following exercise, positive effects were generally observed for all fitness levels. But as a review by Tomporowski et al. (2008) found, children who are physically fit perform cognitive tasks more rapidly than do less fit children. However, to increase the effect of such a PA intervention in a real-life school setting significant support would be needed, particularly from the school and school district. This support would require a significant change to the current paradigm of thought regarding priorities in the education system.

The overall results for this study support the prediction of the researcher that integrating PA with academic lessons traditionally taught in the classroom through sedentary methods would have a positive impact on student learning while significantly increasing the amount of PA for students. The current study did not find an increase in the learning outcomes which were a measured by the quiz scores, but the overall the scores for both conditions were similar. Significantly though, the amount of PA for the students during the lesson was increased. These results bear out the research which shows that academic performance was not negatively affected when opportunities for PA was increased (Ahamed et al., 2007; Koch, 2013; Tremblay et al., 2000; Trudeau & Shephard, 2008) while PA level was increased.

7.6 Implications for Teacher Training

As noted earlier, there are barriers to increasing PA levels of students in schools. Erwin et al. (2011) asked teachers to describe the barriers as well as the facilitators to integrating PA in the classroom and what benefits they thought students would receive from additional PA. "Despite the fact, that lack of time, pressures of academic test scores, and small spaces were described as barriers, the teachers felt the benefits of physical activity (e.g. student attentiveness, concentration) outweighed the constraints" (Erwin et al., 2011, p.250). Notably, the researchers from the study by Erwin et al. continued to facilitate in-services for the teachers to provide assistance with their planning and implementation. Further, the integration of PA into traditional classroom lessons is being introduced and promoted to future teachers in the community as all elementary teacher candidates of the University in which their study took place are required to take the course regarding physical education for the classroom teacher and are responsible for creating PA integrated lessons to be implemented during field experiences. Erwin et al. stated that these future teachers will have a better understanding of the importance of physical activity for children's health and consequently continue to integrate physical activity in the classroom.

As a result of their study, Aiello et al. (2010) concluded that whenever possible, the use of teaching approaches focusing on the experience of the "motor laboratory" to teach subject matter in primary school should be used. This approach not only ensures acceptable educational outcomes, but systematic movement activities that produce energy expenditure can improve the lifestyle and psychological well-being of students and make the time spent at school less sedentary. Aiello et al. stated that recent theoretical considerations on cognition have led, over the last decades in Italy, to a ‘re-conceptualization’ of teaching practices in educational contexts in favour of an enhancement of the bodily-kinaesthetic dimension in the educational processes. Their holistic approach is inspiring as the authors believe that the body and its movement potentialities are not only a privileged instrument to educate and access knowledge but the means through which the quality of relationships and lifestyles of the person, in a state of mental well-being, is realized as the result of the integration of physical and biological elements as well as cultural, social and psychological ones.

According to Aiello et al. (2010), the need for the primary school curriculum to include experiences leading to a healthy lifestyle (which means the prevention of diseases related to hypokinesia) and the enhancement of school and extra-school motor and sport experience is supported in the latest guidelines from the Ministry of Education (2007) in Italy. To achieve these aims, Aiello et al. state that

> “the teachers’ role is to propose a teaching model that shapes the formation of learners and that is oriented, at the same time, by methodological choices aimed at the improvement of cognitive functions with a focus on the well-being conditions that facilitate their success” (p. 37).

To implement this type of approach, classroom teachers would need training, as in the study by Aiello et al., (2010), and suitable facilities as in a motor laboratory. In most schools, classroom space is limited and not conducive to movement and gymnasium time is also limited. This would involve a serious commitment of school boards and government to such teaching methodologies as planning, consultation, and funding would be needed to facilitate effective implementation of physical active lessons in the classroom. However, before that can happen, as stated earlier, a serious paradigm shift is warranted in the school of thought that "academics" take priority over physical activity to increase academic achievement.

7.7 A Paradigm Shift

The limitation of PA promotion primarily as energy expenditure, particularly as it relates to children's development is a concern among researchers (Bailey, Hillman, Arent, & Petitpas, 2013; Pesce et al., 2019). Research evidence has de-emphasized the role played by the metabolic demands of PA, highlighting the joint role played by physical, emotional, and social challenges (Diamond & Ling's, 2016). Pesce et al. (2019) point out that many argue for a shift in focus based upon evidence of the complex interrelations of weight status with motor and cognitive development. He notes the positive predictive role of motor development and competence on both physical and cognitive development and the resulting positive effects on health behaviours and success in life (D'Hondt et al., 2013; Feinstein & Bynner, 2004; Reinert, Po'e, & Barkin, 2013; Robinson et al., 2015; van der Fels et al., 2015).

Further, a shift in the focus from 'how much?' to 'what kind?' of PA has been proposed in the field of exercise and cognition research (Pesce, 2012). PA and sports activities, particularly challenging and engaging games, that emphasize diversification, novelty, and complexity have been viewed as important for the promotion of cognitive child development and therefore, academic achievement. (Best, 2010; Diamond, 2015; Tomporowski, McCullick, Pendelton, & Pesce, 2015). Physically active group games should be considered valuable as they can provide quality learning experiences for children. Engaging PA games and sports that require complex cognition to cooperate with teammates, anticipate the behaviour of teammates and opponents, employ strategies, and adapt to ever-changing task demands place demands on children's executive processes (Best 2010). Group PA games also provide greater opportunities for social interaction which has been shown to enhance the effects of exercise on cognition when combined with the need to apply motor skills in a strategic fashion (Pesce et al., 2009; Stranahan et al., 2006). Another important factor that is often embedded in PA games is enjoyment or the 'fun factor'. This concept is strongly supported by the results of the qualitative portion of this study. Focus group participants were very clear that "fun" and the enjoyment of the PA math lessons contributed greatly to the quality of their learning experience. This was also the predominant reaction reported in a similar study by Riley et al., 2017. Pesce et al. (2019) noted that enjoyment was associated with attention, emotional regulation, and response-produced feedback which are all interwoven with bodily motion (Pesce & Ben- Soussan, 2016).

Chapter 8. Conclusion

"Physical fitness is not only one of the most important keys to a healthy body, it is the basis of dynamic and creative intellectual activity."   -John F. Kennedy

As important as PA is to our physical health alone, it is still treated as secondary need in the education of our children. Time for both PA and PE are limited or restricted so as not to 'interfere' with 'academic' instructional time. PE is often viewed as a break from 'regular' instructional time, a chance for students to burn off the excessive energy and pacify their need to move. PE is an instructional course itself designed to meet learning outcomes that develop children's physical, social/emotional, creative, and intellectual skills through movement. PA is the medium used. Important skills are inherently learned through PA which are utilized in all aspects of a child's life. No wonder it is usually a child's favourite class in school!

Yet PE is not held in the same regard or understood by those who do not teach it or believe in it. It often seems to be under-valued and not taken seriously by other teachers and administrators at both the school and district levels. PA is instrumental in PE but can be instrumental to learning in all aspects of education and is instrumental to the development of the whole child.

The qualitative side of the current study showed the academic side of learning is only one part of the learning experience for children. It is interesting that when most people think 'cognitive growth' they tend to think in terms of 'academic learning' which takes place in a traditional classroom setting. The paradigm shift, discussed earlier in this paper, requires more than considering the child's intellectual development. It needs to consider the whole child, how they feel about learning, their enjoyment and interest in learning. It needs to consider the social/emotional as well as the intellectual and physical aspects of a child's learning experience.

A more holistic approach is needed. Children are young physical beings who have an innate nature and need to move for more than just physical health reasons.
A physically indulgent approach is needed with space and freedom to move and experience learning as a whole person. Further, in the opinion of the researcher, this learning should relate to more real-world experience. School-based learning needs to be less 'academic' and a more of a physical experience for students.

In the future, educators, universities and governing bodies that teach, train, develop, and implement standards, programs, and policies should give serious consideration to the progressive research that provides valuable evidence on the wide scope of benefits that can be reaped through PA. Researchers have emphasized that not only the mental and physical effort generated by novelty and diversification of cognitively-engaging PA tasks/activities, particularly in social groups, but also the success of the learning experience contributes to the impact at different system levels, such as the neurogenic level, the behavioural skill level and the more psychological level of interest, motivation, and well-being (Schmidt & Wrisberg, 2008; Shors, 2014; Sylvester, Standage, Ark, et al., 2014; Sylvester, Standage, Dowd, et al., 2014).

References

Adsiz, E., Dorak, F., Ozsaker, M., & Vurgun, N. (2012) The influence of physical activity on attention in Turkish children. *HealthMED*, *6*(4), 1384–1389.

