ABSTRACT

Title of Dissertation: SIXTH GRADE STUDENTS' MENTAL MODELS OF PHYSICAL EDUCATION CONCEPTS: A FRAMEWORK THEORY PERSPECTIVE

Marina Bonello, Doctor of Philosophy, 2008

Directed By: Professor Catherine Ennis
Department of Kinesiology
School of Public Health

Framework Theory of Conceptual Change (FTCC) is the prevailing theoretical approach guiding current thought and research into the contextualized development of students' mental models. In FTTC Vosniadou (1994) theorized the role academic beliefs and social and contextual variables play in model development. Physical education scholars have not yet applied FTCC to an examination of students' fitness conceptions and little is known about the role academic beliefs play in knowledge development. The purpose of this dissertation was to apply FTCC to an examination of students' mental models of fitness concepts. I conducted a descriptive study using an ethnographic research design to examine the contextualized development of students' mental models. Participants included one class of sixth-grade students and their teachers at two middle schools. Student data (n=18) were collected using written questionnaires and interviews. Additionally, I collected contextual data through document collection, physical education (n=2) and science teacher (n=1) interviews, and field observations of the physical education lessons conducted at the respective schools. In the first analysis, I identified

five generic mental models based upon diverse configurations in students' naive theories to explain *exercise induced physical changes.* Findings suggested students' diverse explanations reflected the inherent complexity of the concept. The emerging coherence of students' perspectives towards scientific views is gradual. Developing sophisticated conceptions entails developmental, applicational, and integrated processes that evolve into complex relational conceptions. In the second analysis, I identified three mental models students used to explain the *concept of intensity* and it's relation to other elements in the FITT principle. In contrast to previous research, all 18 students within this study were familiar with the concept of intensity and the FITT principle. Students' explanations were diverse and reflected variations in their conceptual transitions from a holistic elementary school level conception of FITT and intensity. The diverse models reflected students' purposeful and creative attempts to seek coherence and make interdisciplinary and multi-sensory connections. A myriad of variables appeared to interact to facilitate and sometimes limit students' mental models, including school support, language and tool support, and teachers' values and beliefs about teaching, fitness, and student learning.

SIXTH GRADE STUDENTS' MENTAL MODELS OF PHYSICAL EDUCATION CONCEPTS: A FRAMEWORK THEORY PERSPECTIVE

By

Marina Bonello

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Advisory Committee:
Dr. Catherine D. Ennis, Chair
Dr. Patricia Alexander
Dr. Ang Chen
Dr. Jamie Shultz
Dr. Colleen Farmer

Dedication

To my parents and beloved family for being the greatest blessing in my life!

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Physical education is a performance-based subject with the inherent goal of helping children move to learn and learn to move (Gallahue, 1996). It is comprised of three interdependent dimensions of learning: cognitive, motor, and affective. Gallahue (1996) argued that students' cognitive learning in physical education includes a unique set of physical education domain concepts, some of which are similar to those found in other academic areas (e.g., exercise physiology concepts parallel biological concepts). Physical education domain concepts comprise the body of knowledge experts agree students need to master through systematic instructional experiences to become skillful movers, healthy, and physically active for life (Corbin, Dowell, Lindsey, & Tolson, 1970; Mohensen, 2003). Student learning in physical education focuses on both learning of physical skills and learning through physical activity. This unique focus on the motor domain has the potential to extend and deepen students' understanding of both physical education domain concepts and particular cognitive concepts in other academic areas including science (e.g., exercise induced physiological changes, acceleration, inertia, revolution, and rotation). Because students learn kinesthetically, movement experiences permit students opportunities to learn academic content directly through their body (e.g., using physical movements and muscular force during jumping activities to reinforce physics concepts).

Gallahue (1996) emphasized that students' learning through movement involves the conceptual learning that is foundational to motor skill development and cognitive concept learning. The importance of cognitive concept learning in physical education is evident in the second standard of the Physical Education National Content Standards, "A physically educated person: Demonstrates understanding of movement concepts, principles, strategies, and tactics as they apply to the learning and performance of physical activities" (Standard 2, National Association for Sport and Physical Education [NASPE], 2004, p.11). Scholars have emphasized the importance of the cognitive dimension of learning in physical education and delineated the domain concepts that constitute physical education (Corbin et al., 1970; Mohensen, 2003; National Association for Sport Physical Education Recreation and Sport, 2004).

Recently, physical education scholars have placed a renewed emphasis on the need to examine student learning as both a performance- and cognitive-based subject (Dodds, Griffin, & Placek, 2001; Rink, 1999). Curriculum designers are creating curricula based on theories of learning that place additional emphasis on cognitive knowledge through the explicit inclusion of physical education domain concepts in lesson and unit content (Chen, Rovegno, Todorovich, & Babiarz, 2003; Dyson, Griffin, & Hastie, 2004; Ennis, 2007; Grehaigne, Wallian, & Godbout, 2005; Kirk & Macdonald, 1998; Mitchell, Oslin, & Griffin, 2005; Placek, 2003; Rovegno, Nevett, & Babiarz, 2001). Further, emphasis on achievement motivation, constructivist teaching, and innovative assessment techniques have enhanced students' opportunities to engage with the content and learn the conceptual basis of physical education (Azzarito & Ennis, 2003; Hare & Graber, 2000; Oliver & Lalik, 2004; Solomon, 2003). Placek, Griffin, and Dodds (1998) pointed out, however, the paucity of research describing the exact details of students' conceptions and the instructional strategies teachers use to "support students' learning of (cognitive) concepts" (p. A-99). Thus, there is a need to examine the specific details of students' knowledge conceptions, understand the developmental process, and identify variables that facilitate or constrain students' conceptual learning. These insights can inform future curricular decisions and the development of effective curricula enabling students to master physical education concepts, adopt healthy, active behaviors (Ayers, 2004; Ennis, 2007), and meet the schools' educational goals (Abernathy & Waltz, 1964).

Physical education researchers examining the cognitive domain have expressed concern that some students' conceptual learning is not progressing in the manner intended by their teachers (Ayers, 2004; Hare & Graber, 2000; Stewart & Mitchell, 2003). Additional research is necessary to investigate students' conceptual learning in natural learning contexts in relation to specific content (Chen & Rovegno, 2001). Scholars have gained an appreciation of the active role a learner plays in the teaching-learning process (Dodds et al., 2001; Rink, 1999). Influenced by cognitive learning theories, increasingly physical education scholars are recognizing that students' cognitions play a central role in creating conceptions that reflect their interpretations of domain concepts. For example, Dodds et al. (2001) noted that learners' cognitions include not only their knowledge conceptions but also their beliefs, motivations, interests, attention, and perceptions of self or of the learning environment. These elements are involved in students' cognitive learning and the knowledge conceptions they bring to the physical education lesson. Facilitating students' conceptual learning of physical education domain knowledge has the potential to assist them to (a) perform more skillfully, (b) appreciate other's ability to move skillfully, (c) adopt healthy behaviors, and (d) reinforce conceptual learning in other academic areas.

Traditionally, colleges of education and the physical education teaching profession have emphasized Information Processing Learning Theory (IPT), in physical education. Within this domain-general approach, physical education scholars and teachers have assumed that learning was a process of knowledge enrichment, that is, the goal of teaching was to add more knowledge to students' existing knowledge conceptions. Recently, scholars in other academic areas (Alexander, 2007; Limon, 2001; Vosniadou, Ionnides, Dimitrakopouou, & Papademetrios, 2001) have advocated the use of domain-specific learning approaches such as Conceptual Change Theory. They have argued that both enrichment (addition) and restructuring (re-organization) of students' existing knowledge and belief conceptions are necessary to facilitate conceptual learning. Although physical education scholars acknowledged the role of the learners' prior knowledge, they rarely examined students' developing conceptions or their underlying beliefs about knowledge. Alexander (2006) insisted that learners' prior knowledge conceptions comprise all that they know and believe about the specific domain. Hence, physical education researchers need to examine both learners' knowledge and beliefs when seeking to facilitate conceptual learning in physical education.

Conceptual Change Theory has been used in other domains to examine the role that learners' domain-specific beliefs play in the knowledge acquisition process (Chi & Roscoe, 2002; Vosniadou, 2002). Learners' knowledge and beliefs comprise an integrated conceptual system that structures learners' mental models. Mental models are domain-specific knowledge structures hypothesized to be the mechanisms learners use to create, enrich, or modify their knowledge conceptions about a specific domain (Chi & Roscoe, 2002; Limon, 2001, 2002; Vosniadou, 2002). Recent mental model building perspectives, such as Vosniadou's Framework Theory of Conceptual Change (FCTT) have led scholars to re-interpret learning as a cognitive process of conceptual change influenced by individual, social, and contextual variables (Alexander, 2007; Vosniadou, 2007a, 2007c). Scholars have used FTCC to examine both well- and ill-structured domains and holds potential to inform the process of conceptual learning in physical education. Because many physical education domain concepts are science based (e.g., life and physical sciences), it is reasonable to assume that FTCC and the process of mental model development are applicable to student learning in physical education. Further, insights from FTCC may extend physical education researchers' understandings of the knowledge acquisitions process.

Theoretical Framework

Since the 1980s, researchers in science, mathematics, and history have examined the process and products of student learning as domain-specific phenomenon (Chi, De Leeuw, Chiu, & LaVancher, 1994; Limon, 2002; Posner, Strike, Hewson, & Gertzog, 1982; Vamvakoussi & Vosniadou, 2007; Vosniadou & Brewer, 1992). Findings from this extensive body of research have advanced researchers' understanding of the knowledge acquisition process and the mechanisms through which novices master domain concepts. They have re-defined conceptual learning as a process of conceptual change that occurs uniquely in each subject area. Thus, scholars use CCT to describe the processes by which learners modify their existing knowledge conceptions towards more scientifically held understandings (Murphy, 2007).

Conceptual Change Theory, derived from Constructivist Learning Theory, articulates the knowledge acquisition process within specific subject areas called domains

(Tyson, Venville, Harrison, & Treagust, 1997). CCT describes conceptual learning as a process requiring both the enrichment and restructuring (re-organization) of learners' existing conceptions (Vosniadou & Brewer, 1987). CCT proponents assume that conceptual change begins during infancy and proceeds through learners' ongoing interpretations of their everyday experiences in the lay culture (Vosniadou, 1999). As learners construct their conceptions about a domain, however, they may distort domain concepts in their attempts to link them to their existing conceptions. In doing so, learners develop naïve conceptions, or conceptions that contain some systematic pattern of error (Limon, 2002; Vosniadou, 1999).

Recent conceptual change perspectives hypothesize that mental model building mechanisms underlie the knowledge acquisition process. They also recognize the distinction between knowledge and beliefs about knowledge (aka. domain-specific beliefs or academic beliefs), and view them as overlapping constructs (Chi & Roscoe, 2002; Vosniadou, 2002). Mental models are the mediating mechanisms directly involved in the knowledge enrichment and restructuring process associated with the development of learners' naïve conceptions (Chi & Roscoe, 2002; Greca & Moreira, 2000; Vosniadou, 2002). Advocates of mental model building mechanisms assume that learners' domain specific beliefs play a significant role in the knowledge acquisition process because they affect the manner in which students' understand and develop their knowledge about the domain (Alexander, 2006; Chi & Roscoe, 2002; Vosniadou, 2002).

Vosniadou's (1999) Framework Theory of Conceptual Change is the theoretical framework guiding contemporary examinations of students' mental models. Vosniadou and her colleagues (Vosniadou, 1994, 1999; Vosniadou & Brewer, 1987, 1994;

Vosniadou et al., 2001; Vosniadou, Skopeliti, & Ikospentaki, 2004) have focused on understanding children's developmental phases as they learn domain concepts. They hypothesized that learners' conceptions comprise a complex system of knowledge elements made up of mental models, perceptions, knowledge propositions, and naïve theories. Naive theories comprise ontological and epistemic beliefs about knowledge that in turn, frame the organization of learners' perceptions, and knowledge within their mental models. Vosniadou (1994) assumed that mental models are dynamic, recursive structures that evolve through three sources, namely, individuals' perceptions, social interactions, and experiences within the lay culture. She hypothesized that learners either store or retrieve mental models from long-term memory or "create [them] on the spot to deal with the new demands of specific problem solving tasks" (p.48).

Vosniadou (1991; 1994) proposed that learners' mental models exist in three forms, initial, synthetic, and scientific, that evolve progressively and gradually over time. She explained that learners' develop naïve mental models when exposed to content that is counter-intuitive to the initial mental models they develop directly through their everyday experiences. When scientifically correct models, described as domain concepts, conflict with learners' initial models, children can distort their interpretation of the domain concepts in their active and creative attempts to reconcile them within their initial models. This results in the development of a hybrid model, called a synthetic model that comprises a mix of learner's initial models and scientifically correct models. Vosniadou (1994) hypothesized that students' initial and synthetic models evolve to parallel the scientifically correct domain concept as they acquire domain knowledge and learn to re-interpret their tacit ontological and epistemic domain beliefs. Vosniadou (1999) explained that learners create their mental models without metaconceptual awareness, and thus, they are generally unaware that their mental models are naïve in nature. She also suggested that helping learners develop awareness of the limitations of their own ideas is a necessary pre-requisite to promoting theory-changes in learners' global explanatory framework and/or specific theories.

Vosniadou (1994) hypothesized that learners unconsciously organize their tacit ontological and epistemic beliefs into two types of naïve theories that are hierarchically organized. Global explanatory theories are broad in nature and develop early in infancy. They comprise learners' ontological and epistemic assumptions about knowledge within a specific domain. Specific theories develop from learners' daily life or instructional experiences. They consist of inter-related belief, perceptions, and knowledge propositions that represent the explanations students give to specific phenomenon within a domain.

Vosniadou (1994) explained that an instructional goal should be to help students reinterpret the underlying naïve theories structuring their mental models rather than requiring students to replace flawed mental models. She further clarified that changes to mental models are the result of changes in learners' interpretations of the phenomenon. Theory-changes at the explanatory or specific belief level lead to learners' re-interpretation of their observations and are central to fostering changes to their mental models. Individual, social, and contextual factors can either facilitate or constrain the re-interpretation process (Vosniadou, 2007b).

Ontological and epistemic beliefs within learners' naïve theories play a central role in the knowledge acquisition and mental model development processes because they can facilitate or constrain the enrichment and restructuring process within learners' mental models (Chi, 2002; Mason, 2002; Vosniadou, 2002). Learners' domain-specific knowledge and beliefs are intertwined constructs that work concurrently to inform their conceptions (Alexander, 2006; Chi & Roscoe, 2002; Mason, 2002; Murphy, 2007; Vosniadou, 2002). Effective instruction is central to mental model building when it has the potential to address both epistemic and ontological beliefs and knowledge change (Murphy, 2007; Vosniadou, 1991). Vosniadou assumed that learners' conceptual systems develop within unique social and contextual environments (Entwhistle, 2007, p. 124). As a result, Vosniadou considered instruction for conceptual change as a multi-dimensional process that involves both internal personal variables and external social and contextual influences that together interact to influence the mental model building process (Vosniadou, et al., 2001; Vosniadou, 2007b).

When applying FTCC to the physical education domain, it is imperative that physical educators perceive students' domain knowledge and beliefs in tandem. Learners' beliefs develop unconsciously through their experiences both within and outside the physical education lesson. When instruction targets knowledge and belief change simultaneously, change "is more likely to affect behavior change especially in those domains [such as physical education], where the ultimate aim is to transform attitudes and intentions" (Mason, 2001b, p. 723). Given that a goal of physical education is to help children develop positive attitudes towards movement and physical activity (NASPE, 2004, Standard 6), physical education researchers' re-conceptualization of learners' beliefs about knowledge and knowledge as distinct yet integrated constructs within learners' conceptual systems can facilitate an understanding of students' learning of physical education domain concepts.

Additionally, because learners' mental models are contextualized (Entwhistle, 2007), physical education scholars need to examine students' mental models in relation to specific school, content, and lesson settings. Since learning is a cognitive, social, and contextual phenomenon (Vosniadou, 2007b), the products and processes of student learning can be best understood through examining students' mental models within the physical education class. Some physical education scholars already have embraced this recommendation and future studies can build upon the methodologies adopted by these researchers (Hare & Graber, 2000; Manross, 1994; Rovegno, Nevett, & Babiarz, 2001)

Physical educators need to be sensitive to the fact that students are generally unaware of the naïve nature of their conceptions and benefit from teacher assistance to develop awareness of the naïve nature of their ideas. Teachers can provide specific movement experiences and use assessment strategies to help students reinterpret their existing conceptions to reflect scientifically accurate models, especially when domain concepts present information that conflict with daily experiences.