Ahamed, Y., MacDonald, H., Reed, K., Naylor, P-J., Liu-Ambrose, T., & McKay, H. (2007). School-based physical activity does not compromise children's academic performance. *Medicine and Science in Sports and Exercise, 39*(2), 371-376.

Aiello, P., Di Tore, S., & Sibilio, M. (2010). Energy expenditure implications in the use of teaching methodologies: Possible influence of the laboratory focused on body and movement in improving wellness in primary school students. *Sportekspert, 3*(2), 37-40.

Ang, E. T., & Gomez-Pinilla, F. (2007). Potential therapeutic effects of exercise to the brain. *Current Medicinal Chemistry*, 14, 2564-2571.

Asbury, J-E. (1995). Overview of Focus Group Research. *Qualitative Health Research, 5*(4), 414-420

Bailey, R., Hillman, C., Arent, S., & Petitpas, A. (2013). Physical activity: An underestimated investment in human capital? *Journal of Physical Activity and Health, 10*(3)*,* 289–308.

Barbour, R.S. (2005). Making sense of focus groups. *Medical Education 2005*, *39*, 742-750.

Bartholomew, J. B., & Jowers, E. M. (2011). Physically active academic lessons in elementary children. *Preventative Medicine, 52*, S51-S54

Bassett, D. R., Jr, Toth, L. P., LaMunion, S. R., & Crouter, S. E. (2017). Step counting: a review of measurement considerations and health-related applications. *Sports medicine (Auckland, N.Z.)*, *47*(7), 1303–1315. https://doi.org/10.1007/s40279-016-0663-1

Best, J.R. (2010). Effects of physical activity on children's executive function: contributions of experimental research on aerobic exercise. *Developmental Review, 30*(4), 331–551.

Blaydes-Madigan, J. (2004). *Thinking on your feet* (2nd ed.). Murphy, TX: Action Based Learning.

Graham, G. M., Holt-Hale, S. A., & Parker, M. A. (2009). *Children moving* (8th ed.). Columbus, OH: McGraw-Hill.

Braun, V., & Clarke, V. (2006) Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*, 77-101.

Brisswalter, J., Collardeau, M., & Rene, A. (2002). Effects of acute physical exercise characteristics on cognitive performance. *Sports Medicine, 32*(9), 555–566.

Castelli, D.M., Centeio, E.E., Beighle, A.E., Carson, R.L., & Nicksic H.M. (2014). Physical literacy and comprehensive school physical activity programs. *Preventative Medicine, 66*(0), 95–100.

Carey, J.R., Bhatt, E., & Nagpal, A. (2005). Neuroplasticity promoted by task complexity. Exercise and Sport Sciences Reviews, 33(1), 24–31.

Chang, Y. K., Labban, J. D., Gapin, J. I., & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain research, 1453*, 87–101.

Coe, D. P., Pivarnik, J. M., Womack, C. J., Reeves, M. J., & Malina, R. M. (2006). Effect of physical education and activity levels on academic achievement in children. *Medicine and Science in Sports and Exercise 38*(8), 1515-1519.

Colcombe, S.J., Erickson, K.I., Scalf, P.E., Kim, J.S., Prakash, R., McAuley, E., Elavsky, S., Marquez, E.X., Hu, L., & Kramer, A.F. (2006). Aerobic exercise training increases brain volume in aging humans. *The Journal of Gerontology: Series A, 61*(11):1166–1170.

Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: A meta-analytic study. *American Psychological Society, 14*(2), 125–130.

Colcombe, S. J., Kramer, A. F., Erickson, K. I., Scalf, P., McAuley, E., Cohen, N. J., Webb, A., Jerome, G. J., Marquez, D. X., & Elavsky, S. (2004). Cardiovascular fitness, cortical plasticity, and aging. *Proceedings of the National Academy of Sciences of the United States of America*, *101*(9), 3316–3321. https://doi.org/10.1073/pnas.0400266101

Cone, T. P., Werner, P. & Cone, S. L. (2009). *Interdisciplinary elementary physical education,* 2nd ed., Champaign, IL: Human Kinetics.

Creswell, J.W. (1994). *Research design: Qualitative and quantitative approaches*. Thousand Oaks, CA: Sage Publications, Inc.

Creswell, J. W., & Poth, C. N. (2017). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks, CA: Sage Publications.

Cross, E.S., Schmitt, P.J., & Grafton, S.T. (2007). Neural substrates of contextual interference during motor learning support a model of active preparation. *Journal of Cognitive Neuroscience. 19*(11), 1854–1871.

Denzin, N. K., & Lincoln, Y. S. (2005). Introduction: The discipline and practice of qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (3rd ed., pp 1-32). Thousand Oaks, CA: Sage Publications.

Department of Education (n.d.). *Program of Studies 2014-2015.* St. John's: Government of Newfoundland and Labrador. Retrieved from: http://www.ed.gov.nl.ca/edu/k12/curriculum/descriptions.html

D'Hondt, E., Deforche, B., Gentier, I., De Bourdeaudhuij, I., Vaeyens, R., Philippaerts, R., & Lenoir, M. (2013). A longitudinal analysis of gross motor coordination in overweight and obese children versus normal-weight peers. International Journal of Obesity, 37, 61–67. doi:10.1038/ijo.2012.55

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*, 135–168.

Diamond, A. (2015). Effects of physical exercise on executive functions: Going beyond simply moving to moving with thought. Annals of Sports Medicine and Research, *2*(1), 1011.

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333*(6045), 959–964. doi:10.1126/science.1204529

Diamond, A., & Ling, D. S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. Developmental Cognitive Neuroscience, 18, 34–48.

Donnelly, J.E., Greene, J.L., Gibson, C.A., Smith, B.K., Washburn, R.A., Sullivan, D.K., Dubose, K., Mayo, M.S., Scheizle, K.H., Ryan, J.J., Jacobsen, D.J., & Williams, S.L. (2009). Physical activity across the curriculum (PAAC): a randomized controlled trial to promote physical activity and diminish overweight and obesity in elementary school children. *Preventive Medicine, 49*(4), 336–341.

Donnelly, J.E., Hillman, C.H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., Lambourne, K., & Szabo-Reid, A. N. (2016). Physical activity, fitness, cognitive function, and academic achievement in children: A systematic review. *Medicine & Science in Sports & Exercise. 48*(6):1197–1222.

Donnelly, J. E., & Lambourne, K. (2011). Classroom-based physical activity, cognition and academic achievement. *Preventive Medicine, 52*, S36-S42.

Drollette, E.S., Scudder, M.R., Raine, L.B., Moore, R.D., Saliba, B.J., Pontifex, M.B., & Hillman, C.H. (2014). Acute exercise facilitates brain function and cognition in children who need it most: an ERP study of individual differences in inhibitory control capacity. *Developmental Cognitive Neuroscience, 7*, 53–64. DOI: 10.1016/j.dcn.2013.11.001

Dwyer, T., Coonan, W.E., Leitch, D.R., Hetzel, B.S., & Baghurst, R.A. (1983). An investigation of the effects of daily physical activity on the health of primary school students in South Australia. *International Journal of Epidemiology, 12*(3), 308-313.

Erwin, H. E., Able, M.G., Beighle, A., & Beets, M. W. (2011). Promoting children's health through physically active math classes: A pilot study. *Health Promotion Practice, 12*(2), 244-251.

Erwin, H., Fedewa, A., & Ahn, S. (2013). Student academic performance outcomes of a classroom physical activity intervention: a pilot study. *International Electronic Journal of Elementary Education, 5(*2), 109–124.

Etnier, J. L., Salazar, W., Landers, D. M., Petruzzello, S. J., Han, M., & Nowell, P. (1997). The influence of physical fitness and exercise upon cognitive functioning: A meta-analysis. *Journal of Sport & Exercise Psychology, 19*, 24-277.

Feinstein, L., & Bynner, J. (2004). The importance of cognitive development in middle childhood for adulthood socioeconomic status, mental health, and problem behavior. *Child Development, 75*(5), 1329–1339.

Fontana, A., & Frey, J. (2005). The interview: From neutral stance to political involvement. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (3rd ed., pp 695-727). Thousand Oaks, CA: Sage Publications.

Gao, Z., Hannan, P., Xiang, P., Stodden, D.F., & Valdez, V.E. (2013). Video game-based exercise, Latino children's physical health, and academic achievement. *American Journal of Preventative Medicine, 44*(3 Suppl 3), S240–S246.

Gomez-Pinilla, F., & Hillman, C. (2013). The influence of exercise on cognitive abilities. *Comparative Physiology, 3*(1), 403–428.

GraphPad Prism, (Version 8.1.0) [Computer Software]. San Diego, California, USA: GraphPad Software. http://www.graphpad.com/

Hillman, C.H., Castelli, D.M., & Buck, S.M. (2005). Aerobic fitness and neurocognitive function in healthy preadolescent children. *Medicine & Science in Sports & Exercise, 37*, 1967-1974.

Hillman, C.H., Pontifex, M.B., Raine, L.B., Castelli, D.M., Hall, E.E., & Kramer, A.F. (2009). The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. *Neuroscience 159*(3):1044–1054.

Hillman, C.H., Buck, S.M., Themanson, J.R., Pontifex, M.B., & Castelli, D.M. (2009). Aerobic Fitness and Cognitive Development: Event-Related Brain Potential and Task Performance Indices of Executive Control in Preadolescent Children. *Developmental Psychology, 45*(1), 114–129.

Hillman, C.H., Pontifex, M.B., Castelli, D.M., Khan, N.A., Raine, L.B., Scudder, M.R., Drollette, E.S., Moore, R.D., Wu, C.T., & Kamijo, K. (2014). Effects of the FITKids randomized controlled trial on executive control and brain function in children. *Pediatrics, 134*(4), e1063-1071. DOI: 10.1542/peds.2013-3219

Hofmann, W., Schmeichel, B.J., & Baddeley, A.D. (2012). Executive functions and self-regulation. *Trends in Cognitive Sciences, 16*(3), 174-180.

Howie, E.K., & Pate, R.R. (2012). Physical activity and academic achievement in children: a historical perspective. *Journal of Sport and Health Science, 1*(3), 160–169.

Kamijo, K., Pontifex, M.B., O'Leary, K.C., Scudder, M.R., Wu, C.T., Castelli, D.M., & Hillman, C.H. (2011). The Effects of an Afterschool Physical Activity Program on Working Memory in Preadolescent Children. *Developmental Science, 14*(5), 1046–1058. DOI:10.1111/j.1467-7687.2011.01054.x.

Katz, D.L., Cushman, D., Reynolds, J., Njike, V., Treu, J.A., Katz, C., Walker, J., & Smith E. (2010). Putting physical activity where it fits in the school day: preliminary results of the ABC (Activity Bursts in the Classroom) for fitness program. *Preventing Chronic Disease, 7*(4), A82.

Kitchen, D. & Kitchen, J.K. (2013). Integrating physical education and mathematics: a collaborative approach to student learning. Strategies, 26(1), 31-38, DOI: 10.1080/08924562.2012.749170

Koch, J. L. (2013). Linking physical activity with academics: strategies for integration. *Strategies: A Journal for Physical and Sport Educators, 26*(3), 41-43.

Kopp, B. (2012). A simple hypothesis of executive function. *Frontiers in Human Neuroscience, 6*, 159, https://doi.org/10.3389/fnhum.2012.00159

Krafft, C.E., Schaeffer, D.J., Schwarz, N.F., Chi, L., Weinberger, A.L., Pierce, J.E., Rodrigue, A.L., Allison, A.D., Yanasak, N.E., Liu, T., Davis, C.L., & McDowell, J.E. (2014). Improved frontoparietal white matter integrity in overweight children is associated with attendance at an after-school exercise program. *Developmental Neuroscience, 36*(1):1–9.

Kramer, A.F., Hahn, S., Cohen, N.J., Banich, M.T., McAuley, E., Harrison, C.R., Chason, J. Vakil, E., Bardell, L., Boileau, R.A., & Colcombe, A. (1999). Ageing, fitness and neurocognitive function. *Nature, 400*, 418–419.

Kramer, A. K., & Erickson, K. I. (2007). Capitalizing on cortical plasticity: influence of physical activity on cognition and brain function. *Trends in Neuroscience*, *11*(8), 342-348.

Lambourne, K., & Tomporowski, P.D. (2010). The effect of exercise-induced arousal on cognitive task performance: A meta-regression analysis. *Brain research, 1341*, 12–24.

Lichtman, M. (2010). *Qualitative research in education: A user's guide*. Los Angeles, CA: Sage Publications.

Lyon, G. (1996). Learning Disabilities. *The Future of Children, 6*(1), 54-76. doi:10.2307/1602494

Ma, J. K., Le Mare, L., & Gurd, B. J. (2015). Four minutes of in-class high-intensity interval activity improves selective attention in 9- to 11-year olds. *Applied Physiology, Nutrition, and Metabolism, 40*(3), 238–244.

Magistretti, P. J., Pellerin, L., & Martin, J. (2000). Brain energy metabolism: an integrated cellular perspective. In F. E. Bloom, D. J. Kupfer (eds). Psychopharmacology: the fourth generation of progress. American College of Neuropsychopharmacology.

https://acnp.org/digital-library/psychopharmacology-4th-generation-progress/

Mahar, M. T., Murphy, S. K., Rowe, D. A., Golden, J., Shields, A.T., & Raedeke, T. D. (2006). Effects of a classroom-based program on physical activity and on-task behaviour. *Medicine and Science in Sports and Exercise, 38*(12), 2086-2094.

McMorris, T., Collard, K., Corbett, J., Dicks, M. , & Swain, J. (2008). A test of the catecholamines hypothesis for an acute exercise-cognition interaction. *Pharmacology Biochemistry and Behavior*, *89*(1), 106-115. https://doi.org/10.1016/j.pbb.2007.11.007

Morgan, D. L. (1997). *Focus groups as qualitative research, 2nd edition*. Sage Publications.

Naglieri, J. A. (2003). Current advances in assessment and intervention for children with learning disabilities. In Scruggs, T. E., Mastropieri, M. A. (Eds.), Advances in learning and behavioral disabilities: Identification and assessment (Vol. 16; pp. 163–190). New York, NY: JAI.

Patton, M. Q. (2015). *Qualitative research and evaluative methods: Integrating theory and practice* (4rd ed). Thousand Oaks, CA: Sage Publications.

Pawlowski, C. S., Tjørnhøj-Thomsen, T., Schipperijn, J., & Troelsen, J. (2014). Barriers for recess physical activity: a gender specific qualitative focus group exploration. *BMC Public Health, 14*, 639. Retrieved from: http://www.biomedcentral.com/1471-2458/14/639

Pereira, A.C., Huddleston, D.E., Brickman, A.M., Sosunov, A.A., Hen, R., McKhann, G.M., Sloan, R., Gage, F.H., Brown, T.R., & Small, S.A. (2007) An in vivo correlate of exercise-induced neurogenesis in the adult dentate gyrus. *Proceedings of the National Academy of Sciences USA*, *104*(13), 5638–5643.

Pesce, C., Crova, C., Cereatti, L., Casella, R., & Bellucci, M. (2009). Physical activity and mental performance in preadolescents: Effects of acute exercise on free-recall memory. *Mental Health and Physical Activity, 2*(1), 16–22.

Pesce, C. (2012). Shifting the focus from quantitative to qualitative exercise characteristics in exercise and cognition research. *Journal of Sport and Exercise Psychology, 34*,766-786.

Pesce, C., & Ben-Soussan, T. D. (2016). "Cogito ergo sum" or "ambulo ergo sum"? New perspectives in developmental exercise and cognition research. In T. McMorris (Ed.), Exercise-cognition interaction: Neuroscience perspectives (pp. 251–282). London: Elsevier.

Pesce, C., Croce, R., Ben-Soussan, T.D., Vazou, S., McCullick, B., Tomporowski, P.D., Horvat, M. (2019). Variability of practice as an interface between motor and cognitive development. International *Journal of Sport and Exercise Psychology, 17*(2), 133-152.

Polich, J. (2007). Updating P300: an integrative theory of P3a and P3b. *Clinical Neurophysiology: official journal of the International Federation of Clinical Neurophysiology,118*(10), 2128–2148.

Public Health Agency of Canada. (2011a). Obesity in Canada: overview. Ottawa: Public Health Agency of Canada. Retrieved from: http://www.phac-aspc.gc.ca/hp-ps/hl-mvs/oic-oac/index-eng.php

Public Health Agency of Canada (2011b). *News Release: Government of Canada supports new physical activity guidelines.* Ottawa: Public Health Agency of Canada. Retrieved from: http://www.phac-aspc.gc.ca/media/nr-rp/2011/2011_0124-eng.php

Raven, J., Raven, J. C., & Court, J. H. (2000, updated 2004). *Manual for Raven's Progressive Matrices and Vocabulary Scales*. Section 3: The Standard Progressive Matrices. San Antonio, TX: Harcourt Assessment.

Reed, J.A., Einstein, G., Hahn, E., Hooker, S.P., Gross, V.P., & Kravitz, J. (2010). Examining the impact of integrating physical activity on fluid intelligence and academic performance in an elementary school setting: a preliminary investigation. *Journal of Physical Activity and Health, 7*(3), 343–351.