Because mental models reflect internal, idiosyncratic mental structures, qualitative methods involving both verbal and non-verbal elicitation are effective in providing the rich descriptions necessary to understand these structures. Researchers can infer mental models indirectly through examining students' expressed models (Gilbert, Boulter, & Elmer, 2000) on performance, textual (written), verbal, and visual tasks. Conceptual change scholars recommended a combination of qualitative methods to elicit various forms of students' expressed domain concept models to develop an accurate picture of students' mental model(s) (e.g., Venville, 2004; Vosniadou et al., 2001). Vosniadou (2002) stressed that, because learners' mental models are but one element within the learners' conceptual system, their analysis permits researchers to gain indirect access to influential underlying knowledge and beliefs. Examining mental models can provide researchers with information about the content or products of students' conceptions and information about how students' are learning domain concepts. When researchers examine the contextualized development of students' mental models, they can better understand how cognitive, social, and contextual factors affect conception development (e.g., Vosniadou et al., 2001).

Statement of the Problem

Researchers have used conceptual change theory approaches to examine students' mental models, knowledge, and beliefs about the domains of science, mathematics, and history (e.g. Greca & Moreira, 2001; Limon, 2002; Vosniadou et al., 2001). Their investigations of students' naïve conceptions have lead to a more advanced conceptualization of the learning process than was possible through the sole use of domain-general approaches.

Physical education scholars have increasingly recognized the need to examine the products and process of student learning in physical education. Although a number of scholars have detailed students' domain knowledge, most of this research has been grounded upon domain-general learning theories, such as Information Processing Theory (IPT) or initial approaches of domain-specific conceptual change that were also IPT-based (e.g., Chi, Feltovich, & Glaser, 1981). Physical education researchers have not yet attempted to articulate the relationships among learners' domain-specific knowledge and their beliefs about particular physical education concepts. Research is needed to identify patterns of coherence in students' explanations of physical education concepts that reflect their naïve theories or ontological and epistemic beliefs that structure their knowledge conceptions. The purpose of this study is to use Framework Theory of Conceptual Change to examine students' mental models and infer students' underlying physical education knowledge and beliefs. This theoretical approach to learning offers an additional perspective to interpret students' knowledge conceptions of physical education content and can enhance scholars understanding of the cognitive learning process in physical education that was not possible through traditional, domain-general learning theories.

Research Questions

The purpose of this study is to examine sixth grade students' mental models, knowledge, and beliefs about particular domain concepts in physical education. The specific research questions guiding this study are:

a) What are the characteristics of sixth grade students' mental models of two health related fitness concepts: the concept of intensity and exercise induced physiological changes?

b) How do they organize their knowledge and ontological and epistemic beliefs associated with these concepts?

c) What variables influenced the development of students' mental models?

Assumptions

I adopted four assumptions from the literature to ground my research study. First, students' conceptions are complex systems that comprise mental models, knowledge, and beliefs that are constrained by naïve theories (Vosniadou, 1994). Second, the identification of consistent patterns in students' responses permits the inference of the existence of an underlying mental model (Vosniadou, 1994). Third, social and contextual influences play a role in developing student mental models (Vosniadou et al., 2001). Fourth, students' expressed models of physical education concepts can be externalized through verbal, textual, physical performances, and/or visual means (e.g., Placek et al., 2001; Vosniadou, 1994). These assumptions fueled my methodological decisions. I assumed that students and teachers would give honest and candid answers to the questions I asked and that lessons observed were representative of what normally happens in physical education at each school on a day-to-day basis.

Significance of the Study

Understandings what students know and believe about physical education domain concepts can further our understanding of the student learning process. Examining students' mental models within instructional settings can help scholars identify the social or contextual factors associated with teacher practices that facilitate or constrain the learning process and inform future curricular and lesson plan design and implementation. The results from this study could be utilized in staff development projects to provide teachers with a better understanding of the student learning process and help them to become aware that domain knowledge may be counter intuitive to learners' experience in the existing social and cultural world. Particular information relative to students' mental model building processes can assist teachers to nurture students' naïve models and encourage the development of synthetic models, leading to an understanding of the domain concepts as scientific models.

Limitations of the Study

I based this cross sectional descriptive study on a qualitative multi-site case study approach. One of the goals of qualitative research is to study the setting and its participants. As such, the results will reflect participant meanings in these unique instructional settings and, my interpretations are limited to these populations. In naturalistic research designs, researchers have some control of the trustworthiness of the research through purposeful decisions associated with participant selection, data collection, and analysis protocols. However, other aspects of the setting were left in their natural state. Thus, I also acknowledge that the physical education programs studied may have contained contextual limitations that were beyond my control as researcher.

Delimitations of the Study

In the current study, there are a series of delimitations. First, I selected two schools as data collection sites in which the focus of the curriculum was on student learning and where teachers emphasized students' conceptual learning of health-related fitness concepts during physical education. Within each school, I studied one class of sixth grade students' enrolled at each school as participants in the study. Second, I examined only the knowledge and beliefs implicated in learners' mental models about particular health related fitness concepts in physical education: the concept of intensity and the effects of exercise induced physiological changes.

Definitions of Major Terms

This section provides definitions of the major constructs guiding the research questions addressed in this study.

Conceptual Change Theory (CCT). A theoretical framework that articulates learning as a process of conceptual change. Advocates assume that the knowledge acquisition process is domain specific, occurs uniquely in each subject area, and requires both the enrichment and restructuring of learners' existing knowledge base (Vosniadou, Ionnides, Dimitrakopouou, & Papademetrios, 2001).

Concept. Packages of meaning that capture the patterns, similarities or differences, and relationships among objects, events, and other concepts (Pines, 1985). Entwhistle (2007) noted the term concept refers to both internal and external representations of knowledge. In this research I specifically use the term "concept" (see domain concepts) to refer to external knowledge representations that comprise verified forms of knowledge as determined by experts. I use the term "conception" to refer to internal forms of knowledge representation (see conceptions).

Conceptions. The internal mental constructs individuals create to represent their knowledge, interpretations, and meanings of the world (Klausmeier, 1990). When learners construct their conceptions in parallel with domain concepts, they are considered scientific[1]. However, when learners ascribe incorrect attributes to a domain concept, their conceptions are qualitatively different from the domain concepts. Learners' conceptions containing systematic patterns of errors have been termed misconceptions or flawed mental models by some science educators (Chi, De Leeuw, Chiu, & LaVancher, 1994; Chi, 2005). Developmental psychologists, in contrast, define them as naïve conceptions (Vosniadou, 1999);

[1]. Vosniadou (1999) clarified that Vygotsky (1962) used the term "scientific concepts' to define learner conceptions that were acquired at school during formal instructional experiences, as opposed to "spontaneous concepts" acquired through informal learning experiences. Therefore, scientific concepts are related to students' formal learning of domain concepts in various subject areas, including science, mathematics, and physical education.

they have naïve conceptions that contain systematic error patterns as synthetic models.

Conceptual knowledge. Students' prior knowledge that incorporates their conceptualizations of domain concepts and unique language to define their conceptions (e.g., the words or vocabulary they use to represent domain concepts) (Alexander, 2006).

Conceptual learning/Conceptual understanding/Conceptualizing. Students' learning of domain concepts. The learning of academic domain concepts has been termed conceptualizing (Klausmeier, 1990), conceptual learning (Alexander, 2006), and conceptual understanding (Roth, 1990). Conceptual learning requires students to develop rich, domain-specific networks of knowledge. Alexander (2006) and Roth (1990) explained that conceptual learning progresses through conceptual change. The process of conceptual learning occurs uniquely in diverse domains because different domains place unique conceptual constraints on learners (Vosniadou, 2007b).

Domains. Alexander (2006) defined domains as formalized bodies of knowledge that constitute a subject area. She explained that domain-knowledge must be formally taught to students because they may not acquire it through their everyday experiences. Domains can be well or ill structured (Alexander, 2006; Limon, 2002). Well-structured domains (e.g., mathematics, science) have clearly delineated domain concepts, boundaries, and rules for reaching the correct answer, while ill-structured domains (e.g., history) involve more abstract domain concepts. In ill-structured domains, learners have no clear rules for arriving at the correct answer. Ill-structured domains are characterized by multiple correct answers.

Domain concepts (see also concepts). Limon (2002) defined domain concepts as the subject matter that constitutes an academic area. Domain concepts are externally constructed, standardized concepts that reflect experts' agreement on what knowledge constitutes the essential content in an academic subject area (Alexander, 2006). Domain concepts can be declarative, procedural, or conditional in nature (see Domain Specific Knowledge) and comprise the basic knowledge in both well-structured and ill-structured domains. Domain concepts are inter-dependent and have a relational structure (Vosniadou, 1991). For example, being able to understand the heart rate concept requires students to hold pre-requisite conceptualizations about the heart and pulse and their relationship. Further, students need to be able to count the number of times the heart/pulse beat each minute. Klausmeier (1990) explained that students' attainment of domain concepts is a major education goal.

Domain-specific beliefs (aka. academic beliefs). Beliefs about knowledge and knowledge development in a specific subject area. According to de Jong and Fergusson-Hessler (1996) and Alexander (2006), domain-specific beliefs affect the manner in which students understand and develop their knowledge conceptions about the domain. There are two types of domain-specific beliefs:

a) *Epistemic beliefs.* Beliefs related to how individuals perceive the nature of knowledge and how they come to know (Alexander 2006). According to Tyson et al. (1997), epistemic beliefs are related to how students look inward to view their own assumptions about knowledge. Epistemic beliefs have at least four dimensions. These include beliefs associated with the (a) structure of knowledge: that is, whether students believe knowledge is simple isolated facts or comprises complex related concepts, (b) stability of knowledge: that is, whether students view knowledge as static or evolving, (c) source of knowledge: that is, whether students believe they depend on external sources of information to gain knowledge or believe they can independently and actively seek information for themselves, and (d) justification of knowledge, such as the use of causal explanation to explain how something occurs. (Buehl & Alexander, 2001; Hofer, 2000; Vosniadou, 2007 a). Additionally, Murphy (2007) clarified that epistemic beliefs include learners' (inner) "thoughts, tools, signs, and discourse practices students' value about a particular topic" (p. 44). Vosniadou (2007a) explained epistemic beliefs are not static but are changing and evolving constantly as learners adapt to social and contextual life influences. They also can affect the conceptual change process both directly and indirectly by "influencing students' learning goals and self-regulation (p. 10).

b) *Ontological beliefs*. Beliefs that reflect learners' assumptions about the categories and properties of knowledge in the world (Chinn & Brewer, 1993). They reflect the attributes learners ascribe to phenomena.

Domain-specific knowledge. The declarative, procedural, and conditional conceptual knowledge learners hold about a particular domain (Alexander & Judy, 1988). *Declarative knowledge* is factual information within the domain that describes the nature and function of phenomena (Alexander & Judy, 1988). In physical education, declarative knowledge represents, for example, terminology to describe the skeletal and muscular system components, or the fact that the heart is a muscle and functions to move blood and oxygen. *Procedural knowledge* is "the knowing how to carry the compilation of declarative knowledge into functional units that incorporate domain-specific strategies" (Alexander & Judy, 1988, p. 376). It reflects how learners use their declarative knowledge to carry out procedures and routines (Alexander, Shallert, & Hare, 1991). In physical education, procedural knowledge reflects how to perform. For example, it is used to locate the pulse, compute heart rate in beats per minute, and to perform a motor skill or fitness exercise. *Conditional knowledge* entails the "understanding of when and where to access certain facts or employ particular procedures" (Alexander & Judy, 1988, p. 376). In physical education conditional knowledge represents when and how to apply a particular game tactic or when to adjust exercise intensity level.

Enrichment. The addition or integration of new domain knowledge into a learner's existing conceptions. It is the simplest and most common form of conceptual change and represents everyday developments (Alexander, 2006). It parallels assimilation (Piaget, 1929), accretion (Rummelhart & Norman, 1981), or conceptual capture (Hewson & Hewson, 1984). Within Framework Theory of Conceptual Change (Vosniadou, 1994), enrichment occurs at the naive theory level.

Expressed models. A form of knowledge representation that permits researchers to make inferences about learners' mental models. Because researchers cannot observe directly the content of student's internal mental models, they use multiple methods including verbalizing, writing, drawing, performing, and other symbolic forms to elicit students' understanding of domain concepts (Gilbert, Boulter, & Elmer, 2000)

Mental models. Domain-specific mental representations learners' create during cognitive functioning that reflect some external system (e.g., a domain concept) or internal knowledge representation about the world (Greca & Moreira, 2000). Mental Model Theory (Johnson Laird, 1983) is a theory of thinking and reasoning that articulates mechanisms involved in the conceptual change process. Mental models may be well formed or flawed, but in either case, learners use mental models to think about domain concepts in the world. Vosniadou (1991) theorizes that mental models exist in three types that gradually evolve from one form to another as learners acquire more domain knowledge and learn to reinterpret their prior knowledge. Initial mental models are formed prior to school experiences and reflect learners' direct experiences in the physical world. Scientific models are developed in parallel with externally defined domain concepts. Synthetic mental models comprise a hybrid of initial and scientific models that usually contain some systematic pattern of error. They develop when learners attempt to reconcile information from the domain that is counter-intuitive to their existing initial models.

Naïve theories. Coherent belief structures that frame learners' knowledge propositions.

Students' conceptions are not incoherent knowledge elements; rather, learners' knowledge conceptions are embedded within naïve theories that comprise their domain specific beliefs (Vosniadou, 1994).

Prior Knowledge. Prior knowledge "… encompasses all that one knows and believes… It is a personal stock of information, skills, experiences, beliefs, and memories" (Alexander, 2006, p. 72). Prior knowledge is constantly at work in the individual's mind and affects how people interact and perceive the world. Alexander, Schallert, and Hare (1991) hypothesized that prior knowledge consists of conceptual and metacognitive knowledge that influence the learning process. Conceptual knowledge refers to students' prior knowledge that incorporates their conceptualizations of domain concepts and the language they use to define their conceptions (e.g., the words or vocabulary they use to represent domain concepts) It is concerned with the learning of academic domain concepts. Metacognitive knowledge reflects students' prior knowledge about their own thinking about self, tasks, and strategies.

Restructuring. The modification of learners' existing conceptions that occurs when new domain information cannot be resolved or added within existing conceptions, and, therefore, needs to be re-organized (Alexander, 2006). It parallels accommodation (Piaget, 1929), conceptual exchange (Hewson & Hewson, 1984), and tuning and restructuring (Rummelhart & Norman, 1981). The minor modification to existing conceptions that require re-ordering or shifting of existing categories is called *weak restructuring* (Carey, 1985), while a major or drastic modification of existing conceptions resulting in the development of new conceptions is called radical restructuring (Carey, 1985).

CHAPTER 2

REVIEW OF RELATED LITERATURE

Conceptual Change Theory has the potential to enhance the study of student learning in physical education. This chapter provides an overview of the advancements in researchers' understandings of learning as a domain-specific phenomenon that involves dynamic mental models as mediating cognitive mechanisms. Scholars in diverse subject areas such as science, mathematics, and history have examined students' mental models through an array of designs and instruments. Scholars in physical education have also investigated students' domain knowledge and learning within this predominately performance-based domain. Although they have used different learning theories (e.g. Information Processing Theory), their studies use methodologies that parallel those used by scholars in other academic domains. Conceptual change as a process of mental model building may provide an important perspective for investigating student cognitive learning in physical education. There is a need for physical education researchers to examine both what students know and believe about the physical education domain within the context of existing learning environments.

Conceptual Change Theory

Deriving from constructivist roots, Conceptual Change Theory (CCT) describes learning as a *process of conceptual change* and details domain concept learning within specific subject areas (Driver et al., 1994; Posner et al., 1982; Vosniadou, 1999). Often, students' conceptual understandings originate in initial conceptions that are qualitatively different from those of experts. Conceptual change is the process through which students gradually modify their existing understandings towards more scientifically held understandings (Murphy, 2007). Both science educators (e.g., Chi, 2002) and developmental psychologists (e.g., Vosniadou, 1999) have provided significant insights into student conception development. Conceptual change constitutes both the enrichment and restructuring of learners' conceptual knowledge systems that comprise naïve theories (beliefs) and mental models (knowledge).