Reinert, K. R. S., Po'e, E. K., & Barkin, S. L. (2013). The relationship between executive function and obesity in children and adolescents: A systematic literature review. Journal of Obesity, doi:10.1155/2013/820956

Riley, N., Lubans, D. R., Holmes, K., & Morgan, P. J. (2014). Rationale and study protocol of the EASY Minds (Encouraging Activity to Stimulate Young Minds) program: cluster randomized controlled trial of a primary school-based physical activity integration program for mathematics. *BMC Public Health, 14*, 816.

Riley, N., Lubans, D. R., Holmes, K. and Morgan, P. (2016). Findings from the EASY Minds cluster randomized controlled trial: evaluation of a physical activity integration program for mathematics and primary schools. *Journal of Physical Activity and Health, 13*, 198-206.

Riley, N., Lubans, D., Holmes, K., Hansen, V., Gore, J. and Morgan, P. (2017). Movement-based mathematics: enjoyment and engagement without compromising learning through the EASY Minds program. *EURASIA Journal of Mathematics Science and Technology Education, 13*(6), 1653-1673.

Ritchie, J. & Lewis, J. (2003). *Qualitative research practice: A guide for social science students and researchers*. London, UK: Sage Publications.

Roberts, K. C., Sheilds, M., de Groh, M., Aziz, A., & Gilbert, J. (2012). Overweight and obesity in children and adolescence: Results from the 2009 to 2011 Canadian health measures survey. *Health Reports, 23*(3), 3-7.

Robinson, L. E., Stodden, D. F., Barnett, L. M., Lopes, V. P., Logan, S. W., Rodrigues, L. P. & D'Hondt, E. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Medicine, 45*(9), 1273–1284. doi:10.1007/s40279-015-0351-6

St Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *Quarterly Journal of Experimental Psychology*, *59*(4), 745–759. https://doi.org/10.1080/17470210500162854

Sallis J.F., McKenzie T.L., Kolody B., Lewis M., Marshall S., & Rosengard P. (1999). Effects of health-related physical education on academic achievement: project SPARK. *Research Quarterly for Exercise and Sport, 70*(2),127–34.

Schaeffer, D.J., Krafft, C.E., Schwarz, N.F., Chi, L., Rodrigue, A.L., Pierce, J.E., Allison, A.D., Yanasak, N.E., Liu, T., Davis, C.L., & McDowell, J.E. (2014). An 8-month exercise intervention alters frontotemporal white matter integrity in overweight children. *Psychophysiology, 51*(8), 728–733. DOI: 10.1111/psyp.12227.

Schmidt, R. A., & Wrisberg, C. A. (2008). *Motor learning and performance*. Champaign, IL: Human Kinetics

Shephard RJ. (1996). Habitual physical activity and academic performance. *Nutrition Reveiws*, *54*(4), S32–6.

Shephard, R. J. (1997). Habitual physical activity and academic performance. *Pediatric Exercise Science*, *9*, 113–126.

Shors, T. J. (2014). The adult brain makes new neurons, and effortful learning keeps them alive. *Current Directions in Psychological Science, 23*(5), 311–318. doi:10.1177/0963721414540167

Sibley, S. A. & Etnier, J. (2003). The relationship between physical activity and cognition in children: A meta-analysis. *Pediatric Exercise Science 15*, 243-256.

Stewart, J. A., Dennison, D. A., Kohl, H. W., III, & Doyle, A. J. (2004). Exercise level and energy expenditure in the TAKE 10!®. in-class physical activity program. *Journal of School Health*, *74*(10), 397-400.

Stranahan, A.M., Khalil, D., & Gould, E. (2006). Social isolation delays the positive effects of running on adult neurogenesis. *Nature Neuroscience, 9*(4), 526–533.

Sylvester, B. D., Standage, M., Ark, T. K., Sweet, S. N., Crocker, P. R., Zumbo, B. D., &

Beauchamp, M. R. (2014). Is variety a spice of (an active) life?: Perceived variety, exercise behavior, and the mediating role of autonomous motivation. *Journal of Sport and Exercise Psychology, 36*, 516–527. doi:10.1123/jsep.2014-0102

Sylvester, B. D., Standage, M., Dowd, A. J., Martin, L. J., Sweet, S. N., & Beauchamp, M. R. (2014). Perceived variety, psychological needs satisfaction and exercise-related well-being. *Psychology & Health, 29*, 1044–1061. doi:10.1080/08870446.2014.907900

Telford, R.D., Cunningham, R.B., Fitzgerald, R., Olive, L.S., Prosser, L., Jiang, X., & Telford, R.M. (2012). Physical education, obesity, and academic achievement: a 2-year longitudinal investigation of Australian elementary school children. *American Journal of Public Health, 102*(2), 368–374.

Tomporowski, P.D., Davis, C.L., Miller, P.H., & Naglieri, J.A. (2008). Exercise and children's intelligence, cognition, and academic achievement. *Educational Psychology Review, 20,*111-131.

Tomporowski, P.D., Lambourne, K., Okumura, M.S. (2011). Physical activity interventions and children's mental function: an introduction and overview. *Preventative Medicine*, *52*, S3–9.

Tomporowski, P. D., McCullick, B., Pendelton, D. M., & Pesce, C. (2015). Exercise and children's cognition: The role of exercise characteristics and a place for metacognition. *Journal of Sport and Health Science, 4*(1), 47–55. doi:10.1016/j.jshs.2014.09.003

Tomporowski, P. D., McCullick, B., & Pesce, C. (2015). Enhancing children's cognition with physical activity games. Champaign, IL: Human Kinetics.

Tremblay, M.S., Inman, J.W., & Willms, J.D. (2000). The relationship between physical activity, self-esteem, and academic achievement in 12-year-old children. *Pediatric Exercise Science, 12*(3), 312-23.

Trudeau, F., & Shephard, R. J. (2008). Review: Physical education school physical activity, school sports and academic performance. *International Journal of Behavioral Nutrition and Physical Activity, 5*(10), 37-40

Tudor-Locke, Catrine. (2001). A preliminary study to determine instrument responsiveness to change with a walking program: physical activity logs versus pedometers. *Research Quarterly for Exercise and Sport, 72*(3), 288-292.

Tudor-Locke, C., Bassett, D.R., Shipe, M.F., & McClain, J.J. (2011). Pedometry methods for assessing free-living adults. *Journal of Physical Activity and Health, 8*(3), 445-453.

van der Fels, I. M., Te Wierike, S. C., Hartman, E., Elferink-Gemser, M. T., Smith, J., & Visscher, C. (2015). The relationship between motor skills and cognitive skills in 4–16-year-old typically developing children: A systematic review. *Journal of Science and Medicine in Sport, 18*, 697–703.

van Praag, H. (2008). Review. Exercise and the brain: something to chew on. *Trends in Neuroscience*, *32*(5), 283-290.

Vaynman, S., Ying, Z., Wu, A., & Gomez-Pinilla, F. (2006). Coupling energy metabolism with a mechanism to support brain-derived neurotrophic factor-mediated synaptic plasticity. *Neuroscience*, *139*, 1221-1234.

Vaynman, S., Ying, Z., & Gomez-Pinilla, F. (2004). Hippocampal BDNF mediates the efficacy of exercise on synaptic-plasticity and cognition. *European Journal of Neuroscience*, *20*(10), 2580-2590.

Vazou, S., Gavrilou P., Mamalaki, E., Papanastasiou, A. & Sioumala, N. (2012). Does Integrating physical activity in the elementary school classroom influence academic motivation? *International Journal of Sport and Exercise Psychology*, *10*(4), 251-263.

Webber, S.C., Magill, S.M., Schafer, J.L., & Wilson, K.C. (2014). GT3X+ accelerometer, Yamax pedometer and SC-StepMX pedometer step count accuracy in community-dwelling older adults. *Journal of Aging and Physical Activity, 22*(3), 334-341.10.1123/japa.2013-0002

Winter B, Breitenstein C, Mooren FC, Voelker K, Fobker M, Lechtermann A, Krueger, K., Korsukewitz, C., Floel, A., & Knecht, S. (2007). High impact running improves learning. *Neurobiology of Learning and Memory, 87*(4),597–609. [PubMed: 17185007]

World Health Organization (WHO). 2016. Consideration of the evidence on childhood obesity for the Commission on Ending Childhood Obesity: report of the ad hoc working group on science and evidence for ending childhood obesity. World Health Organization. Geneva, Switzerland.

Zitomer, M. R., & Goodwin, D. L. (2014). Gauging the quality of qualitative research in adapted physical activity. *Adapted Physical Activity Quarterly, 31*, 193-218.

Appendix 1. Interview Guide

Integrating Physical Activity with Academic Outcomes for Learning

Focus Group Guide:

Setting: classroom

Groups: Eight per experimental group for a total of two focus groups

Session: 30 minutes for each group.