Learning is a Domain-Specific Phenomenon

Until recently, domain-general approaches to conceptual learning such as Information Processing (IPT) and Constructivist Learning Theories (CLT) assumed that learning occurred in the same manner, irrespective of subject area or domain. With the increased acknowledgement of the domain-specific nature of learning, scholars' views moved towards cumulative-domain-specific approaches and they perceived learning as a process of conceptual change (Alexander, 2006; Vosniadou, 2007b). Although conceptual change occurs in all academic domains (Alexander, 2006), Vosniadou (2007b) clarified that each domain places different constraints on the learner. Thus, conceptual change may occur differently in well-structured domains (e.g., science) than it does in the less structured domain of history (Mason, 2002; Vosniadou, 2007b). Conceptual change comprises a process whereby individuals' existing conceptions are modified to a greater or lesser extent by new domain information (Limon, 2002). It requires "modifications or revisions to existing knowledge structures" (Vosniadou, Ionnides, & Dimitrakkoupoulou, 2001, p.382).

Historically, CCT originated in Piaget's (1929) and Vygotsky's (1978) foundational cognitive constructivist development theories. Beginning in the 1980s, science educators and developmental psychologist investigated the product and process of student learning in science (Carey, 1985; Dole & Sinatra, 1998; Klausmeier, 1990; Pintrich, 1993; Posner et al., 1982; Roth, 1990; Smith III, diSessa, & Roschelle, 1993; Vosniadou, 1999). Results of these studies suggested that children's understandings were qualitatively different from those of experts. They noted with interest that students' knowledge conceptions were often flawed in comparison to scientifically accurate domain concepts (Chi et al., 1981; Chinn & Brewer 1993; Posner et al., 1982). Recently, CCT has also been applied in a diverse of domains, including history, social studies, economics, and mathematics.

CCT scholars have hypothesized ways in which students process information and construct their conceptions. According to Sinatra and Pintrich (2003), when students' existing conceptions were consistent with the domain concept information their teachers introduced, their existing conceptions could scaffold new domain knowledge construction and learning. However, when students' existing conceptions were incomplete or conflicted with the information presented in the classroom, they produced conceptions that were qualitatively different from that intended by their teachers. In the latter instances, students often were unable to reconcile the new information within their existing conceptions, leading them to either reject or distort it; in the later case developing conceptions that contained some systematic pattern of error. CCT scholars developed diverse models as they sought to understand this phenomenon and offered different perspectives on how educators could target learners' conceptions that contained some systematic patterns of error (Murphy & Mason, 2006).

Differing Perspectives on Conceptual Change

Traditionally, science educators and developmental psychologists ascribed to different domain-general learning theory assumptions to describe students' systematic error patterns and have proposed different perspectives to facilitate conceptual change. Grounded in IPT, early science education conceptual change researchers (Chi et al., 1994; Hewson & Hewson, 1984; Thagard, 1992) used Posner's model as the guiding paradigm to understand knowledge change within well-structured domains (Posner et al., 1982). Influenced by IPT novice-expert investigations, they assumed that (a) learners extracted and organized knowledge acquired from the environment, and (b) learners' conceptions comprised perceptual and knowledge elements. They viewed conceptual change as primarily a personal cognitive process and that novices lacked the complex domain conceptualizations demonstrated by experts. Reflecting this deficit perspective, science educators traditionally described students' conceptual errors using terms, such as *misconceptions* (e.g. Chi, 2005) and *anomalies* (Posner et al., 1982). These scholars argued that students' misconceptions are difficult to change (Chi, 2005; Chinn & Brewer, 1993). Like IPT scholars, they assumed a static view of conceptions and assumed that to facilitate the correct learning of domain concepts, students must *replace* misconceptions with more appropriate scientifically accurate conceptions (e.g., Chi & Roscoe, 2002)

Conversely, developmental psychologists ascribed more closely to constructivist tenets. They assumed that knowledge development "cannot exist with human construction" (Alexander, 2006, p. 68). Indeed Vosniadou (2007a) explained that a fundamental characteristic of the human's cognitive system is individuals' ability to create their own understandings about the world by organizing and constructing conceptual knowledge structures. Developmental psychologists ascribed learners an active role in interpreting, creating, and modifying their conceptions and viewed conceptual change as an interactive individual cognitive, social, and contextual phenomenon (e.g., Vosniadou, 1994). Reflecting their constructivist roots, these scholars described students' conceptual errors as naïve conceptions (Murphy & Mason, 2006; Vosniadou, 1999) and some scholars (Roth, 1990; Smith, di Sessa, & Rochelle, 1993) cautioned that focusing on '*mis'*-conceptions emphasized the erroneous nature of students' conceptions and overlooked their creative, active attempts to construct their own understandings. In contrast to science educators' views, Vosniadou and Brewer (1992) argued that naïve conceptions are not due to learners' metacognitive deficits or a lack of coherence in students' ideas. Instead, naïve conceptions reflect phases along the developmental learning process that reflect learners' unique efforts to establish mental coherence as they link their initial conceptions about the subject matter with the new information presented by their teacher. Hence, in contrast to science educators, she does not view naive conceptions as being unilaterally negative, but rather as necessary phases towards more scientifically correct conceptualizations.

Developmental psychologists assumed that learners' conceptual knowledge base comprises more than just knowledge elements. Alexander (1996, 2006) explained that all a learner knows and believes about a domain forms the conceptual knowledge base learners use as scaffolds to supports the construction of all future learning. Carey (1985) and Vosniadou and Brewer (1987) were the first conceptual change scholars to suggest that learners' *knowledge* and *beliefs about knowledge* are inter-connected constructs. They suggested that students' conceptions are actually embedded within their *naïve theories* (beliefs) about the domain. Naïve theories differ qualitatively from experts' theories in their lack of sophistication and external verifiability and develop unconsciously through learners' informal experiences in the physical world. Naïve conceptions are not always resistant to modification; teachers can use students' naïve conceptions to scaffold student learning within a specific domain (Alexander, 1996; Roth, 1990; Smith et al., 1993; Vosniadou, 1994).

Levels of Conceptual Change

Duit and Treagust (2003) clarified that the term conceptual change reflects a pathway learners follow as they move toward more sophisticated understandings about a domain. Mason (2002) indicated that all forms of classroom learning require modifications to existing conceptions. Yet, Alexander explained, the "processes to make simple adjustments to conceptual knowledge are different from those needed to shape understandings drastically" (Alexander, 2006, p.123).

Limon (2003) differentiated two levels of conceptual change: enrichment and restructuring. Alexander (2006) explained that *enrichment* involves the simple addition or integration of new domain knowledge into a learner's existing conceptions. It is the simplest and most common form of conceptual change. *Restructuring* involves modifications to the internal structure of existing conceptions. Learners may find it difficult to add new information to their existing conceptions and thus must restructure their core conceptions to understand the unfolding complexity associated with the domain concept (Alexander, 2006). Carey (1985) further distinguished restructuring into weak and radical restructuring, depending on the extent to which learners modify their core conceptions. *Weak restructuring* involves either the creation of new relationships within existing conceptions or some minor qualitative modifications in the categorization of existing conceptions. Core conceptual frameworks remain intact and the student's conceptual understanding adjusts to accommodate new information. Conversely, *radical restructuring* involves substantial changes to core conceptions and affects all components of the conception. It entails either major modifications to existing conceptions or the creation of new ones, resulting in changes that reflect an alteration of the learner's conceptual domain understanding (Alexander, 2006; Carey, 1985; Vosniadou, 1994).

Both levels of conceptual change are continuously involved in the process of conceptual change and implicated in the development of both correct and naïve conceptions. Learners develop correct conceptions when they effectively and appropriately integrate new knowledge into their existing conceptual structures. However, as Roth (1990) explained, as novice learners attempt to enrich or restructure their conceptions, they sometimes do so ineffectively because they capture only bits of disciplinary information. When this occurs, students' naïve conceptions may contain systematic error patterns, either because the conceptions contain correct and incorrect elements or because they may be incomplete, lacking some elements. Variables both internal and external to the learner's conceptions mediate both accurate and inaccurate enrichment and restructuring processes (Vosniadou et al., 2004).

Contextualized Conceptions

Scholars also have identified several variables related to the learner and formal learning environment that facilitate or constrain what and how students' learn. Limon (2001) identified variables related to the: (a) learner (e.g., beliefs about the subject matter, values, interests and motivations), (b) social context in which learning takes place (e.g., the role of peers, teacher-learner relationships), and (c) teacher (e.g., content knowledge; beliefs about learning and the subject matter; teaching strategies).

Additionally, influential learning variables related to curriculum design, including the breath and depth of instructional sequences (Gabel, Stockton, & Monoghan, 2001; Vosniadou et al., 2001) and assessment strategies (Boscolo, 2002; Mason, 2002). Tekkaya (2003) noted that the nature of teacher language used in presentations, curriculum documents, and textbooks affects how students interpret information and create their meanings about a domain. The nature of the concepts, themselves, influences the difficulties students' experience in learning some content, for example, concrete vs. abstract concepts. The relational structure between domain concepts; the interdisciplinary nature of some concepts (Chiu & Lin, 2005; Jones, Lynch, & Reesink, 1987; Michael et al., 2002; Vosniadou, 1999). Limon (2003) noted that, while several researchers have identified the myriad of external contextual variables involved in conception enrichment or restructuring, few have described the internal (cognitive) mental mechanisms that mediate the conceptual change process. Chi and Roscoe (2002) and Vosniadou (2002) hypothesized that mental model building mechanisms mediate the knowledge enrichment or restructuring processes.

Model Building Mechanisms

Mental-model-building mechanisms appear to underlie the conceptual change process (Mayer, 2002). Chi & Roscoe's (2002) and Vosniadou's (1994) incorporation of mental model constructs from Mental Model Theory (Genter & Stevens, 1983; Johnson-Laird, 1983) have extended earlier conceptual change approaches. Beliefs about knowledge play influential roles in model building mechanisms. Several scholars noted that Vosniadou's (1994) *Framework Theory for Conceptual Change* offers the more powerful theoretical perspective to describe the mechanisms underlying conceptual change (Greca & Moreira, 2000, 2001; Mason, 2007; Murphy, 2007 Sharp & Kuerbis, 2005).

Framework Theory of Conceptual Change

Vosniadou (1994) articulated a powerful conceptualization of mental model building that is serving as the primary theoretical framework guiding current conceptual change research (Greca & Moreira, 2000, 2001; Hannust & Kikas, 2007; Havu-Nuutinen, 2005; Mayer, 2002; Mazens & Lautrey, 2003; Sharp & Kuerbis, 2005; Venville, 2004; Venville & Treagust, 1998). According to Havu-Nuttinen (2005), Vosniadou characterizes the learning process as an active knowledge acquisition process in which dynamic, evolving mental models are the primary mediating mechanisms involved in conception development and modification. Vosniadou is the first cognitive scholar to hypothesize the role that individual cognitions and social and cultural factors play within the mental model building process (Mason, 2007). Continuous interactions between individuals and their surrounding contexts are instrumental in shaping student knowledge and beliefs (Vosniadou, 2007a). Further, learners' domain-specific beliefs (ontological and epistemic) and knowledge are intertwined constructs. Vosniadou (2002) maintained that an examination of both learners' domain-specific knowledge and beliefs as implicated in their mental models, offers researchers insight into the learning process not yet offered by earlier learning approaches.

Development of the Framework Theory

Vosniadou (Stathopoulou & Vosniadou, 2007; Vamvakoussi & Vosniadou, 2007; Vosniadou, 1991, 1994; Vosniadou & Brewer, 1987, 1992, 1994) investigated the process of conceptual change in various domains. She examined students' mental models of complex concepts, such as the earth, day-night cycle, force, and fractions. Vosniadou is a developmental psychologist whose research is grounded in constructivist assumptions and focuses on understanding how students learn domain concepts. Vosniadou (1991) argued that experts can create more effective curricula when they are sensitive to children's subjective domain interpretations. She argued that instruction is more likely to lead to meaningful learning when researchers/educators understand the role played by both students' domain-specific knowledge and beliefs in their mental model development. Students' conceptions change towards domain concept mastery when educators incorporate students' naïve mental models into the curriculum and use instructional strategies developed to match students' developing conceptualizations of the subject area.

In contrast to science educators' perspectives, Vosniadou (2002) emphasized the complexity of learners' conceptions and the richness of their knowledge systems comprising many knowledge components such as perceptual information, beliefs, and mental models that are organized in complex yet coherent ways. In Framework Theory, Vosniadou integrates Johnson-Laird's (1983) perspective on mental models and Carey's (1985) premise that conceptions are actually embedded within learners' naïve theories (beliefs). Vosniadou (1994) proposed that naïve theory-change underlies the mental model-building process. It entails a gradual and incremental process involving qualitative shifts in learners' interpretations of their ontological and epistemic beliefs. These shifts, in turn, lead to the modifications to learners' mental models (Vosniadou, 1994, 2002, 2007).

Mental Models

Mental models are essentially the domain-specific knowledge structures individuals use to think, reason, and mentally represent their knowledge about the world (Brewer, 1987). Vosniadou (1994) explained that learners retrieve them from long-term memory or generate them during the learning process. Recently, she clarified that the ability to form mental models is a basic characteristic of the human cognitive system. Even young children can construct mental models as "mediating mechanisms for the revision of existing knowledge and construction of new ones" (Vosniadou, 2007a, p. 62).

Mental models are internal, idiosyncratic, dynamic, and recursive mental structures that can exist in multiple forms. They develop through three sources, namely, individuals' cognitions (e.g. perceptions and beliefs), social interactions, and experiences in the lay culture. Mental models actively influence how individuals conceptualize, interpret, and think about domain concepts (Modell, Michael, & Wenderoth, 2005; Sharp & Kuerbis, 2005). They are functional in nature, permitting learners to make predictions and develop causal explanations for phenomenon they observe in their environment (Greca & Moreira, 2001). Mental model development is influenced by learners' symbolic systems (e.g., language and cultural artifacts) and their domain-specific beliefs.

The role of symbolic systems. Language and cultural artifacts plays a significant role in mental model development (Vosniadou et al., 2004). Greca and Moreira (2000) noted that, "Individuals construct mental models based on what they already know about the meaning of the words and about what they know they don't know" (p.109). Learners may need to construct new mental models to attach meaning to new information. Roth

(1990) describes language as the cognitive tool that learners use to manipulate their interpretations in their minds. It is the medium that engages learners directly in the learning process and plays a central role in the attainment of domain concepts (Pea, 1993; Reiss & Tunnicliffe, 2001).

***The role of domain-specific beliefs*.** Beliefs about a domain are implicated in learner's naïve theories because they affect the type of mental models learners are able to construct (Chi & Roscoe, 2002; Mason, 2002; Vosniadou, 2002). Murphy and Mason (2006) explained that beliefs refer to assumptions within a specific subject area that learners unconsciously assume, accept, or desire, irrespective of verifiability. Vosniadou and Brewer (1992) were the first conceptual change scholars to insist that learners' domain-specific beliefs consisted of ontological and epistemic beliefs that develop through learners' everyday experiences. They maintained that both kinds of beliefs influence learners' interpretations and perceptions of domain concept information.

Ontological beliefs inform how students view the outside world (Tyson, et al., 2001) and refer to the assumptions learners hold about "the fundamental categories and properties of the world" (Chinn & Brewer, 1993, p.17). They represent the attributes learners ascribe to phenomena within each subject area. An example of an ontological belief identified in science is the assumption that hotness/coldness is a property of objects (Vosniadou, 1994).

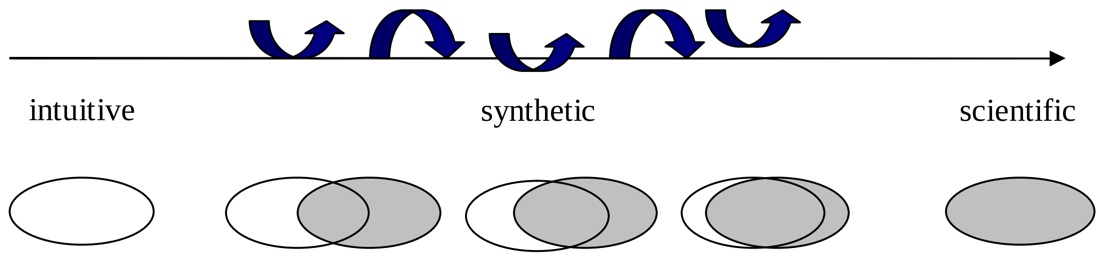
Epistemic beliefs refer to those assumptions that learners hold "about the nature of knowledge and the process of knowing" (Vosniadou, 2007a, p. 10). Tyson et al. (1997) explained they relate to how students look inward to view their own assumptions about knowledge. Epistemic beliefs have been differentiated into at least four dimensions. They include beliefs associated with the (a) *structure of knowledge*: that is, whether students believe knowledge comprises simple isolated facts or comprises complex related inter-relational concepts, (b) *stability of knowledge*: that is, whether students view knowledge as static and unchanging vs. dynamic and evolving, (c) *source of knowledge:* that is, whether students believe they depend on external sources of information to gain knowledge or believe they can independently and actively seek information for themselves, and (d) *justification of knowledge*, such as that phenomena need to be explained in terms of causal explanations (Buehl & Alexander, 2001; Hofer, 2000; Vosniadou, 1994; 2007a). Additionally, Murphy (2007) argued that epistemic beliefs include the inner "thoughts, tools, signs, and discourse practices students' value about a particular topic" (p.44).

Within FTCT, learners' beliefs about knowledge play a critical role in the knowledge acquisition process, providing the structure of the coherent theories within which learners' create, enrich, or restructure their mental models. Learners organize unconsciously organize their beliefs within their naïve theories, in ways that either facilitate or constrain the way learners build their mental models (Vosniadou, 1994).

Conception Development and Modification

Vosniadou's perspective to model building reflects a learning continuum of mental model structures that originate from three sources, individuals' perceptions, social interactions, and cultural experiences. Vosniadou (1991; 1994) hypothesized that students' mental models exist in three forms (see Figure 1 on the next page). Mental models begin from learners' *intuitive* models, transition through intermediary *synthetic* models of the phenomenon, to assume eventually, the domain-concept attributes within a *scientific* model.

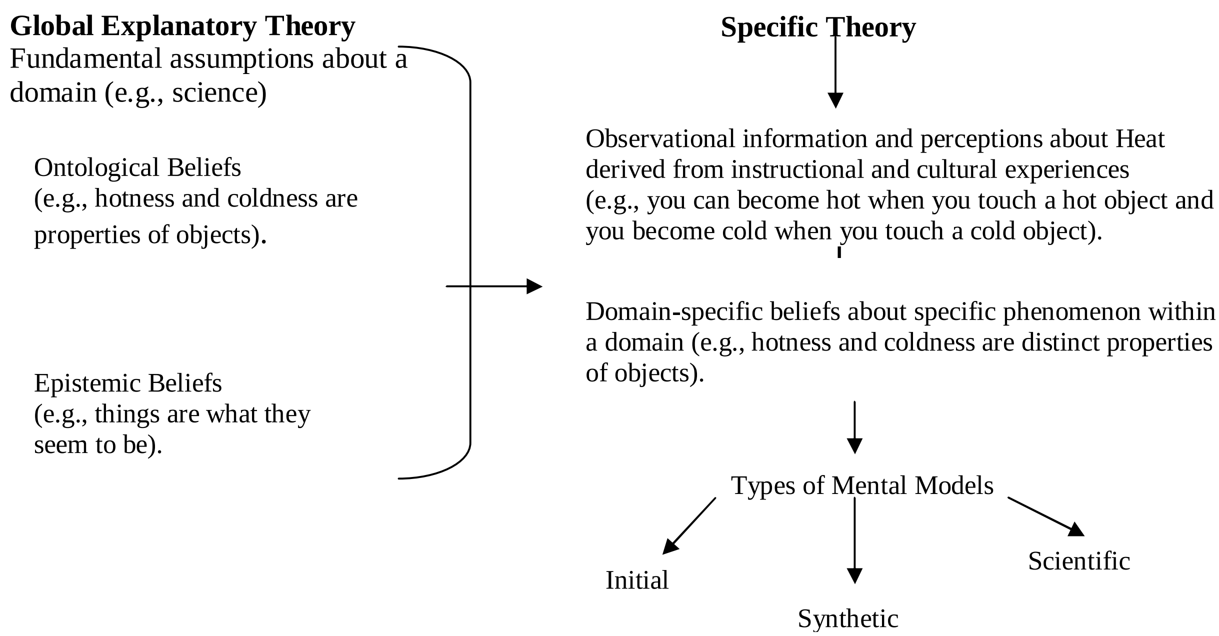
Figure 1. Schematic representation of the mental model continuum.



At either end of the continuum pictured in Figure 1 is the learner's initial intuitive model and the agreed upon scientific models, respectively. *Intuitive models* are the initial mental models learners' develop informally through their direct experiences in the lay culture prior to their schooling experiences. *Scientific models* develop during learners' school experiences and parallel the correct, externally agreed upon domain concepts. *Synthetic models* develop during the instructional process and reflect learners' creative, active, but ineffective, attempts to link new information (external) domain concepts with their existing (internal) intuitive models. Synthetic models develop because the domain concepts contain information that may be counter-intuitive to students' direct experiences in the world (Vosniadou, 1994). For example, students are sometimes required to learn domain concepts or use instructional models (e.g., the earth is a globe) that provide information that may be counter-intuitive to their everyday experiences (e.g., their perception that the earth is flat). Therefore, as students try to integrate or reconcile these two conflicting sources of information, they unconsciously misinterpret or distort the domain concept(s) they internalize within their intuitive models. Mental model transitions can be both internally and externally mediated (Vosniadou, 2007a). Internal transformation occurs via changes in the epistemic and ontological beliefs that underlie learner's naïve theories, while external transformations can be mediated by teachers' practices and instructional resources.

Global and Specific Naïve Theories. Vosniadou (1994, 1999) differentiated learners' naïve theories about a domain into *global explanatory theories* and *specific theories*. The schematic representation in Figure 2 below illustrates how both theories influence the types of mental models learners construct about the concept of heat in the domain of science.

Figure 2. Hypothetical conceptual system underlying learners' mental models of heat[2]



• [2] Adapted from Vosniadou, S. (1994). "Capturing and Modeling the Process of Conceptual Change" *Learning and Instruction, 4*, p.45-69.

Global explanatory framework theories are global beliefs about the domain as a whole that develop early during infancy (e.g., beliefs about the nature of science). They comprise ontological and epistemic assumptions about the world that are unconsciously developed and confirmed through learners' everyday experiences. Vosniadou (1994) pointed out that explanatory framework theories are first order constraints that shape learners' specific theories and mental models. *Specific theories* also develop from learners' everyday experiences or through instructional experiences. They consist of perceptual information and beliefs about specific phenomenon within a domain (e.g., beliefs about the concept of heat). Vosniadou (1994) explained that specific theories are second order constraints that shape learners' mental models.

Unlike other scholars, Vosniadou (1994) suggested that enrichment or restructuring occurs at the levels of the naïve theories rather than at the level of the mental models. Modifications to either or both theories facilitate or constrain the enrichment and restructuring of learners' mental models. Therefore, both theories may be involved in shaping the mental models learners constructs and use during the knowledge acquisition process. Explanatory theory changes are more difficult for learners to modify than specific theories because they comprise beliefs that may be entrenched and tied to years of confirmation. Additionally, explanatory theories affect modifications to all the inter-connected components of learners' conceptual systems, that is, specific theories, perceptions, and mental models. Vosniadou (1999) explained that naïve theory change may be hard to achieve because students lack *metaconceptual awarene*ss of the naïve nature of their theories.

Promoting Transitions in Learners' Mental Models

Vosniadou et al. (2001) proposed that educators should first help learners' develop awareness for their naïve conceptions through the use of questioning and assessment tasks. Learners will then be more open to instructional strategies that enable them to reinterpret their existing epistemic/ontological beliefs to parallel the correct scientific forms. Instructional experiences can permit learners to enrich or restructure their theories, facilitating reinterpretation of their observations. Theory-change helps students "open up the conceptual space through increased metaconceptual awareness for the limitations of their understandings and promotes awareness of the need to change them" (Vosniadou, 2007a, p. 62).

Vosniadou and her colleagues recently clarified that learners can form mental models not only of their every day experiences, but also of the external cultural artifacts and symbolic systems they use (Vosniadou, et al., 2004). They explained that because the learner's cognitive system is flexible and capable of using both internal and external forms of knowledge representations, naive theory-change can be fostered through sources external to the human mind.

Vosniadou et al., (2004) explained:

> There can be different modes of knowing and reasoning in the process of learning science, from those that require students to generate their own (internal) mental models and reason on the basis of them, to those that require the simple manipulation of an externally given model. (p. 336)

Learners can use external models (e.g., globes) or symbolic systems (e.g., language) for constructive acts of interpretation and the transmission of cultural meanings. They use these types of external sources as prosthetic devices in future thinking and reasoning activities. Extensive social and curricular support provided by educators through curricula and instructional practices assists learners to make transitions in their mental models necessarily to adopt more scientifically correct conceptual understandings (Vosniadou, 2007a; Hatano, 2003). Learners' mental models are contextualized constructs that change constantly as learners' learn to adapt to contextual variables.

Significance of Vosniadou's Research

The Framework Theory for mental model building has become the guiding learning theory both theoretically and methodologically for recent conceptual change research in several countries. Findings from field-based studies provide initial insights into the design of curricula and learning environments that can foster meaningful learning. Vosniadou (1991) emphasized that research into student learning holds implications for curriculum design when instructional experiences parallel children's thinking and concept acquisition. Instruction is more effective when educators are aware of students' naïve mental models because "it is only when we understand how students think, know, and believe, that we shall be able to slowly lead them (learners) to form the increasingly more sophisticated models closer to those that are culturally accepted" (p.230). Mason (2002) recently reiterated the importance of recognizing the inter-connected nature of learners' knowledge (mental models) and belief constructs (naïve theories). She explained that when instruction targets changes to learners' domain specific knowledge and beliefs as an integrated conceptual system, it also affects behavioral changes, especially in those domains where the ultimate aim is to transform students' attitudes.

It is imperative to examine the integrated role of students' domain knowledge and beliefs within their mental models as windows to student learning. If researchers are able to glean information about learners' underlying mental models, they also can infer the naïve theories (ontological and epistemic beliefs) that shape them. These insights can help researchers better understand how and why learners develop naive conceptions that can then fuel the design of instructional experiences to support students' conceptual learning.

Prevailing Research Methodologies

Conceptual change research methodologies have "captured successfully the patterns of coherence in learners' explanations… by identifying the kinds of mental models learners hold and from which misconceptions can be generated" (Chi, 2005, p. 163). A diverse range of methodological tools currently exist to examine students' mental models, focusing on *one* major complex domain concept (e.g., the solar system or living things). Each domain concept actually involves a number of interdependent conceptual areas and sub-domain concepts (Hubber, 2006; Jones et al., 1987; Vosniadou et al., 2001). For example, an understanding of the concept of the earth necessitates that children conceptualize how the earth's size, spatial, and gravitational aspects function together as a system. Vosniadou (1991) explained that students' interpretation of *each* sub-domain concept influences the mental models they construct. Therefore, research designs and techniques are needed that enable students to externalize their knowledge and beliefs about the major concept and its sub-components. This section presents a review of the assumptions, selection criteria, research designs, instruments, and analysis methods scholars have used to investigate learners' mental models.

Assumptions Guiding Investigations of Students' Mental Models

Researchers have identified students' mental models and beliefs theories in different subject areas (e.g., Chi & Roscoe, 2002; Greca & Moreira, 2000; Mason, 2002; Vosniadou, 1994). Five assumptions have guided these scholars' examinations of students' mental models. Firstly, mental models are personal, idiosyncratic mental representations that reflect the learner's *subjective* world (Greca & Moreira, 2002). Therefore, interpretive qualitative methods are appropriate to elicit and determine learners' mental models. Secondly, mental models are one component within a connected conceptual system comprising many elements, including knowledge and beliefs. Therefore, elicitation of learners' mental models permits researchers to indirectly access the ontological and epistemic beliefs within students' naive theories that shape their knowledge (Vosniadou, 1994). Thirdly, learners operate through internally coherent mental models. According to Hannust and Kikas (2007), researchers have focused their attention on determining the level of consistency in students' response patterns. If learners' responses to certain questions about domain concept characteristics reflect consistent patterns across several data sources, researchers can infer the mental models that guide learners' responses. Fourthly, researchers cannot directly observe learners' mental models, yet they can infer them indirectly through students' *expressed models* (Gilbert et al., 2000). Researchers purposefully utilize instruments to elicit expressed models about a concept that include students' verbalizations, writings, drawings, and performances. Researchers then use the data obtained to make inferences about learners' internal mental models and underlying belief systems. Finally, learners' mental models are dynamic in nature. They can provide information about student learning products and processes and demonstrate how cognitive, social, and contextual factors affect conception development (Venville, 2004; Vosniadou et al., 2001).

Site and Participant Selection

Representativeness is an important criterion in selecting participants for mental model research when the goal is to identify the range of students' mental models within a classroom. Purposeful selection involves selecting a representative student sample and assuring both gender and academic representativeness (Coll & Treagust, 2003; Venville, 2004). In developmental designs whereby researchers followed students over the course of an instructional unit, researchers purposefully selected learning environments that provided optimal settings in which to investigate conceptual change. In single site case studies, for example, researchers purposefully selected sites where teachers emphasized cognitive learning strategies within a series of lessons based on specific teaching strategies (Harrison et al., 1999; Taylor, Barker, & Jones, 2003; Venville, 2004). In multi-site case studies, researchers (Hannust & Kikas, 2007; Sharp & Kuerbis, 2005; Venville & Treagust, 1998; Vosniadou et al., 2001) purposefully selected sites that offered contrasting opportunities to view the process of conceptual change. For instance, teachers at one site implemented a student-centered constructivist curriculum whereas, at the other site, teachers used a more traditional, teacher-directed approach.

Research Designs

Designs to examine mental models utilize several different protocols to reflect scholars' research questions. Researchers have conducted cross-sectional descriptive studies to obtain a snap shot description of students' conceptions at one specific moment in time (e.g., Vosniadou, 1992). Others have conducted developmental designs (e.g., quasi-experimental or ethnographic case-studies) to document the specific contexts within which learners' conceptions develop and to track any changes in participants' mental models over the course of an instructional unit or teaching strategy implementation (e.g., Venville, 2004).

Cross sectional snap shot studies. According to Gay, Mills, and Airaisan (2006), snap shot cross-sectional, descriptive designs permit researchers to collect data from individuals or groups of students in a single observation or trial. Several studies used written surveys alone, administered once, to develop a quantitative snap shot of learners' mental models of a major concept such as body organs or the cardiovascular system (e.g. Michael et al., 2002; Reiss & Tunnicliffe, 2001; Tunnicliffe, 2004). Other scholars, however, used a combination of written and interview surveys to obtain both quantitative and qualitative descriptions of learners' mental models of the cardiovascular system, electricity circuits, or day-night cycle (Chi et al., 1994; Coll & Treagust, 2003; Jones et al., 1987; Teixeira, 2000; Vosniadou & Brewer, 1994).

Cross-sectional designs describe mental models of several different student groups at one data collection point (snap shot) or over an extended period (longitudinally). Participant groups in these designs typically consisted of a representative group of learners from different grade levels attending the same school (e.g., Vosniadou, 1992) or different schools (e.g. Coll & Treagust, 2003). Although a definite advantage of cross-sectional designs is the examination of data from different groups, the constraint of a single data collection point does not permit close examination of individual students' curricular experiences, or mental models development and change over time, or the influence of social or contextual variables (e.g., curricular or instructional factors) on mental model development.. The combined use of multiple data collection points and ethnographic methods can be used to overcome some of the limitations of the single data point cross sectional approach.

Developmental studies. Developmental design protocols permit researchers to map learners' mental model development and document the influence of social and contextual variables (Vosniadou et al., 2001). Most scholars used developmental protocols in the form of an ethnographic case study (e.g. Harrison, 2000; Venville, 2004), whereas a few conducted multi-site case studies (e.g., Venville, et al., 1998) and quasi-experimental design (Chiu et al., 2002; Vosniadou et al., 2001). The combined use of dynamic assessment and ethnographic techniques enhances the robustness of developmental designs. Multiple data sources collected at multiple data points as repeated measures enhance measurement validity and reliability of measurement. *Dynamic assessment techniques* permit researchers to track the process of students' mental model development before, during, and after instruction (Chiu et al., 2002). Additionally, developmental designs benefit from ethnographic methods to describe both the curricular and contextual influences on conceptual change. Magnusson et al. (1997) explained that investigating mental model building requires the careful documentation of students' mental models accompanied by detailed lesson observations and document analysis to permit researchers to make inferences about mental models changes.