Questions and discussion:

- Introduce investigator, co-investigator
- Inform students the session will be audio-recorded for reflection/analysis of the researcher
- State the reason for the meeting – to reflect on their experience during the specific lessons associated with the study.
- Describe briefly the lessons involved in the study

Question 1

How did you feel about learning math using physical activity?

Question 2

How would you compare learning math in the classroom, as you normally do, to your experience of learning math using physical activity in the gym?

Question 3

Do you have any other comments about your experience from the lessons taught during this study?

Generic Probes:

- Tell me more.
- Do you have a story that illustrates that idea?
- I'm not clear, can you tell me another way?
- How would you explain your idea to someone else not familiar with…

Appendix 2. Informed Consent Form

Informed Consent Form (parent)

Title:	Integrating Physical Activity with Academic Outcomes for Learning
Researcher(s):	Sherri Lynn Colbert-Paddock, BPE, B.Ed., graduate student M.Sc. (Kin.), 709.685.6075, sherrilc@mun.ca
Supervisor(s):	Dr. Fabien Basset, Faculty of Human Kinetics and Recreation, 709.864.6132, PE 2022, fbasset@mun.ca

You are invited to take part in a research project entitled ***"Integrating Physical Activity with Academic Outcomes for Learning."***

This form is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. It also describes your right to withdraw from the study. In order to decide whether you wish to participate in this research study, you should understand enough about its risks and benefits to be able to make an informed decision. This is the informed consent process. Take time to read this carefully and to understand the information given to you. Please contact the researcher, **Sherri Lynn Colbert-Paddock**, if you have any questions about the study or would like more information before you consent.

It is entirely up to you to decide whether your child takes part in this research. If you choose for your child not to take part in this research or if you decide to withdraw your child's participation from the research once it has started, there will be no negative consequences for you or your child, now or in the future.

Introduction:
Hi, my name is Sherri Lynn Colbert-Paddock, I am a physical education teacher with the Newfoundland and Labrador English School District, currently working on a Masters of Science in Kinesiology degree at the School of Human Kinetics and Recreation,

Memorial University of Newfoundland and Labrador. As part of my Masters Thesis I am conducting research under the supervision of Dr. Fabien Basset.

Purpose of study:

It is widely accepted that physical activity benefits our overall health and the prevention of chronic diseases, particularly childhood obesity, but continuing research shows the cognitive or learning benefits of physical activity particularly during growth and development. Therefore, it follows that combining physical activity with curriculum content in schools has the potential to improve both learning and the health of society as a whole. Since most children spend the majority of their daily lives in school learning mainly through traditional methods that involve minimal movement and many students are not acquiring the recommended 60 minutes of moderate to vigorous physical activity (MVPA) a day, school seems to be the ideal place to address the need for more physical activity. The reported trend to reduce opportunities for physical activity during the school day in lieu of more academic time (Koch, 2013: Ahamed et al.,2007: Trudeau and Shephard, 2008; Tremblay, Inman, & Willms, 2000) due to increased emphasis on standardized test performance (Sibley & Etnier, 2003) is challenged by the research that suggests that physical activity may help improve academic achievement, both directly and indirectly (Erwin et al., 2011). While teachers are generally supportive of physical activity interventions they find it difficult to find enough time to maintain of any health-related, non-academic intervention (Bartholomew & Jower, 2011). As a response many researchers are working to combine physical activity interventions with academic content in order to provide teachers with academic lessons that use active movement in the review or teaching of core academic content. With time as a major factor, the need for physical activity-integrated lessons for classroom teachers and strategies for doing this effectively has become an important consideration. Integrating physical activity within their lessons is a way to maximize academic learning while helping to meet physical activity recommendations. The purpose of this research is to investigate the effect of physical activity-integrated lessons on learning outcomes.

What your child will do in this study:

Students will participate in a total of six lessons during regular class time that meet prescribed outcomes for math alone in four of the six lessons and both math and physical education outcomes in two of the six lessons. During each lesson all students will wear pedometers to measure activity with approximately ten randomly selected students wearing heart rate monitors as well to indicate intensity of activity. Each lesson will be followed by a short post quiz to measure math outcomes learned during the lesson. Each lesson, both in the gym and classroom, will also have an approved independent observer present.

As a follow-up, some students will be asked to participate in one of two focus groups (8 students per group). The use of focus groups will allow students to discuss their experience during the lessons included in the main study and may allow the researcher to understand and further interpret the results obtained from the main study. Group sessions will take place during school hours in a classroom or in the gymnasium and will last approximately 30 minutes. The session will be audio-recorded and a co-facilitator will take notes for analysis.

Length of time:
The experimental process will consist of a total of six consecutive half hour lessons. There will be a seventh half hour session for group discussion but only for those students selected and willing to participate.

Withdrawal from the study:
Since lessons taught during this study will teach normally prescribed curriculum outcomes for both math and physical education during regular class time students will be expected to participate but any data collected will be removed or excluded from the results if a student or the parents/guardians of a student choose for that student to withdraw their participation in the study. If parents/guardians wish to withdraw their consent for collection of results from their child for the purpose of the study they may notify the researcher by email or written note. However, once results have been compiled they cannot be removed as they will have been anonymized and will be not be associated with the personal identities of the students.

Possible benefits:
Student participants may benefit from enhanced learning or enjoyment of learning through the combination of classroom outcomes and physical activity. As well, there will be an immediate measurement of what has been learned resulting in timely feedback for students.

Possible risks:
There will be no additional risk to students participating in this study than that of normal classroom or physical education lessons.

Please note that your decision to allow your child to participate or withdraw from the study will not have any impact on their standing in the class or on their final grade.

Confidentiality:
The ethical duty of confidentiality includes safeguarding participants' identities, personal information, and data from unauthorized access, use, or disclosure.

Participants’ privacy and confidentiality will be maintained as students’ names or personal information will not be included in the study.

Anonymity:
Anonymity refers to protecting participants’ identifying characteristics, such as name or description of physical appearance.

Data recorded for the purpose of the study will not be associated with the individual identities of the students and will be codified.

Every reasonable effort will be made to ensure participants’ anonymity; and participants will not be identified in publications without explicit permission.

Since participants will be in a existing group setting which is characteristic of real life situations or field research, participant anonymity may not be possible but keeping the data anonymous is possible by not associating results with individual identities.

Storage of Data:
Gathered data will be stored on a hard drive and/or USB device but will be password protected. Any hardcopies of recorded data will be stored securely in a locked filing cabinet in the office of the research supervisor, room PE2022, MUN. Consent forms will be stored separately from the data. Data will be accessible to the principle investigator conducting the study, research supervisor, and class teachers.

Data will be kept for a minimum of five years, as required by Memorial University’s policy on Integrity in Scholarly Research. Retaining or destroying data beyond the required 5 years is at the discretion of the researcher.

Reporting of Results:
The data gathered in this study will be published as part of a thesis submitted to the School of Human Kinetics and Recreation at Memorial University of Newfoundland. The thesis will be publically available at the QEII library.

Sharing of Results with Participants:
A summary report of the findings of this study will be available to parents/participants after the project is complete.

Questions:

You are welcome to ask questions at any time before, during, or after your child's participation in this research. If you would like more information about this study, please contact: Sherri Lynn Colbert-Paddock, 709-685-6075, sherrilc@mun.ca or Supervisor, Dr. Fabien Basset, Faculty of Human Kinetics and Recreation, 709.864.6132, PE2022, fbasset@mun.ca .

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research, such as the way your child has been treated or their rights as a participant, you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.

Consent:

Your signature on this form means that:

- You have read the information about the research.
- You have been able to ask questions about this study.
- You are satisfied with the answers to all your questions.
- You understand what the study is about and what your child will be doing.
- You understand that you are free to withdraw your child's participation in the study without having to give a reason, and that doing so will not affect your child now or in the future.
- You understand that the data, once collected, will be anonymized, that is, separated from individual identities, and therefore cannot be removed after data collection has ended.

I agree to my child being audio-recorded (only for students participating in the follow-up discussion groups)	☐ Yes ☐ No
I allow data collected from my child's participation to be archived in room PE2022, Memorial University	☐ Yes ☐ No

By signing this form, you do not give up your legal rights and do not release the researchers from their professional responsibilities.

Your signature confirms:

- ☐ I have read what this study is about and understood the risks and benefits. I have had adequate time to think about this and had the opportunity to ask questions and my questions have been answered.
- ☐ I agree to allow my child to participate in the research project understanding the risks and contributions of my child's participation, that my child's participation is voluntary, and that I may end my child's participation.
- ☐ A copy of this Informed Consent Form has been given to me for my records.

______________________________ ______________________________
Name of participant Class

______________________________ ______________________________
Signature of parent Date

Researcher's Signature:
I have explained this study to the best of my ability. I invited questions and gave answers. I believe that the participant fully understands what is involved in being in the study, any potential risks of the study and that he or she has freely chosen to be in the study.