Developmental studies generally examine a small number of students (or classes) and enable researchers to describe the learning context and its influence on individual student's mental model growth over time (e.g., Venville, 2004; Vosniadou et al., 2001). Scholars have patterned their studies on three data collection protocols. In the first protocol, researchers such as Taylor et al. (2003) administered a questionnaire to all students in one class (N=26) prior to instruction, carried out field observations of students engaged in the unit of instruction, and conducted post-instruction interviews with a representative sample of students (n=6) and their classroom teacher (See Table 1). A similar pattern was used in the multi-site case study conducted by Venville and Treagust (1998). Researchers first distributed written questionnaires to all 83 students across three schools and later interviewed 8-13 students at

each school.

*Table 1.*Questionnaire – observation - interview protocol

Instructional Period		
Before	During	After
Written questionnaire administered to all students.	Ethnographic field observations Document Analysis	Interview with a representative sample of students. Formal teacher interview

In the second protocol, (see Table 2) researchers used an interview involving a combination of elicitation techniques with a representative sample of students prior to and after instruction, and conducted field observations during the instructional period. Venville (2004), for example, interviewed eleven students from a class of 26 in a single-site case study. Hannust et al., (2006) used the same protocol in a multi-site case study. Approximately 16-20 students in each class of kindergarten and 1st grade in two schools were interviewed (approx.45 % of class population).

Table 2 Interview – observation - interview protocol

Instructional Period		
Before	During	After
Interview with a representative sample of students.	Ethnographic field observations Document Analysis	Interview with the same representative sample of students.

The third protocol used by Vosniadou et al. 2001 (see Table 3) involved the administration of written questionnaires to all students in a class (N= 22) prior to and after instruction. Additionally, a representative student sample from each class was interviewed after each written questionnaire. Researchers also conducted field-

Table 3. Questionnaire - interview - observation – questionnaire - interview protocol

Instructional Period		
Before	During	After
Written questionnaire administered to all students. Interview with a representative sample of students.	Ethnographic field observations Document analysis	Written questionnaire administered to all students. Interview with the same representative sample of students. Formal teacher interviews.

observation and document analyses during the instructional period. They reviewed teachers' curricula and lesson plans, and students' class assignments. One researcher (Taylor et al., 2003) also conducted informal teacher interviews after the instructional period.

This third protocol facilitates the combined use of verbal and non-verbal elicitation techniques prior to, during, and after instruction. This design permits greater data triangulation at each data point. The advantage of staging the student interview after the questionnaire is to clarify issues regarding students' responses that may not be addressed through analysis of their written questionnaire responses, alone (Vosniadou, 2001).

Instruments

Researchers combine a variety of qualitative elicitation techniques to access students' mental models. Because researchers cannot observe mental models directly, they must infer them through examinations of students' expressed models. *Expressed models* are a form of knowledge representation (i.e., writing, verbalizations, drawings, or actions) that reflect students' internal mental models (Gilbert et al., 2000).

It is important to select instruments that facilitate learners' expressive ability and provide accurate representations of the concept characteristics as whole and the relationship between its components. For example, Driver and Erickson (1983) pointed out that children have different expressive abilities that should be accommodated in instrument selection. For example, one child may be able to articulate verbally her understandings, whereas another child may find it easier to express herself through drawings. Additionally, Vosniadou and Brewer (1994) indicated that learners might verbally express some sub-domain concepts quite easily (e.g., the movement of the sun), while other concepts are better expressed through pictorial representations (e.g., where people live on the earth). Researchers can infer learners' beliefs (i.e., ontological or epistemic) through a line-by-line microanalysis of students' verbalizations, performances/actions, and written concept descriptions. They can identify which learners' responses reflect consistent patterns and the extent to which learners use underlying mental models consistently. Therefore, appropriate instrument selection is critical for eliciting expressed models sufficiently detailed to permit pattern analysis (Chiu, et al., 2002; Sharp & Kuerbis, 2005; Vosniadou, 1994).

To capture the complexity of learners' mental models, researchers collect data from students using a combination of methods that permit researchers to elicit various forms of students' expressed models. For example, the *interview* adopted by Vosniadou and her colleagues (Vosniadou & Brewer, 1992, 1994; Vosniadou et al., 2004) involved a one-on-one interview protocol that allowed students to express their understandings in three primary ways: (a) verbally through interviews, (b) textually and visually through drawings, and/or (c) physically through manipulative tasks. The combined use of observations of students' performance on manipulative tasks, questionnaires, and interviews are used to triangulate data describing learners' complex conceptual systems. Therefore, researchers need to consider the student, the content, and the context when determining appropriate instruments for their study.

Elicitation Techniques

Sharp (2005) and Venville (2004) pointed out that combining verbal and non-verbal techniques (e.g., verbal, textual, visual, and behavioral) permits comprehensive interpretations of students' mental models, triangulation of data sources, and enhanced potential to address trustworthiness issues. Chiu et al. (2002) and Driver and Erikson (1983) reiterated that the use of one elicitation technique is not sufficient to capture comprehensive understandings of students' subjective thinking. For example, Vosniadou et al. (2001) explained the sole use of written questionnaires does not enable researchers to uncover learners' domain-specific knowledge and beliefs as integrated conceptual systems. Additionally, it is difficult to assign students' responses to an underlying mental model or naïve theory. For these reasons, researchers have used various elicitation techniques in combination. Using a combination of methods enable researchers to overcome the inherent limitations within each individual method. For example, interview protocols combine the traditional verbal interview with visual, textual, and/or manipulative elicitation techniques. These techniques are effective in permitting respondents to externalize their expressed models in various ways (Sharp, 2005; Vosniadou, 1994). The four primary elicitation techniques are verbal, visual, textual, and behavioral methods.

Verbal. The interview method is the prime means to obtain learners' expressed models. When students discuss, explain, or describe their understandings about domain concepts, researchers can examine their verbalizations and language choices to make inferences about their thinking and beliefs (Chi & Roscoe 2002; Chui et al., 2002; Vosniadou, 1994). Typically, the verbal elicitation protocol involves individual, standardized 20-40 min. student interviews. An interview guide facilitates comparative analysis by ensuring that all interviewees will receive similar questions and protocols. Interviews provide researchers with access to data that may remain hidden when using observational or written measures (Parker, 1984). They are more likely to elicit learners' knowledge and beliefs, revealing patterns in students' responses that may reflect an explanatory theory or mental model.

The predominant verbal elicitation technique is the structured, one-on-one interview method using open-ended questions. Structured interviews require precisely worded questions to elicit respondents' words, thoughts, and beliefs. Open–ended questions encourage students to express their understandings, values, knowledge, and beliefs (Patton, 2002). They also permit researchers to ask a range of questions, probing for additional clarification when necessary (Vosniadou, 1991).

In developmental studies where scholars interviewed students before and after instruction, they generally chose to use the same set of questions before and after the instructional period (e.g., Hannust & Kikas, 2006; Vosniadou, et al., 2001). At times, scholars incorporated the "interview-about-instances format" (e.g., Harrison, 1999; Venville 2004) and incorporated additional questions that related specifically to events observed during the instructional period.

Visual. Visual techniques provide students with opportunities to express their mental models through drawing activities. They take students' age, drawing abilities, and the nature of the concept into consideration to provide alternative opportunities for student expression. Researchers have involved students in activities that required them to use free-hand drawing tasks, label pictures, or draw concept maps (e.g., Chiu et al., 2002; Hannust et al., 2006; Harrison & Treagust, 2000; Vosniadou et al., 2004). Alternatively, other scholars used visual aids as probes for verbal questioning, including ready-made picture cards (Nobes, Martin, & Panagiotaki, 2005; Venville, 2004), concept cartoons (Keogh & Naylor, 1999), real artifacts (Jewell, 2002), and manipulative models (Coll & Treagust, 2003; Harrison, 2000; Mazens et al., 2000).

***Textual*.** Researchers use written products to obtain tangible evidence of students' mental models and examine their conceptual understanding (Vosniadou, et al., 2001). According to Mason (2002) and Harrison (2000), students' writings, such as questionnaires and classroom assignments, are a means through which students' expressed models can be elicited to textually display and explain the range of domain knowledge and beliefs within a class.

Questionnaires are typically administered by the classroom teachers or researchers to all students in the class during the regular instructional period (e.g., Sharp & Kuerbis, 2005; Taylor, et al., 2006; Venville, 2004). In other studies, researchers administered the questionnaire as part of the interview (e.g., Hannust & Kikas, 2006).

Other researchers administered the written measure on a single day either prior to (or following) instruction. After a preliminary analysis, they used the students' questionnaire responses to conduct follow-up interviews the following week with a representative sample of students. Questionnaire format depends on the learners' age and the domain concept characteristics investigated. For example, Chiu and Lin (2005) provided elementary students with task sheets requiring them to fill in the blanks, label diagrams, and circle correct answers. They also permitted students to draw their responses, if they could express their understandings better through drawing than writing words. Other researchers used open-ended questions that required younger students to write sentences (Taylor et al., 2003) or short paragraphs (e.g., Mason, 2001; Venville & Treagust, 1998), and older students to write essays (e.g. Harrison, 2000).

Students' products also comprise textually expressed models and include students' regular school assignments and other classroom products. These products are used in conjunction with document analyses of teachers' lesson plans and curriculum guides to permit researchers to contextualize students' developing understandings (e.g., Harrison & Treagust, 1999; Venville, 2004; Vosniadou et al., 2001).

Behavioral. Parker (1984) explained that observations of students' performances permit researchers to make *indirect* inferences about learners' knowledge and beliefs. Vosniadou et al. (2001) and Venville and Treagust (1998) explained that observations of students' expressed actions (verbal and non-verbal) can reveal students' understandings and permit researchers to examine participant dynamics within the learning environments. Researchers can examine students' behaviors and actions in two ways. First, they observe students' as they work on manipulative tasks staged during the one-on-one interview (e.g., Vosniadou et al., 2004). Additionally, in developmental studies, researchers use field observations to observe and document students' behaviors and actions as they occur in the classroom (e.g., Venville, 2004). Field observations enable researchers to document participants' lived experience within the learning environment (Patton, 2002). Researchers can describe the learning context and document student and teacher interactions and non-verbal behaviors. Such data provide a means through which researchers can understand the social and contextual nature of the learning process to infer influences on students' knowledge and beliefs.

Researchers collect observational data as non-participant-observers (e.g., Venville, 2004) or as participant-observers (e.g., Vosniadou et al., 2001). Some researchers supplemented field observations with video and audio recordings to capture the details of students' interactions and activities (e.g., Chiu, et al., 2002; Hannust & Kikas, 2006; Taylor, et al., 2003; Vosniadou et al., 2001). Vosniadou et al., (2001) explained that analyses of classroom behaviors are critical to understanding the learning process because they help clarify variables in the learning environment that contribute to mental model development

Nature of Questions

The nature of questions used on the questionnaire or interview protocol can facilitate or constrain researchers' ability to elicit students' expressed models. Vosniadou (1994) stressed that the types of questions researchers use to elicit students' mental models is paramount to obtaining quality data. Open-ended questions are effective in eliciting different forms of students' beliefs, and knowledge (i.e., declarative and procedural) about concepts (e.g., earth) and sub-concepts (e.g., size, shape). Vosniadou used three types of open-ended questions to elicit learners' domain-specific knowledge: factual, explanation, and generative. Factual and explanation questions elicit prior knowledge, asking students to explain phenomena they already know. Generative questions ask students to apply their knowledge to explain novel phenomena. These questions encourage students to solve problems, apply factual knowledge, and "generate their mental models on the spot" (Vosniadou, 1994, p. 65). They are particularly effective in "providing information about children's underlying conceptual structures" (Vosniadou & Brewer, 1992, p.542). Vosniadou suggested the use of confrontation and follow-up questions to elicit students' beliefs about a concept and encourage children to elaborate and clarify their answers. Researchers then are able to make inferences about learners' beliefs through a careful analysis of students' responses to a wide range of questions.

Some scholars recommended the use of closed-ended questions, such as forced-choice, true-false, or multiple-choice questions, to assess the scientific accuracy of the developing model (e.g., Nobes, et al., 2005). Vosniadou, et al., (2004) conversely argued that closed-ended questions might bias some children towards socially acceptable responses. In other words, the child selects answers they think that researchers are seeking. Moreover, in multiple-choice formats, closed-ended questions limit responses to those researchers have anticipated, at times constraining students' choice and creativity.

Analysis of Mental Models

Analysis of data sources can provide researchers with access to students' mental model development. The above-mentioned studies used inductive and deductive analysis techniques either alone or in combination to examine the range of students' responses at the class level and to identify patterns in individual student's understandings. Basic deductive procedures enabled scholars to identify, for example, the frequency of correct or incorrect responses, or the frequency of mental models identified. Most researchers placed stronger emphasis on inductive analysis. They sought to identify coherent pattern in students' responses from which they could infer their mental models.

The use of the constant comparison technique (Strauss & Corbin, 1998) permits researchers to identify students' domain knowledge and interpret their underlying beliefs from different data sources. Strauss and Corbin (1998) articulate three levels of qualitative data analysis: open, axial, and selective. Open coding techniques are used to analyze the raw data at the individual response level. Interview transcripts, questionnaires, and observations are analyzed line by line to describe what the students said, did, wrote, or drew about the target concept under investigation. Open coding is effective in establishing the range of responses and examining the dimensions and properties of initial categories. Scholars next use axial coding techniques (Strauss & Corbin, 1998) to identify patterns in categories of students' responses across elicitation techniques. It can be used to compare responses across questions and data sources and to make inferences about learners' underlying epistemic or ontological beliefs. Interpretations of participant responses as consistent patterns are central to the axial coding process in mental model building research. Scholars next used selective coding techniques to examine the impact of contextual variables (e.g., classroom interactions, curriculum utilized) on student responses. The analysis involves the *post hoc* use of theoretical sampling techniques (Strauss & Corbin, 1998) across all data sources and learning environments to examine the patterns of coherence across students' expressed models. Using this process, researchers examine mental model cases at the individual or at class case level, to identify patterns in relation to expected (scientific model) and actual patterns found (initial or synthetic models).

Summary of Conceptual Change Research

Three major issues have emerged from investigations of learner's mental models as the mediating cognitive mechanisms involved in the conceptual change process. First, researchers assume that learners' conceptions comprise a complex conceptual system made of many inter-connected components. They infer learners' domain specific knowledge and beliefs and interpret them as integrated conceptual systems structured by learner's naïve theories.

Second, scholars assume conceptual change is a gradual process unique to each student. It involves a continuum of evolving mental models that are recursive and continually enriched and restructured. It requires learners to re-interpret their naïve theories and acquire additional and increasingly more complex domain knowledge. Time is necessary for some students to reinterpret their theories, especially if they comprise deeply entrenched beliefs. Scholars found that some students' continue to hold naïve conceptions following instruction. Quasi-experimental designs (Sharp & Kuerbis, 2005; Vosniadou, et al., 2001), single site case studies (Mason, 2001; Hannust & Kikas, 2006;Venville, 2004) and multi-site case studies (Venville & Treagust, 1998) have confirmed that students within a class have diverse mental models prior to and after instruction irrespective of curricular approach.

Third, scholars need to examine students' mental models within existing social and contextual environments using an array of designs, instruments, and protocols. Combined techniques permit researchers to more accurately identify and map students' mental models and assess their domain specific knowledge and beliefs. Hatano & Inagaki (2003) and Vosniadou (2007) noted that contextualized examinations of students' mental models enhance researchers' understandings of the social and cultural influences that may influence students' ability to advance their conceptual understanding. This information is essential to teachers' understandings of how best to present domain knowledge and curriculum developers ability to design curricula that parallel children's thinking and mental model development within specific academic domains (e.g. Mason, 2001; Venville & Treagust, 1998; Venville 2004; Vosniadou, et al., 2001).

Learning in Physical Education

Physical education is a unique domain in the school curriculum because it focuses on learning through movement and physical activity experiences. It has the goal of helping students learn to move and move to learn (Gallahue, 1996; Rink, 2003). Its formalized body of domain concepts from the discipline of kinesiology provides the foundation for the inter-connected content areas of the physical education curriculum (Jewett, Bain, & Ennis, 1995). Educators and researchers assume that students' conceptual learning of the body of kinesiological knowledge will enhance their motor skill development and concept learning in physical education (Gallahue, 1996; Rink, 2001). Further, they assume that physical education will help students develop the habits, performance abilities, and cognitive skills necessary to adopt physically active and healthy lifestyles (Corbin, 2002). In recent years, physical education curriculum scholars have turned to cognitive learning theories to inform the design of curricular experiences that promote student learning. Scholars have begun to examine more closely the content of students' knowledge conceptions (e.g. Placek et al., 1998) and the process through which they develop (Rovegno, et al., 2001).