______________________________ ______________________________
Signature of Principal Investigator Date

Appendix 3. Classroom Math Lessons for Research Study

Classroom Math Lesson Plans for Research Study by Sherri Lynn Colbert-Paddock

Chapter 5: 2-D Geometry

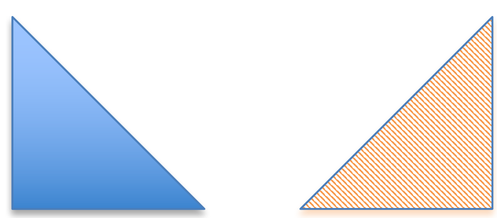
Lesson #1 – Strand: Shape and Space (3-D objects and 2-D shapes)

Specific Outcomes: *Students will be expected to:*
4SS5 demonstrate an understanding of congruency, concretely and pictorially.

Write the following definition on the board and discuss with students. Ask students to write the definition in their notebooks.

Definition:

Congruent
Two 2-D shapes are **congruent** if they are identical in shape and size-that is, if one is an exact duplicate of the other and can be transformed into the other through series of reflections, translations and/or rotations.
Figures can be different colors, or oriented in different ways, and they will still be congruent if they are the same size and shape.
Example:



Activity A:
Working with a partner, ask one student created design using pattern blocks of tiles. The partner then creates a congruent design. Congruent designs may not necessarily use the same pattern blocks. Ask students how they know their two designs are congruent. Possible explanations might include tracing on paper or taping designs together to superimpose them. Repeat with other partner creating a design.

Activity B:
Teacher creates a shape on a transparent geoboard and challenges the students to create a congruent shape of a different orientation on their geoboards. Students should test for congruency. To do this, they could place one geoboard on the other.

Activity C:

Provide students with pairs of 2-D shapes. Ask students to colour the corresponding sides and /or vertices the same colour. Ask them to justify that they have correctly identify the corresponding sides and vertices by tracing one shape and superimposing the congruent shape

Lesson #2 – Strand: Shape and Space (Transformations)

Specific Outcomes: *Students will be expected to:*
4SS6 Demonstrate an understanding of line symmetry by:

- Identifying symmetrical 2-D shapes
- Creating symmetrical 2-D shapes
- Drawing one or more lines of symmetry in a 2-D shape

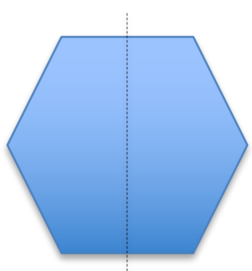
Write the following definition on the board and discuss with students. Ask students to write the definition in their notebooks.

__**Definitions:**__
Lines of Symmetry
A **line of symmetry** is a line that divides a 2-D shape into equal halves.

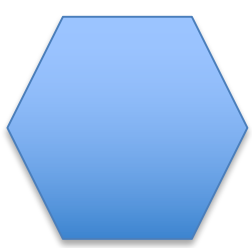
A 2-D figure has line symmetry when it can be divided or folded so that the two parts match exactly. The fold line is referred to as a line of symmetry. It may also be said that each of the halves are mirror images of each other.

Congruent
The two matching parts of any symmetrical shape are said to be **congruent** along the lines of symmetry.

Examples:
This hexagon is symmetrical. The line of symmetry shown in each diagram divides the shape (hexagon) into two congruent parts (pentagons).



Ask students to identify different lines of symmetry in the hexagon (visualize).



A shape is **symmetrical** when it has at least 1 **line of symmetry**.

Activity A:

Provide copies of **2-D Shapes 1, 2, 3**, pp. 48-50, Teacher's Resource, Chapter 5 (attached).

For each sheet:

1. a) Cut out shapes and attempt to identify lines of symmetry in each shape by using a transparent mirror and then folding.
   b) Sort shapes into two groups: shapes without lines of symmetry or shapes with lines of symmetry.
   c) Draw lines of symmetry on the shapes with lines of symmetry.

2. Using poster paper, create a t-chart and paste grouped shapes from exercise #1 b) under the two headings: "Shapes without lines of symmetry" and "Shapes with lines of symmetry". Leave space for more shapes.

Lesson #3 – Strand: Shape and Space (Transformations)

Specific Outcomes: *Students will be expected to:*
4SS6 continued…

<u>Activity A:</u>

Provide a different variety of shapes and ask students to sort them, grouping those with symmetry and those without symmetry.

Use poster with T-chart from Lesson #2, Activity A, exercise #2, and paste shapes according to which group they belong in. (Paste only shapes that are different from the ones that are already there.)

<u>Activity B:</u>

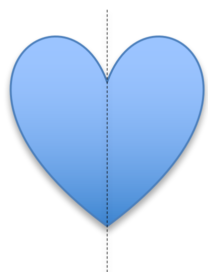
Using class set of Ipads, have students work in pairs and take digital photos which show symmetry in their environment. Allow students to move throughout the school. Set a time limit, ~10 minutes. Have students share some of their pictures with the class. Draw at least one of these pictures and show the lies of symmetry.

Lesson #4 – Strand: Shape and Space (Transformations)

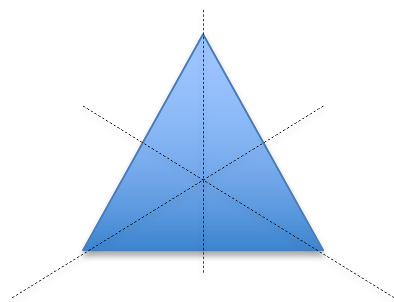
Specific Outcomes: *Students will be expected to:*
4SS6 continued…

Notes:

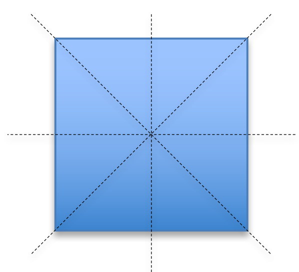
Figures may have multiple lines of symmetry which can be vertical, or horizontal, or diagonal.



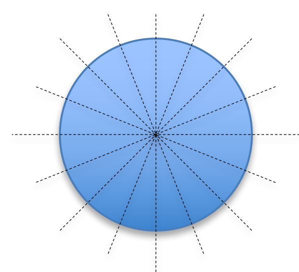
1 line of symmetry



3 lines of symmetry



4 lines of symmetry



infinite number of lines of symmetry

<u>Activity A:</u>

Ask students if all triangles have the same number of lines of symmetry. Students should record their answers for reference later. Teachers then provide sets of triangles cut outs for each pair of students (include examples of equilateral, scalene, and isosceles triangle's, although students need not know those terms). Allow students the opportunity to prove or disapprove their predictions by folding, cutting and superimposing.

<u>Activity B:</u>

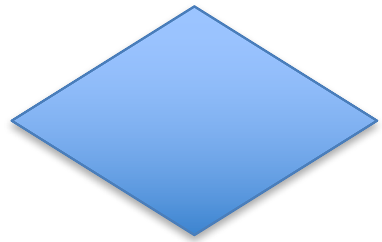
Provide students with labeled 2-D shapes similar to those on the next page. Ask students to indicate which shapes in the set are symmetrical. Instruct them to draw all the lines of symmetry on each symmetrical shape. Students then sort the shapes by number of lines of symmetry (no lines of symmetry, one line of symmetry, or more than one line of symmetry). They should record answers in a table, as shown below. Invite students to share their ideas about sorting this set of shapes.

Lines of symmetry	Letter names for the shapes
No lines of symmetry	
One line of symmetry	
More than one line of symmetry	

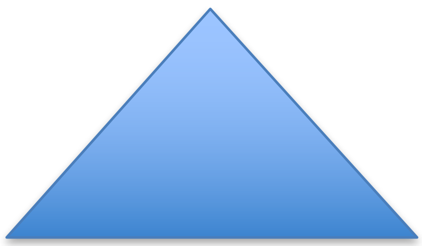
Lesson#4- Activity B

A.

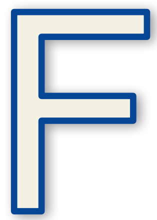
B.



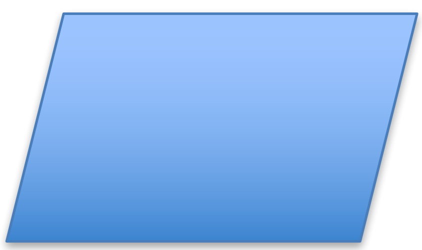
C.



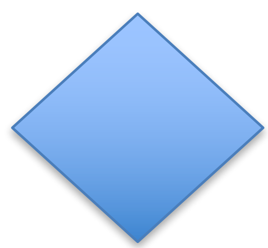
D.



E.

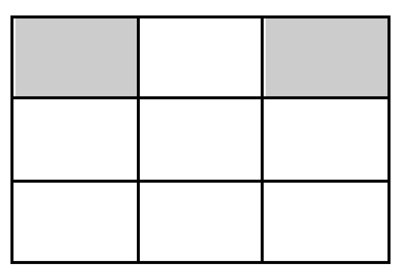


F.



G.

H.



Appendix 4. Physically Active Lessons for Research Study

Physically Active Math Lesson Plans Grade 4
for Research Study by Sherri Lynn Colbert-Paddock

Chapter 5: 2-D Geometry

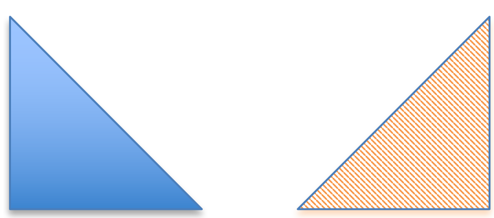
Lesson #1 – Strand: Shape and Space (3-D objects and 2-D shapes)

Specific Outcomes: *Students will be expected to:*
4SS5 demonstrate an understanding of congruency, concretely and pictorially.

Post the following definition on the screen and discuss with students. Provide students with a copy of the definition to be placed in their duo tang.

Definition:

Congruent
Two 2-D shapes are **congruent** if they are identical in shape and size-that is, if one is an exact duplicate of the other and can be transformed into the other through series of reflections, translations and/or rotations.
Figures can be different colors, or oriented in different ways, and they will still be congruent if they are the same size and shape.
Example:



Activity A:

Working with a partner, students line up at a pylon on one side of the gym across from their station directly opposite. One partner sprints to the opposite side and creates a design using large pattern block tiles and sprints back. The next partner then sprints up and creates a congruent design. Congruent designs may not necessarily use the same pattern blocks. Students then sprint across together to check that their two designs are congruent. Ask how they know their two designs are congruent. Possible explanations might include tracing on paper or taping designs together to superimpose them. Repeat with other partner creating a design.

Activity B:

Teacher creates a shape by running along certain lines on the gym floor and challenges the students to create a congruent shape of a different orientation using different lines running with their partner.

Activity C:

Working with a partner again, students line up at a pylon on one side of the gym across from their station directly opposite. At each station a poster with pairs of 2-D congruent shapes is posted and crayons at available in a bin below. One partner sprints to the opposite side and colours the corresponding sides of one pair of congruent shapes the same colour. The next partner then sprints up and colours the corresponding sides of the next pair of congruent shapes the same colour. Continue for next two pairs. Repeat exercise but each partner will label the corresponding vertices with a letter. Finally, have both partners sprint over together and ask them to justify that they have correctly identify the corresponding sides and vertices by tracing one shape (paper in bin below) and superimposing it on the congruent shape.

Lesson #2 – Strand: Shape and Space (Transformations)

Specific Outcomes: *Students will be expected to:*
4SS6 Demonstrate an understanding of line symmetry by:

- Identifying symmetrical 2-D shapes
- Creating symmetrical 2-D shapes
- Drawing one or more lines of symmetry in a 2-D shape

Post the following definition on the screen and discuss with students. Provide students with a copy of the definition to be placed in their duo tang.

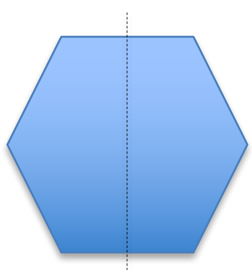
Definitions:

Lines of Symmetry
A **line of symmetry** is a line that divides a 2-D shape into equal halves.

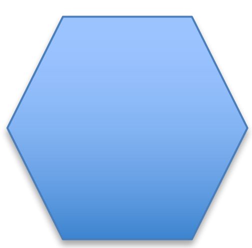
A 2-D figure has line symmetry when it can be divided or folded so that the two parts match exactly. The fold line is referred to as a line of symmetry. It may also be said that each of the halves are mirror images of each other.

Congruent
The two matching parts of any symmetrical shape are said to be **congruent** along the lines of symmetry.

Examples:
This hexagon is symmetrical. The line of symmetry shown in each diagram divides the shape (hexagon) into two congruent parts (pentagons).



Ask students to identify different lines of symmetry in the hexagon (visualize).



A shape is **symmetrical** when it has at least 1 **line of symmetry**.

Activity A:

- Obtain enlarged copies (attached) of **2-D Shapes 1, 2, 3**.
  (pp. 48-50, Teacher's Resource, Chapter 5)
- Form groups of 4.
- Each group get 12 skipping ropes.
- All groups work within inner perimeter of gym leaving an outside track.

For each shape:

2. a) Form copies of shapes on floor using skipping ropes.
   b) Extend other skipping ropes across shape and attempt to identify lines of symmetry in each shape. Once the number of lines of symmetry are determined all students in group should run an equivalent number of laps around the gym.
   c)) Sort shapes into two groups: shapes without lines of symmetry or shapes with lines of symmetry.
   d) Team lines up on black line (lengthwise) across from poster on opposite wall, each team member takes turns sprinting to poster with one shape and taping it under the correct heading on t-chart: "Shapes without lines of symmetry" and "Shapes with lines of symmetry".

T-chart:

Shapes without lines of symmetry	Shapes with lines of symmetry

Lesson #3 – Strand: Shape and Space (Transformations)

Specific Outcomes: *Students will be expected to:*
4SS6 continued…

Activity A:

Working with a partner, students line up at a pylon on one side of the gym across from their station on the opposite wall. A poster with a t-chart is hung on the opposite wall with the two headings: “Shapes without lines of symmetry” and “Shapes with lines of symmetry”.

Provide students with a different variety of shapes. One partner takes a shape and sprints to the other side sorting the shape by folding to determine lines of symmetry and then pasting it under the correct heading. The next partner then sprints up and sorts the next shape. Continue until all shapes are sorted. Finally, have both partners sprint over together and ask them to justify that they have correctly sorted the shapes by drawing the lines of symmetry. (Pencil and rulers should be available in a bin below the poster)

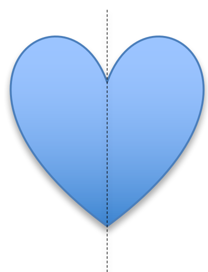
Activity B:

Have students dress for outside. (If weather is not suitable may do inside throughout the school at a jog pace). Using class set of iPads(?), have students work in pairs and take digital photos or ask students to collect and/or note things in the environment that show symmetry (i.e. trees, cones, tree needles, playground equipment, fence…) in their environment. Set a time limit, ~10 minutes. Have students share or describe some of their pictures with the class. Draw at least one of these pictures and show the lies of symmetry.

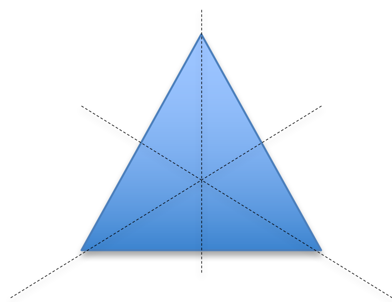
Lesson #4 – Strand: Shape and Space (Transformations)

Specific Outcomes: *Students will be expected to:*
4SS6 continued…

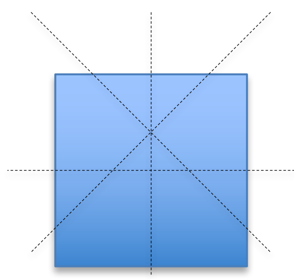
Notes:
Figures may have multiple lines of symmetry which can be vertical, or horizontal, or diagonal.



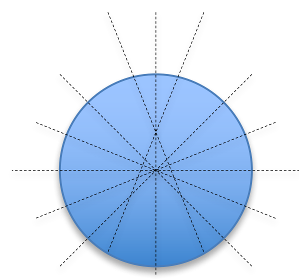
1 line of symmetry



3 lines of symmetry



4 lines of symmetry



infinite number of lines of symmetry

Activity A:

Ask students if all triangles have the same number of lines of symmetry. Ask each group to form triangle shapes on floor using skipping ropes and cones to investigate. Extend other skipping ropes across shape and attempt to identify lines of symmetry in each shape. Once the number of lines of symmetry are determined students in group should run an equivalent number of laps around the gym.
Ask students to discuss their answers. Teacher should provide sets of triangles cut outs for each group of students (include examples of equilateral, scalene, and isosceles triangle's, although students need not know those terms) for reference. Allow students the opportunity to prove or disapprove their predictions by folding paper shapes.