Domain Concepts in Physical Education

Estes (1994) explained that physical education has its own formalized body of knowledge and ways of knowing (epistemologies). It comprises domain concepts experts have agreed students need to master through systematic instructional experiences to become knowledgeable, skillful movers who are healthy and active for life (Mohensen, 2003). Domain concepts derive from the kinesiological body of knowledge that includes motor development, biomechanics, psychology, sociology, exercise science, aesthetics, philosophy, and history concept (Estes, 1994; Mohensen, 2003). Placek (2003) and Gallahue (1996) noted that physical education comprises content unique to the subject area, overlaps concepts found in other subject areas (e.g., exercise physiology parallel biological concepts), or relates to concepts that cut across all subject areas (e.g., personal development or social development).

Conceptual learning in physical education enhances students' physical and cognitive understanding and application of domain concepts. According to Jewett, Bain, and Ennis (1995), the physical education curriculum is the means through which educators can embed, relate, and apply domain concepts. Various scholars have developed curricular models that delineate domain concepts within games, fitness, gymnastics, and dance content areas (Allison & Barrett, 2000; Graham, Parker, & Holt/Hale, 2004; Logsdon et al., 1977; Siedentop, Hastie, & Van Der Mars, 2004). The concepts and principles within these curricula delineate the essential skills and concepts necessary for the conscious and unconscious application and appreciation of movement experiences.

Physical education content is very diverse and comprises a myriad of concepts. Depending on the nature of the curriculum model or the respective content area, a physical education program can represent both well-structured cognitive concepts, such as target heart rate range, and less well-structured movement concepts such as spatial awareness, explored when selecting creative ways to move in educational dance. Domain concepts can be declarative (e.g., sports rules, names of bones), procedural (e.g., how to measure the pulse rate, how to perform an underhand throw), and conditional (e.g., when to perform tactical concepts in a game context, when to adjust exercise intensity level on a tread- mill).

Researchers' Views of Cognitive Learning in Physical Education

Physical education scholars and teachers' understanding about the nature of learning has paralleled the development of learning theories. However, they adapted and applied them to address learning in the motor domain and the dynamic nature of many physical education concepts (Grehaigne & Godbout, 1995; Rink, 2001). As physical education researchers transitioned from behaviorist to cognitive approaches, they have embraced learning as an active process (Grehaigne & Godbout, 1995). Learning is no longer viewed solely in terms of permanent changes in performances. Scholars have accepted readily the role of students' prior knowledge base as a mediator of changes in performance and concept learning and have examined students' knowledge conceptions and the processes through which they develop (e.g. Nevett, Rovegno, Babiarz, & Mc Caughtry, 2001; Rovegno, Nevett, Brock, & Babiarz, 2001). Scholars examining conceptual learning in physical education have traditionally ascribed to two primary domain-general cognitive approaches, namely Information Processing Theory (IPT) and Constructivist Learning Theory (CLT). Recent scholars have also combined learning theories to describe student learning in physical education.

Information Processing Learning Theory approaches. IPT has dominated the examination of motor learning and performance since the 1960s. Scholars accepted the representational nature of knowledge and assumed that individuals actively *acquire* knowledge from the external environment. They perceived learning as a personal cognition process that involves perceiving, encoding, and storing information in terms of action sequences or goal concepts that could be processed automatically. They acknowledged sources of information within the physical context of the immediate task or physical activity (French, Spurgeon, & Nevett, 1995; Magill, 1998, 2004)

Students' cognitive decision-making (declarative and procedural knowledge) and skillful performance in youth sports such as tennis and baseball have been examined within the motor development and motor learning literature (Abernathy & Waltz, 1964; French et al., 1996; McPherson, 1994). In parallel with early conceptual change research, these studies primarily focused on the differences between experts and novices' conceptions, their information processing abilities, and their movement application capabilities. They hypothesized that experts' structures reflected more node linkages, resulting in their ability to demonstrate better decision-making, attention to detail, and physical execution skills, than novices. For example, French et al., (1996), and McPherson (1994) specified that differences between novices and experts lie in their conceptions of the purpose of the game (goal concepts), temporal decisions about the execution of movements or tactical solutions (action concepts), and ability to predict and anticipate changes in the game environment.

Motor learning scholars also used IPT as the theoretical basis to explain how cognitive mental representations and information processing contributed to motor learning. Fitts and Posner (1967) hypothesized the stages through which individuals learn motor skills. They depicted a three-stage learning continuum that progresses through cognitive, associative, and autonomous stages. Magill (1998; 2004) described the relationship between individual's perceptions and body movements. He also hypothesized that within specific physical contexts, students' performances could be constrained by information processing occurring both internally (e.g., ball-movement perception and body coordination) and externally (e.g., the temporal and spatial characteristics of a moving ball). These constraints influenced how individuals execute motor skills with success. In line with educational psychologists, Magill (1998) also noted that concept learning related to performance skills occurs through informal and formal experiences, regardless of students' level of conscious awareness. This principle parallels Vosniadou's (1999) explanation that students are able to learn academic domain concepts in science without metaconceptual awareness.

Constructivist Learning Theory approaches. CLT has provided an important window into the understanding of movement skill and concept learning. For example, the premise that "individuals and groups *construct* their own knowledge" (Alexander, 2006) has complimented the long-standing perception that learning in physical education is an individual, social, and contextual phenomenon that affects all individuals involved in the learning community (Logsdon et al., 1977; Ennis, 2003). Based on constructivist tenets, scholars have assumed that individuals (e.g., teachers, students) create their own perceptions, knowledge, beliefs, and values regarding physical education content, the learning environment, and themselves as individuals (Azzarito & Ennis, 2003; Ennis, 2003; Kirk & Macdonald, 1998). The roots of this re-conceptualization of learning in physical education lie in the constructivist philosophies espoused since the 1960s by influential scholars such as Abernathy and Waltz (1964), Bain (1995), Cassidy (1965) and Jewett and Mullan (1977). Abernathy and Waltz (1964), for example, maintained that learning in physical education is associated with the knowledge and beliefs learners derive from constructing their own personal meaning of movement experiences. Allison and Barrett (2000) explained that movement is the avenue through which students learn about their environment and construct their meanings about the world.

Contemporary constructivist physical education scholars assume learning involves acts of personal and social cognition (Azzarito & Ennis, 2003; Ennis, 1996; 2003; Oliver & Lalik, 2004). Extending the notion of context beyond that of the immediate physical context of the task (as in the case of IPT), they included social and cultural contexts as significant sources of information that influence students' construction of domain concepts. Ennis (1996, 2003) summarized the myriad of interactive variables that influence student learning within the *values context model*. In this model, she schematically represented interrelationships among students, physical educators, schools (personnel, structure, and culture) and external community influences that interact to mediate the teaching-learning process. She explained that the confluence of these variables interact, affecting students' constructions and valuing of physical education concepts.

Integration of IPT and CLT. In parallel with Mayer's (2002) comments, domain-general approaches, alone, have not been sufficient to explain diverse forms of domain concept learning in physical education. Dodd et al. (2001) and Rink (2001) noted that no single learning theory has successfully described the complex phenomenon of student learning in physical education. Greghaine and Godbout (1995) hypothesized the integration of IPT and CLT (domain-general learning approaches) with mental models (domain-specific knowledge structures) to explain the complex and dynamic processes involved in learning tactical game concepts. They maintained the IPT assumption that learners process information to *acquire* tactical domain concepts processed automatically as action rules and sequences during tactical decision-making. However, they envisioned that learners first need to *construct* their tactical knowledge conceptions through a process involving temporary mental representations (mental models). Unlike traditional IPT scholars, they assumed that learners' conceptions were dynamic constructs that developed progressively as learners constructed their tactical understanding through the physical game experiences. As learners process and interpret information, they initially construct temporary mental models of action concepts. Mental models reflect learners' initial interpretation of the teacher explained tactical concept needed in game success. When a mental model is no longer sufficient to meet complex tactical demands, learners must construct a new mental model that enables a more effective tactical concept application. Learners automatically apply this new mental model through a series of automated action sequences delineated by IPT assumptions.

Greghaine and Godbout (1995) suggested that this automatic process occurs simultaneously as students develop expertise, integrating the relation between the actual performance and tactical concept thinking. This perspective parallels the mental model building mechanisms espoused by conceptual change scholars. However, unlike conceptual change scholars, Greghaine and Godbout's (1995) rendition of mental modeling reflects an emphasis on IPT assumptions. For example, they focused on personal cognition and viewed learners' conceptions as comprising knowledge elements and perceptions (not beliefs); additionally they limited their descriptions of context to the immediate physical game context. Further, Greghaine and Godbout's (1995) perspective does not account for the learner's domain-specific beliefs or the social and contextual influences in which the activity is embedded, as is assumed by current conceptual change scholars.

Rovegno and her colleagues (Nevett, Rovegno, & Babiarz, 2001; Rovegno, Nevett, & Babiarz, 2001; Rovegno, Nevett, Brock et al., 2001) combined domain-general learning theories and theories from motor development to explain the relational structure among players in an invasion game, thus overcoming the limitations of IPT. They used IPT to describe how learners mentally represent their declarative and procedural prior knowledge of cutting and passing in an invasion game. To overcome the inherent limitation of IPT (not recognizing the *social and contextual nature* of learning) they integrated IPT with socio-cultural (SC) and situated cognition (SG) learning theories. Further, they used Newell's (1986) constraints theory (CT) to explain the complexities of cutting and passing skills. This perspective explains learners' prior knowledge (IPT) and the *situated nature* of learning (SC, SG and CT). The researchers maintained that the integrated strengths of these theories may help researchers in physical education understand the complex interplay between *learner-task-activity* involved in invasion games.

Other scholars have adopted socio-cultural learning theory to reflect the social context inherent in physical education (Kirk, 2006; Kirk & Macdonald, 1998). Kirk and his colleagues applied this theory to describe the learning process within curricular models such as Sports Education. Kirk (2006) maintained it provides a viable way to understand the "learning trajectories of learner-players within the sport education model" (p. 259). He argues it is a useful theory that permits researchers to understand how students' opportunities to experience various leadership roles within a sports education games unit holds potential to enhance their involvement, understanding, and appreciation for sport in physical education.

Learning theories inform the design of instructional experiences. Cognitive learning theories hold the potential to enhance researchers' understanding of the processes involved in the cognitive and psychomotor learning of the diverse body of knowledge in physical education. This, in turn, can inform the development of physical education curricula that facilitate learning (Kirk & Macdonald 1988). Recently, physical education scholars have placed a renewed emphasis on the need to examine student learning as both a performance- and cognitive-based phenomenon (Dodds et al., 2001; Rink, 1999). Curriculum designers are creating curricula based on theories of learning that place additional emphasis on cognitive knowledge through the explicit inclusion of physical education domain concepts in lesson and unit content (Dyson et al., 2004; Ennis, 2007; Mitchell et al., 2005; Placek, 2003; Rovegno, Nevett, & Babiarz, 2001). Additionally, research on achievement motivation, constructivist teaching, and innovative assessment techniques has enhanced the design of lessons that provide students' opportunities to engage with the content to learn the conceptual basis of physical education (Azzarito & Ennis, 2003; Ennis, 2007; Hopple & Graham, 1995; Solomon, 2003; Solomon, Lee, Belcher, Harrison, & Wells, 2003).

Students' subjective experiences of domain concepts. Educators cannot assume students' conceptual learning of domain concepts (Luke & Hardy, 1999). Laws and Fisher (1999) noted that physical educators need to ask the children to determine what they understand since they are central participants in the learning process. Dyson (1995) noted that, while researchers have acknowledged the learner's role in the learning process, they have only rarely consulted them directly about their own perspective of the learning process. In support, Placek, et al. (1998) pointed out that "little research has been conducted to ascertain the specific details of what students know about the cognitive component of movement activities, or how teachers can successfully support student learning outcomes" (p. A-99). Physical education researchers now recognize the necessity of directly examining students' subjective understandings of physical education domain concepts. Many physical education researchers examining concept learning have expressed concerns that many students' conceptual learning is *not* progressing in the manner intended by their teachers and domain experts (Ayers, 2004; Hare & Graber, 2000; Stewart & Mitchell, 2003). Rink (2001) suggested that scholars examine why student learning is not progressing in the manner anticipated.

Examining Student Learning in Physical Education

Identifying the products and process of conceptual change is receiving more attention in physical education research and driving efforts to design effective learning environments (Dodds et al., 2001; Ennis, 2007). As the emphasis on physical activity, health, and well-being gain increased social attention, the content focus of new physical education curricula is shifting to helping students develop the comprehensive domain knowledge necessary to make positive, healthy decisions, and participate successfully in movement activities (Xiang, Chen, & Bruene, 2005).

Conceptual Change Research in Physical Education

Scholars have begun to develop a database that describes in detail students' knowledge conceptions in relation to specific motor skills, tactical concepts, and fitness concepts (e.g., Hare & Graber, 2000; Placek et al., 2001; Rovegno, et al., 2001). Examining students' conceptions of physical education concepts is in some ways unique from research done in other subject areas. In addition to verbalizations and textual elicitations, expressed models in physical education include students' movement performances from which to infer both the cognitive and motor learning. Examinations of students' conceptions in physical education have paralleled the development of research designs carried out by conceptual change scholars.

Expressed models in physical education. Eliciting physical performances is central to researchers' understanding of students' learning in physical education. Traditionally, physical education teachers have relied on observations of students' performances to infer students' content learning. Both Dodds et al. (2001) and Rovegno et al. (2001) noted that students' overt actions or performances during the physical education lesson permit indirect access to students' procedural conceptual knowledge. However, Rink (2001) noted that inferring students' conceptual learning solely from observations of physical performances is problematic.

A conundrum that perplexes physical education scholars is the interplay between students' expressed knowledge through their physical skills (performances) and that expressed cognitively through verbal or textual methods. Scholars have noted discrepancies between students' physically demonstrated knowledge versus students' verbally articulated knowledge. French et al. (1996) and Manross (1994) found that both low skilled and high skilled students were able to express advanced tactical solutions or accurately describe how to perform the overhead throw (correct conceptions). Yet they also found that some low and high skilled students expressed less advanced tactical solutions or throwing cues (naïve conceptions). A reliance on observations of students' performances on physical tasks or verbal/textual cognitive tasks, alone, cannot accurately depict students' learning of domain concepts in physical education.

Magill (1998) explained the conundrum by suggesting that this phenomenon relates to the fact that students learn physical education concepts and motor skills through both informal and formal experiences, consciously and unconsciously. Magill stressed that the critical issue here is that students' can demonstrate their cognitive understanding of physical education concepts in several different ways. He clarified that some children might be able to perform a movement and verbally express their understanding of how to execute the movement. Others may not yet be able to perform a movement but are able to describe what and how they need to move to execute the moment. Still others may be able to perform the movement without being able to describe it verbally. Researchers' understanding of this range of possibilities is important to understanding the process of conceptual learning in physical education. Magill also added that some children could learn knowledge tacitly through just performing the skill, whereas others may need to first consciously process externally provided information (e.g., by their teacher) before they are able to perform a movement. He explained that either pathway reflected the coupling between children's perceptions of the environment or their body parts, and their ability to select the conception that leads them to execute a movement.

Elicitation techniques and designs. Researchers in physical education can better infer student learning by eliciting both the observable (physical performances) and unobservable (cognitive concepts) aspects of students' conceptual understandings. Driver and Erickson's (1983) observation that children may be able to express their understandings of science in many different ways is also applicable in physical education. Children have different expressive strengths in physical education. There may be developmental delays between students' cognitive and motor development or discrepancies due to children's developing skill level (Hare & Graber, 2000; Magill, 1998).

Physical education researchers have elicited students' conceptions in a variety of ways, including movement performances, manipulative performances, verbalizations, drawings, and textual products (Griffin et al., 2001; MacPhail & Kinchin, 2004; Placek et al., 2001). Interviews involved three different visual elicitation techniques, namely, asking students to (a) review and comment on videos of their game play (Placek, et al., 1998), (b) suggest which component of fitness was being represented on selected fitness cards (Placek et al., 2001), and (c) manipulate miniature player pieces on a board depicting a soccer field as they described their tactical solutions to a game problem (Griffin et al., 2001).

Other scholars used a combination of elicitation techniques and also sought to identify the sources of students' knowledge. Burrows, Wright, & Jungensen-Smith(2002) used a combination of qualitative elicitation techniques, including student interview, performances tasks, and written tasks with open-ended questions. Rovegno and her colleagues (2001) conducted skills tests, student interviews, and a written questionnaire with closed-ended questions. Other scholars used students written questionnaires and teacher self-report surveys (Ayers, 2004; Stewart & Mitchell, 2003). Still others recorded students' performances and social interactions during the physical education lesson using written tasks, think-alouds, ethnographic field observations, and video technology (Hare & Graber 2000; Rovegno et al., 2001). The combined use of these methods strengthens researchers' inferences about students' knowledge conceptions.

Similar to conceptual change scholars, physical education scholars have primarily conducted cross-sectional studies in which they collected data from students at one specific moment in time. Some scholars developed a quantitative snap shot description of students' conceptions (Ayers, 2004; Desmond, Price, Lock, Smith, & Stewart, 1990; White, Albanese, Anderson, & Caplan, 1977). Others developed a qualitative snap shot description (Burrows et al., 2004; Griffin et al., 2001; Hopple & Graham, 1995; Manross, 1994; Placek et al., 1998; Placek et al., 2001). In these studies, scholars examined the products of conceptual change and sought to identify variables that influenced their development.

Two teams of scholars used developmental studies to examine changes in students' conceptions. Hare and Graber (2000) conducted a case study examining students' conceptions over the course of a 5-lesson hockey unit and a 5-lesson soccer unit. They formally interviewed two teachers prior to and after the instructional units. Hare and Graeber collected student data during the instructional unit in four ways: (a) at the end of each lesson they asked all fifth grade students to write down on index cards what they learned during the lesson; (b) they conducted multiple interviews as three short, formal one-on-one interviews with four children; (c) they conducted four think-aloud interview protocols with the same four children; and (d) they conducted informal interviews with students whenever possible during the lesson as they waited on the sideline. Additionally they conducted field observations of all the lessons as non-participant observers using video technology. The researchers acknowledged that a design limitation was that they did not collect data about students prior to the instructional unit to determine their initial skill levels and cognitive concepts. Thus, they were not able to examine effectively changes in students' conceptions from pre-to-post instruction. They also indicated that the think-aloud technique was the least effective elicitation technique.

Another team of scholars conducted a teaching experiment design (Roving et al., 2001; Nevett, et al., 2001). The research-team adopted participant observer roles and taught a 12-lesson unit on invasion game concepts (passing and cutting) based on situated learning theories. They examined fourth grade children's conceptions about cutting and passing and examined how they responded to the learning tasks presented. Rovegno and her colleagues (2001) used a combination of qualitative and quantitative measures in a dynamic assessment manner (Chiu & Lin, 2002) to examine changes in students' tactical conceptions from pre-to-post-instruction. They administered a (a) questionnaire (multiple-choice format); (b) skill test that involved a performance task in a modified aerial basket ball game; and (c) traditional one-on-one interview. Additionally, during the instructional period, the researchers conducted field observations as participant observers

(Patton, 2002) and met after-school to summarize their lesson observations, audio recording their discussions.

Emerging findings. Physical education researchers' examinations of student learning in physical education offer a window into the complex phenomenon of how students create their conceptions about physical education concepts. Recent scholars examining students knowledge conceptions have grounded their studies primarily upon Information Processing Theory (Ayers, 2004; Stewart & Mitchell, 2003) and science educators perspective on conceptual change which is also grounded on IPT tenets (Dodds, et al., 2001; Griffin, et al., 2001; Hare & Graber, 2000; Nevett, et al., 2001). Only one team of scholars used developmental psychologists' perspective on conceptual change and acknowledged learners knowledge and beliefs (Placek, Griffin, & Dodds, 1998). A few used achievement motivation approaches (Merkle & Treagust, 1993; Solomon et al., 2003) and one used critical pedagogical approaches (Burrows et al., 2002). These varied approaches have offered unique perspectives to examinations of students' conceptions of physical education content.

Researchers have verified the products of conceptual change by asking students to express their conceptions of physical education concepts to gain insights into what they understand about physical education domain concepts (e.g., Placek, et al., 1998). Researchers have examined variables that affect the process of conceptual change, indentifying student-related, social, and contextual variables. Less emphasized is researchers' examination of the process of conceptual change within natural settings. Rovegno and her colleagues' (2001) research examines the products of conceptual change and document any changes or pathways learners follow, at various points in the learning process, as they move from less complex to more complex understandings of domain concepts.

Students in physical education hold a number of naïve conceptions. Scholars have identified and described students' naive conceptions of some K-12 physical education concepts. At the elementary level, for example, scholars examined students' conceptions of specific motor skills (Hare & Graber, 2000; Manross, 1994), cutting and passing concepts (Rovegno, et al., 2001), and fitness and health concepts (Ennis, 2007; Hopple, 1994). At the middle school level, scholars examined students' conceptions of fitness concepts (Burrows, et al., 2002; Placek et al., 2001; White, 1977) and soccer tactics (Griffin, et al., 2001; Placek et al., 1998). At the high school level, scholars examined students' naïve conceptions of a sample of concepts from seven sub-disciplines of kinesiology (e.g., Ayers, 2004) and focused on fitness and health concepts (Stewart & Mitchell, 2003).

These researchers confirmed that students' conceptions were often qualitatively different from the target domain concepts and that students within the same class held a range of naïve conceptions about the target content area. Some naïve conceptions ranged across all three levels of schooling. For example, in the fitness content area, scholars reported that students associated being healthy and fit with appearance (e.g., being thin) rather than with the specific health benefits that accrue, such as overall wellness and prevention of cardiovascular disease (Burrows, et al., 2002; Placek, et al., 2001). Burrows et al. (2002) reported that students associated participation in physical activities with a means to lose weight (e.g., you can lose fat through sweating). Placek et al. (2001) reported that students lacked foundational declarative and procedural knowledge about several fitness components (e.g., definitions of health components). Students also lacked application knowledge (e.g., the principle of specificity) such that many were unable to design a fitness plan because they held incorrect generalizations and faulty reasoning (Burrows, et al., 2002; Desmond, et al.,1990). Scholars also identified that students experienced conceptual difficulties with the concept of intensity and an applied understanding of the FITT principle (Placek et al., 2001; Stewart & Mitchell, 2003).

The above researchers identified a range of variables that influence students' developing conceptions, namely (a) social and cultural variables, (b) instructional variables, and (c) motivational variables.

Identifying social and cultural variables. Researchers noted that variables both within and outside the physical education class affect student learning. Scholars used both indirect (e.g., interviews, teacher self-report) and direct methods (e.g. field observations) to document these variables. Although scholars (Burrows, et al., 2002; Griffin et al., 2001; Placek, et al., 1998) did not describe the type of curriculum used or the nature of the physical education class, they identified sources of students' knowledge from the interviews.

Griffin et al. (2001) noted that students' opportunities to play soccer in the neighborhood community and the physical education class influenced their ability to articulate their tactical knowledge of soccer and solutions to tactical problems. They found that students' prior knowledge base of soccer develops through multiple sources, including the physical education class, community soccer programs, the media, and friends or family. The influence of experience on soccer knowledge was unclear, whereas, experience did relate to their tactical solutions. Students having opportunities to learn soccer outside of the physical education class were able to generate more complex offensive solutions than those with limited experience. Students offering the least sophisticated tactical solutions held declarative knowledge (e.g., rules, positions,) but limited decision-making ability in regards to moving players or opponents within the overall game (e.g., they were unable to make “if-then’ conditional statements).

The Burrows et al. (2002) study noted that students develop naïve conceptions because they receive mixed messages about physical education concepts. These scholars examined the external culture influences on students’ concept of health. In investigating the impact of a new wellness curriculum, they found that while students understood the relationship between health and fitness, their beliefs and knowledge about health and fitness reflected a guilt discourse rather than a conceptual understanding of health. These scholars used a critical discourse perspective to explain that students’ experiences within the external culture mediated their subjective constructions of health and fitness information. The researchers reported that students’ subjective constructions (beliefs) were deeply entrenched, and re-confirmed continuously through sources within the physical education class and the external culture (e.g., media, parental practices, teacher-reinforced-stereotypes, societal expectations). These influences at times contradict curriculum content, thus sending mixed messages to students.

Instructional and curricular variables. The importance of documenting the nature of the learning context is still emerging. Scholars have noted that students’ naïve conceptions also emerge within the physical education class due to curriculum or teacher-related variables. Students’ opportunities to learn domain concepts can be facilitated or constrained by teachers’ practices unintentionally.

Scholars collected information about the learning context indirectly by asking teachers to self-report the content covered to determine content coverage, modes of delivery, and instructional resources used (Ayers, 2004; Stewart & Mitchell, 2003). Teachers' curricular decision-making influence students' opportunities to learn domain concepts. For example, Ayers noted that teachers' content knowledge and value of the various sub-disciplinary areas within the curriculum influenced their content emphasis: for example, some teachers included exercise physiology concepts in their programs, yet omitted philosophy and history concepts. She also found that many teachers did not provide conceptual instruction or integrate concepts across instructional units. Stewart and Mitchell (2003) noted that although self report measures may help identify what instructional methods teachers used, they do not permit researchers to understand *how* teachers implement their curriculum and utilize instructional materials to promote cognitive concept learning.

A few scholars documented the nature of learning context directly using ethnographic field observations. Hare and Graber (2000) conducted field observations of a hockey and soccer unit. They reported that students' naïve conceptions related to their teachers' degree of experience, skill in providing clear instructions, developing appropriate task progressions, and conducting assessments. In this study, the student-teacher emphasized classroom management as content rather than students' cognitive understanding of the skills cues associated with soccer skills. On other hand, the experienced teacher used open-ended tasks permitting students to work at their own level on various hockey skills. She periodically assessed her students before moving them onto the next task.

Hopple (1994) and Manross (1994) examined students' knowledge about the purpose of fitness tests and over hand throw, respectively, in two different curricular models: multi-activity and concept oriented. Findings from their studies echo those by conceptual change scholars: students in the concepts-based curriculum demonstrated more conceptually correct knowledge than students in the multi-activity curriculum about the purpose of the fitness test and skill cues associated with the over hand throw. However, a number of students in both programs demonstrated naïve conceptions.

When examining naïve conceptions, it is important for researchers to examine the nature of the curriculum, students' opportunities to learn the content, and document teachers' use of instructional resources and delivery of the curriculum (Chen et al., 2001; Hopple, 1994; Manross, 1994; Stewart & Mitchell, 2003). Studies of this nature hold potential to inform the design of future curricular interventions because they provide information about students' perspectives on learning domain concepts and permit identification of curriculum designs or teacher practices that support conceptual learning (or not).

Motivational variables affect the development of students' conceptions. Motivation scholars identified a range of personal cognitive variables (beliefs, interests, goals, expectancy values, etc., that influence students' willingness to learn domain concepts and participate in physical activity (e.g., Solomon & Boone, 1993; Xiang, Mc Bride, Guan, & Solomon, 2003). Few scholars have included a knowledge measure in their study, and many of the beliefs investigated were personal beliefs about self, others, tasks, or the learning environment rather than domain-specific beliefs about knowledge. For example, Merkle & Treagust (1993) examined students' knowledge of health and fitness concepts and their personal beliefs about the locus of control over their own health. They found that many students held a number of misunderstandings regarding several health concepts. Students holding more scientifically correct conceptions felt they had control over their own health. On the other hand, those that held naïve conceptions about the health and fitness components believed in chance for their personal health. They also noted that possessing correct knowledge does not necessarily affect students' habits. Many students described that they should eat properly and exercise. However, they indicated that they did not participate in regular physical activity experiences or eat the "right food" (p.357).

Other scholars measured students' domain-specific beliefs about participation in various activities but did not directly measure students' knowledge. Solomon, Lee, Belcher, Harrison, and Wells (2003) examined students' beliefs about the gender appropriateness of some physical education activities (tasks). They reported that these beliefs influence students' willingness to participate in physical activities (e.g., if girls believe that participation in a sport is inappropriate), their cognitive engagement, and conceptual learning. Laws & Fisher (1999) examined students' beliefs about the nature and purpose of physical education. They reported that the belief systems students associate with physical education (e.g., competition, personal development, boredom, and fun) influence their motivation to learn, hence also their knowledge development. Findings from achievement motivation researchers highlight that students' own motivational variables may influence the process of conceptual change in physical education.

Conceptual change is a slow and fragile process. Rovegno and her colleagues recently examined the process of conceptual change in physical education through a teaching experiment (Rovegno et al., 2001; Nevett et al., 2001). They developed an instructional unit based on IPT and situative approaches. When examining students' responses to an instructional unit purposefully designed to teach explicitly invasion game tactics of cutting and passing, Nevett et al., (2001) reported that at the class-level, students' made gains from pre-to-post instruction. For example, students' performance on the questionnaire improved from 44.3% to 53.3%. In reporting the performance of individual students, they reported that students thinking patterns were varied; while some students' decision-making knowledge was slowly progressing towards a more sophisticated understanding of tactics, some others maintained their naïve conceptualizations and a few regressed, especially when the complexity of the game-context increased. Students' could verbally express tactical concepts; however, their passing and cutting performances were inconsistent. These findings match Magill's (1998) explanations regarding the complexities involved in examining conceptual change in a performance-based subject.

Summary of Physical Education Research

Physical education researchers have initiated systematic research programs that focus on different aspects of students' learning of domain concepts and the process of conceptual change in physical education. This body of research has highlighted that students' constructions of physical education content is dependent upon learner-related variables, and variables within and outside the physical education class. What students know and believe about physical education is receiving more attention. However, physical education scholars tend to examine students' domain-specific knowledge and beliefs separately and use the terms interchangeably. Apart from the complexities involved in measuring students' varied cognitions (Dodds, et al., 2001), this is also possibly due to the predominance of IPT within our domain. Although scholars have increasingly recognized that individuals *construct* their own conceptions, most scholars still ascribe to initial perspectives of conceptual change grounded on IPT (science educators' perspective). Burrows, et al. (2002) and Placek et al., (1998) are among the few scholars in physical education who acknowledge both students' domain specific knowledge and beliefs about physical education content. However, they did not specifically articulate an integrated relationship between *knowledge* and *domain-specific beliefs* nor differentiate within the latter construct into ontological and epistemic beliefs. Understanding the role of domain-specific beliefs in the knowledge acquisition process of physical education concepts is still in its infancy. Characteristics of student domain specific knowledge and beliefs in physical education are still emerging. Some scholars have acknowledged the "fuzzy distinction" between knowledge and beliefs (Dodds, et al., 2001, p. 301), and in fact, have used these terms interchangeably when reporting their findings (Burrows et al., 2002; Placek et al., 1998; Placek, et al., 2001).

Mental model building approaches to conceptual change offer physical education researchers an alternative way to understand student learning. Because many physical education domain concepts are science based (e.g., life and physical sciences), it is reasonable to assume that Vosniadou's Framework Theory approach to mental model development is applicable to student learning in physical education. It offers physical education scholars another perspective from which to examine the process of cognitive learning in physical education that differs from previous approaches. Unless instructional experiences help students develop awareness for their naïve conceptions and target naïve theory (belief) change, it is unlikely that students will be able to *enrich and restructure* their existing conceptions (Ennis, 2007; Vosniadou, 1994). Being able to understand how students create and modify their conceptual knowledge in meaningful ways is thus essential to meet the goals of the new physical education.

CHAPTER 3

METHODOLOGY

The purpose of this study was to examine the characteristics of sixth grade students' mental models of health related fitness concepts and made inferences about their underlying domain-specific beliefs about this content. A secondary purpose was to examine variables affecting mental model development. I conducted a cross-sectional descriptive study involving an ethnographic multi-site case involving two middle schools. Since students' mental models are not directly observable or measurable, I used a combination of qualitative methods including questionnaires and interviews to elicit students' expressed mental models (Gilbert, Boulter, & Elmer, 2000). Since learners' mental models develop in relation to specific learning contexts (Entwhistle, 2007), I also conducted document analysis, field observations, and teacher interviews to understand the nature of the physical education and science program that contextualized students' mental models. The research design employed evolved through three phases. This chapter describes the nature of the methodology utilized as it related to (a) selecting sites and gaining entry, (b) setting and participants, (c) research design, (d) data collection sources and instruments, (e) data analysis, and (f) trustworthiness and transferability of the data.

Site Selection and Entry

I examined sixth grade students' mental models in two schools that served as sites for this study. To identify these research sites, I visited 14 schools in three Maryland school districts from November 2007 to early February 2008. The purpose of these visits was to determine which sites held potential to address my research questions and to learn about the nature of the physical education program, the teachers' pedagogical practices, and the content they planned to teach between April and June, 2008.