Activity B:

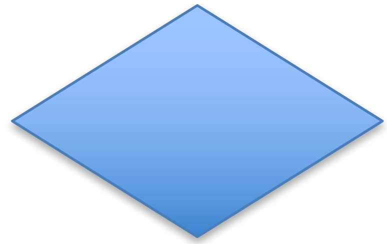
Provide students with labeled 2-D shapes similar to those on the next page. One partner takes a shape and sprints to the other side sorting the shape according to the lines of symmetry and then pasting it under the correct heading on a table as shown below (post table on wall). The next partner then sprints up and sorts the next shape. Continue until all shapes are sorted. Finally, have both partners sprint over together and ask them to justify that they have correctly sorted the shapes by drawing the lines of symmetry. (Pencil and rulers should be available in a bin below the poster)

Invite students to share their ideas about sorting this set of shapes.

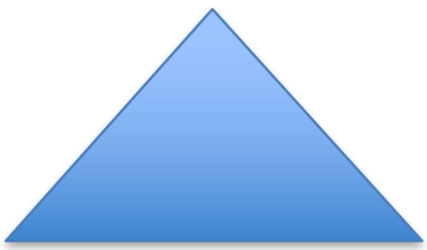
Lines of symmetry	Shapes
No lines of symmetry	
One line of symmetry	
More than one line of symmetry	

A.

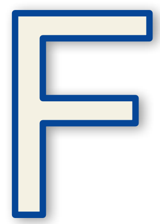
B.



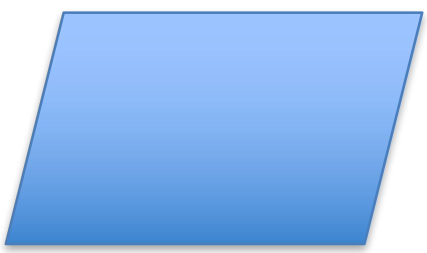
C.



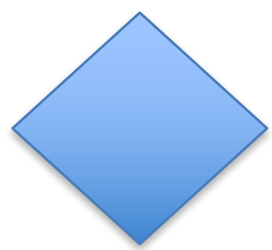
D.



E.

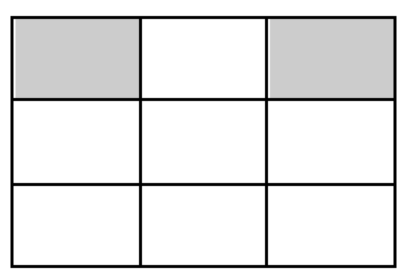


F.



G.

H.



Appendix 5. Assessments/Quizzes for Math Lessons 1-4

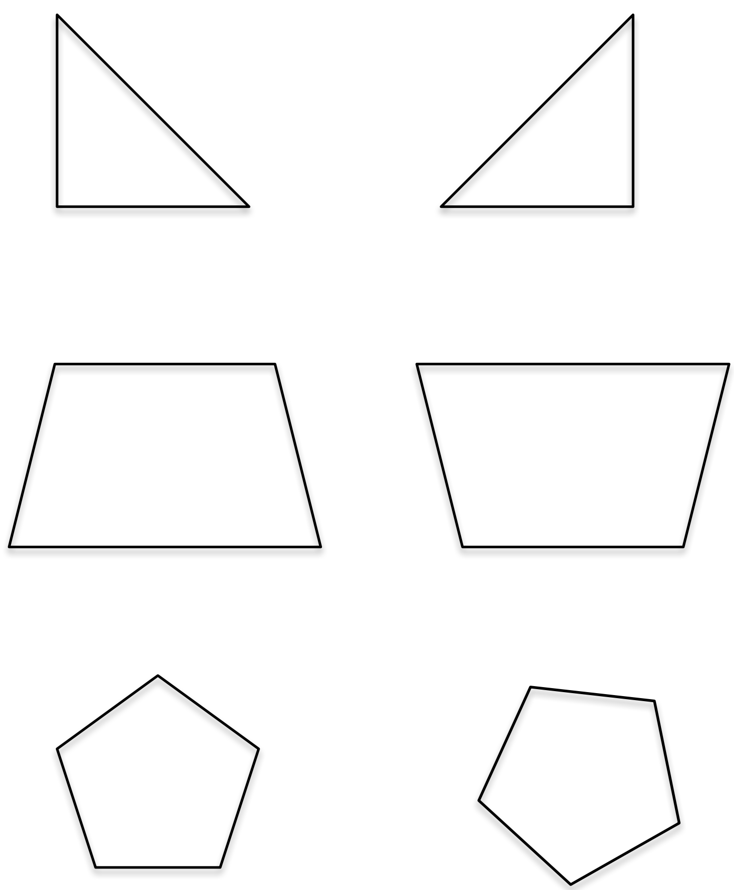
Chapter 5: 2-D Geometry: Lesson #1 – Strand: Shape and Space (3-D objects and 2-D shapes)
Assessment/quiz

1. a) On the top half of the attached sheet of dot paper draw two congruent shapes oriented the same way but colour these two different colours.

   b) On the bottom half of the attached sheet of dot paper draw two congruent designs that are oriented differently from one another, that is, reflected or rotated differently.

2. a) For each pair of congruent 2-D shapes below label the corresponding (matching) sides by colouring them the same colour.

   b) For each pair of congruent shapes below label the corresponding vertices by marking them with the same letter.



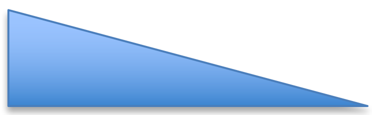
Chapter 5: 2-D Geometry Lesson #2 – Strand: Shape and Space (Transformations)
Assessment/quiz

1. Decide whether each shape is symmetrical or not symmetrical. Draw lines of symmetry.

a)

symmetrical ☐ not symmetrical ☐

b)



symmetrical ☐ not symmetrical ☐

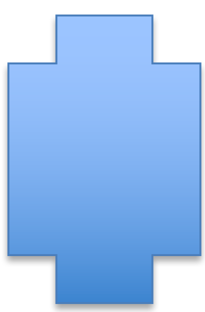
c)

symmetrical ☐ not symmetrical ☐

d)

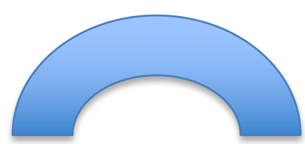
symmetrical ☐ not symmetrical ☐

e)



symmetrical ☐ not symmetrical ☐

f)



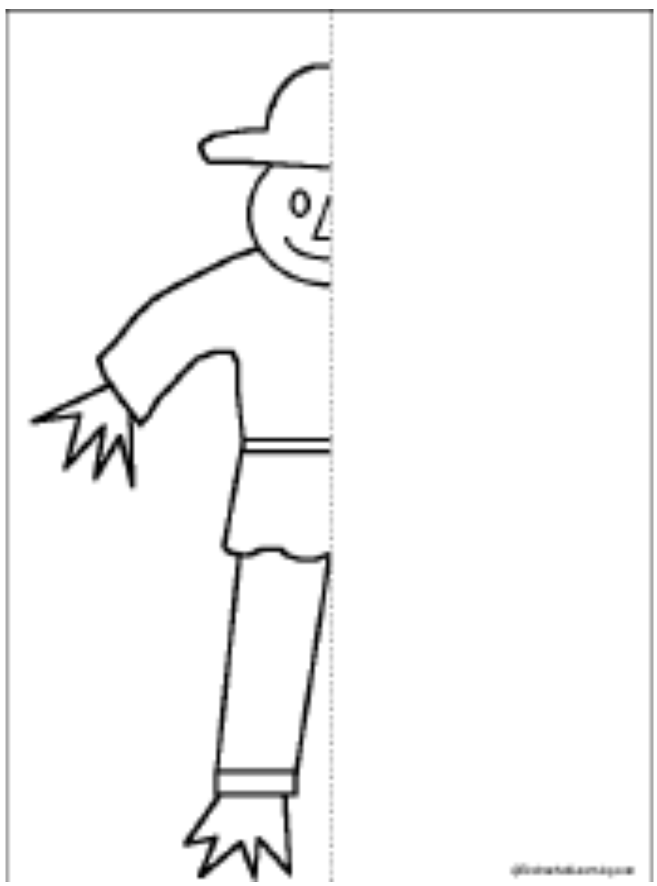
symmetrical ☐ not symmetrical ☐

Chapter 5: 2-D Geometry **Lesson #3– Strand: Shape and Space (Transformations)**

Assessment/quiz

1. Have students complete worksheet from Math Focus 4 Workbook Blackline Masters, page 40, for Chapter 5, Lesson 3.

2. Complete the drawing below to make it symmetrical.



Chapter 5: 2-D Geometry **Lesson #4– Strand: Shape and Space (Transformations)**
Assessment/quiz

1. Draw all the lines of symmetry on each shape below.

2. Sort the shapes using the chart below.

Shape	A	B	C	D	E	F	G	H	I
Number of lines of symmetry