I used three criteria in final site selection. First, it was important that the physical education teacher was an effective teacher with a focus on cognitive learning of fitness concepts. I had contacted physical education supervisors in three school districts who identified two to four master teachers within their respective school districts. I spent a minimum of six hours observing classes and talking informally with the teacher regarding her/his physical education program. For the purpose of this study, the teacher's philosophy, practice, and curriculum reflected an emphasis on teaching physical education cognitive concepts. For example, the teacher emphasized the vocabulary (e.g., asked students to name or define terms), used instructional charts, incorporated writing tasks, questioned children, and emphasized conceptual understandings (e.g., asked students to identify which muscles were being targeted when performing a 'bicep curl'). Second, the schools provided adequate instructional time and had class size with teacher-to-student ratios reflecting that of academic classrooms in that school. I defined adequate instructional time as a minimum of 60-90 minutes twice a week. Third, teachers would be teaching health-related fitness concepts between April and June, 2008.

After selecting the two final sites and receiving tentative teacher support to conduct my study, I met with the physical education supervisor to describe the proposed research and gain supervisor support. I then met with the administrators in the school district research office and submitted my application package seeking permission to conduct research. The process took 3 weeks.

Upon approval, I negotiated official entry and distributed University of Maryland

Institutional Review Board approved forms. I met with sixth grade students in the selected classes to inform them of the study and ask them to return parental permission forms and signed assent forms supporting their participation in the research. I asked participating teachers to sign a consent letter and ensured their confidentiality. To minimize the Heisenberg effect (Patton, 2002), I did not disclose the exact purpose of the current study to the participants. Instead, I presented a generic intent, indicating my interest in understanding how sixth-grade students learn physical education fitness domain concepts.

Setting and Participants

The Setting

I conducted this research study in a suburban school district in the Mid-Atlantic region of the United States that enrolled 41,000 students comprising 75.3% Caucasian, 12 % African American, 8% Hispanic, and 4.6 % Asian/Pacific/Native American. According to the 2007 school report, State Assessment scores for reading and mathematics in this school district surpassed state and nationwide average scores. There was a low student mobility rate of 6.2 % and students were from low, middle, and high social economic status. All teachers in the district held certification in their respective subject areas and approximately 50-55 % held advanced certification qualifications.

Physical education. All middle schools in this school district were equipped with a gymnasium, a weight/fitness room, and outdoor facilities. Lessons comprised a 90-minute time block during which all the classes from one grade level had physical education two or three times each week. The physical education curriculum placed a strong emphasis on (a) developing an acceptable level of personal fitness and appreciation for the life-long value of fitness through personalized physical education activities, and (b) developing students' positive self-concept, physical skills, and a conceptual understanding of fitness concepts (e.g., fitness components, FITT principle, effects of exercise on the human body) to facilitate efficient and creative movement. The *Essential Curriculum* for physical education emphasized students' participation in sequential and varied movement experiences to develop their fitness levels and physical and cognitive skills. Physical education concepts reflected the State's Voluntary State Curriculum for Physical Education and were organized within six content areas, exercise physiology, biomechanics, social psychological principles, motor learning, physical activity, and skillfulness. Specific concepts and sample learning outcomes were provided for each content area. For example, the exercise-physiology standard suggests that students will be able to analyze and demonstrate the effects of physical activity on body systems. The parallel learning outcome indicated that students should be able to explain and discuss how the cardiovascular, muscular, and skeletal systems respond to physical activity (school district, 2005). The Science Essential Curriculum for sixth graders also emphasized students' cognitive understanding of human body functioning and the effects of exercise on the human body.

The Participants

Two middle schools, I renamed Oak (enrollment, 762) and Beech (554), served as the sites for this study. The district physical education teacher had recommended these schools for their quality physical education programs developed by experienced master teachers. Schools were well equipped and the facilities included outdoor fields, tennis courts, basketball courts, and a running track. The indoor facilities included a large spacious gymnasium, weights room equipped with free weights and weight machines, and a fitness room equipped with various aerobic machines such as rowers, stationary bicycles, treadmills, and elliptical machines. Participants at each school included one experienced physical education teacher and one of her assigned sixth grade classes. An additional participant was one experienced science teacher at Beech middle school.

Teachers. Pam and Sue were master physical education teachers at Oak and Beech Middle Schools, respectively, having 18 and 28 years of teaching experience in the school district. They were active professionals involved in physical education curriculum district writing workshops. Pam held a master's degree in educational technology and Sue held a masters degree in curriculum development. Both held advanced certification to teach health and physical education. Each was a member of a three to four teacher team at her respective school and was responsible for a specific class at each grade level during each quarter of the scholastic year. Teachers had two 90 min. teaching blocks in the morning, a planning and lunch period, followed by a third teaching block in the afternoon.

A science teacher, Sandy, at Beech middle school was an additional adult key informant. Although in my original research design I had not envisaged involving science education teachers as participants, during the course of the first interview, students at both schools referenced their science class as another source of information they tapped to understand fitness concepts. Given the emerging nature of the study, I thus sought to interview students' science teachers. Sandy agreed to participate in the study and provided consent. She had 9 years of teaching experience, was the head of the science department at her school, and was an active curriculum writer within the school district science curriculum writing projects. The science teacher at Oak middle school was unavailable at the time of the teacher interviews due to out-of-school based field trips.

Students. I conducted this study at the middle school level because the extended 90 min. class periods twice each week and every other Friday provided adequate instructional time for concept learning. I selected sixth-grade students because identifying what they know and believe about physical education content is foundational to learning seventh- and eighth-grade physical education content. Sixth grade physical education is a transition year because students experience a different physical education instructional experience and have a more extended instructional time as compared to their elementary experiences. They rotated through health education during one quarter and physical education during the other three quarters of the academic year.

I selected one sixth-grade class assigned to Pam and Sue. My final class selection was based upon (a) the teachers' recommendations that students in a particular class were able to express themselves in a variety of ways and (b) the feasibility of being able to observe all the lessons for these classes at each school. I selected a representative sample of nine students from each class to serve as key informants for the duration of the study. I purposefully selected the students based on their responses on the first written questionnaire. As I detail in the data analysis section, I identified three students at the high, average, and low levels to reflect the range of cognitive abilities within each class. I also took into consideration gender and student demographics in making my selection. I sought confirmation from Pam and Sue that the selected students were representative of the grade level and would be willing to verbalize their ideas. All students approached agreed to participate in the study and returned assent forms and parental permission slips.

This enabled me to examine a representative sample of 18 students from these two schools.

The researcher. I am a fourth-year doctoral student pursuing a post-graduate degree in physical education pedagogy. I am originally from Malta (Europe) and read for an undergraduate and masters physical education degree in Malta and the USA, respectively. I have been a full-time elementary physical educator for seven years in a private school in Malta and one year in a public school in the eastern United States. For the past four years, I have worked as a research-assistant and collaborated on a research team involved in a curriculum intervention study. Through this experience, I developed skills in conducting document analyses, interviews, and field observations. My research interest includes a focus on understanding students' cognitive learning to understand how teachers can support students' conceptual learning.

A bias that underpins this research is my belief that physical education is a valuable subject in the overall development of students. Physical education needs to be an educational experience and not simply a recreational activity so that it can contribute to students' life-long academic goals and fulfill its potential as a unique area of study. Cognitive concept learning is central to these goals. The effective mastery of its diverse conceptual basis is important to students' physical development and achievement in physical education and other domains. I believe that researchers' understanding of students' subjective experiences of the conceptual basis of physical education can facilitate effective instruction. It is important to examine students' *knowledge* and *ontological and epistemic beliefs* about physical education as a whole, and the respective domain concepts within each content area. I believe it is necessary for physical educators to understand more deeply: (a) the nature of students' cognitive conceptions, (b) *how* and *why* students develop their conceptions, and (c) the effects/consequences of their pedagogical practices. Because I ascribe to constructivist tenets, I believe that insight into these areas can lead to meaningful instructional experiences because learners' own conceptions are used as scaffolds during the educational enterprise. This can lead to the development of instructional experiences that are sensitive to students' developing conceptualizations of the diverse conceptual basis of physical education. Valuing what students know and believe about each content area (e.g., fitness) is central to understanding how to support their development in becoming knowledgeable and skillful movers who adopt active and healthy behaviors.

Research Design

In this cross-sectional descriptive study I used an ethnographic multi-site case study design because it permitted a concentrated, in-depth contextualized examination of students' mental models. The study evolved over three phases and an overview of the goals and timelines involved are presented in Table 4 on the next page. *Phase One* entailed identifying data sets, obtaining Institutional Review Board and school district approval, and conducting preliminary document analyses of the school district physical education curricula. *Phase Two* entailed gaining entry and collecting pre-existing teacher unit or lesson plans for the particular concepts selected, developing and piloting the first set of student instruments, and seeking participant consent. *Phase Three* involved ongoing data collection and analysis prior to, during, and after the instructional period.

Table 4. Goals and Timelines of the Multi-site Case Study

Phase	Goals	Time Line		
		Preliminary Work November to March 2008	Data Collection Phase April to June 2008	Data Analysis April to September 2008
1	Identify sites and seek permission	√ √		
	Preliminary document collection and analysis of district curriculum	√ √		
2	Pilot procedures	√ √		
	Receive permission forms from participants	√ √		
3	Data collection		√ √	
	Develop teacher interview		√ √	
	Data analysis		√ √	√ √
	Peer review		√ √	√ √
	Reporting			√ √

During this time, I also developed and piloted the second set of student instruments and developed the teacher-interview guides. Additionally, I deepened and triangulated my analyses across all data sources, and conducted negative case checks, member checks, and peer review to enhance the trustworthiness of the final report.

Data Collection and Management

The data collection protocol reflected the qualitative methodological recommendations from conceptual change (e.g. Venville, 2004; Vosniadou, et al., 2001) and physical education research (e.g., Hare & Graeber, 2000; Placek et al., 2001; Rovegno, Nevett, & Babiarz, 2001). Table 5 indicates the data sources and collection techniques during phases two and three of this study. The phase two data collection was to identify the specific domain concepts the physical education teachers covered during the instructional unit. I also developed the student instruments in relation to the content the teachers presented at each site. This ensured that I asked students questions related to the opportunities they had to learn the content.

Table 5. Data collection purposes, sources and techniques

Phase	Purpose	Sources	Data collection techniques	Before	Instructional period	After
2	Collect data for instrument development	Learning context	Document collection	√		
3	Multiple collection of evidence of students' expressed mental models and document nature of learning context	Students	Instructional Written Task: Knowledge and belief questionnaire involving textual and visual elicitation techniques administered to whole class at each site. Served as Pre-interview task for selected interviewees.	√		√
			Interview: Follow up questions involving verbal, visual, and performance elicitation questions conducted with the representative sample of nine students at each site	√		√
			Informal interviews		√	
		Learning context	Document collection		√	
			Field observations		√	
		Teachers	Informal interviews :		√	√
			Formal interview			√

The phase three data collection protocol permitted a descriptive examination of students' mental models. Additionally, it permitted the documentation of the nature of the learning environment that contextualized students' mental models. I used a combination of verbal and non-verbal elicitation techniques to collect students' expressed models using: (a) written questionnaires administered to all students in each sixth grade class. This task entailed a series of questions that elicited students' expressed mental model textually and visually, and (b) follow-up, one-on-one interviews with a representative group of students from each class. The purpose for the interview was to elicit additional data about students' expressed mental models of the target concept through their performances, verbalizations, and drawings. I detail the development of each data collection methods later in this chapter. Additionally, where possible, I also conducted informal interviews with students during their physical education lessons.

I triangulated the document collection of student products, questionnaire responses, and interview data for each interviewee to develop an *interviewee profile* that summarized their understandings about the particular domain concepts. I combined data from the multiple data points (prior to, during, and after the instructional period) to develop a profile for each student respectively permitting the examination of each student as a unique case. This enabled me to become aware of variations and parallels in students' explanations. Student cases facilitated the identification of the range of mental models in the class.

I documented the nature of the learning environment during the instructional period by conducting ethnographic field observations and informal conversations with teachers between lessons. Additionally, I collected student products and teacher instructional materials as available. After the instructional period, I conducted a one-on-one interview with two physical education teachers and one science education teacher to examine their perspective on the target concepts and student learning within their lessons. The information gathered provided opportunities to document the social and contextual nature of the learning environment that contextualizes students' mental models. I review the piloting process before detailing each data collection technique.

Piloting Experiences

During phase two, I piloted the format, administration protocols, and timing of the first student questionnaire and interview guide. I sought expert review (from university faculty and teachers) for content validity and readability levels of these methods. I practiced administering the questionnaire and interview guide with a sample of sixth grade students who were not involved in the study.

Document Collection: Description of Documents

The school district's physical education essential curriculum, teachers' teaching and instructional resources, and students' in class and homework assignments comprised the documents collected in this research phase. During phase two, I conducted a content analysis of the district's essential curriculum and compared the skills and concepts with those articulated in the Maryland Voluntary State Curriculum for Physical Education.

Teacher products. During phase two and three, I gathered information about the domain concepts teachers included in the instructional unit and documented their usage of teaching resources. Products included teachers' personal planning notes, lesson plans and power point presentations, teaching manuals, and web-based instructional resources. I also reproduced and photographed teachers' instructional charts to record opportunities students received to learn the particular concepts.

Student products. During phase three, I collected and photocopied student products such as written work completed during the lessons or for homework.

Data management. In preparation for document analysis, I summarized the content analysis of all documents collected and described them "within the context from which they were extracted" (LeCompte & Preissle, 1993, p.220). I incorporated phase two information in a word.doc file that described the nature of the curriculum and a description of the particular domain concepts covered. During phase three, I kept all reproductions of teacher and student products in a folder. Where applicable I incorporated descriptions of these products within lesson field notes to substantiate/enrich the descriptions of the observations. I saved all notes in word-document-format and rich-text-file format to facilitate import into MAX-QDA 2. Used in conjunction with lesson observations and interviews, the content analysis of document collection data enriched and further validated the data obtained (LeCompte & Preissle, 1993).

Questionnaires

The written questionnaires were consistent with the sixth-grade physical education curriculum at the respective schools. I created one version of the first questionnaire for both classes on the first administration (April) but two versions of the second questionnaire on the second administration (June) to reflect each teacher's respective sports-based unit. Administration protocols were consistent across the two sites.

Purpose and development. The questionnaire responses were used to: (a) obtain information about students' domain knowledge and beliefs about fitness in general, the components of fitness and the FITT principle, cardiovascular exercise intensity, and physiological indicators of exercise intensity at the individual-student and class level, (b) provide data to facilitate student interviewee selection, (c) serve as a pre-interview task for the selected interviewees and to prompt student responses during the follow-up interview, and (d) triangulate with the interview data.

The written questionnaire format reflected methodological recommendations from conceptual change and physical education scholars (Alexander, 2006; Merkle & Treagust, 1993; Vosniadou et al., 2001) and the content analysis of documents (e.g., district curriculum guide, teacher lesson plans, and emails). Questions comprised a range of open and closed questions to elicit students' ideas about the specific concept (e.g. the components of fitness) as a whole and its sub-components (e.g. asking students to explain cardiovascular endurance). The questionnaires involved a combination of visual and textual representations so that students could write and/or draw their responses. Open questions provided students the opportunity to express their understandings in their own words/visual representations. Closed questions that partially paralleled the format the teachers used as part of their regular in-class assessments (e.g., matching tasks, multiple choices) were adapted following the recommendations of Alexander (2006). For example, I created more answer options than question stems on the matching task item to limit guessing. On the two true –false items, I provided students additional space to write an explanation for their choice.

Protocol and management. I administered the 20 min. questionnaires together with the teachers during students' regular physical education class time and used their existing writing protocols. When administering the questionnaire the first time prior to instruction, the teacher informed the students about the researcher's interest to learn what they know about fitness. I adopted the scenario strategy recommended by Buelhl & Alexander (2001) explaining to students that a new student, Brendan, was visiting their school. Hence, the students were asked to teach Brendan all they knew about fitness. I asked them to express their ideas as if they were teaching him about fitness concepts. I also informed the students that I would be joining them for the upcoming physical education lessons. Students completed their answers independently and wrote/drew their responses. Once collected, I prepared the questionnaires for analysis by scanning all sheets and assigning each a numeric code. To ensure data security, I stored all original sheets in a locked cabinet.

Interviews

One-on-one formal interviews permit researchers to capture participants' perspectives with deep access (Parker, 1984). I used singular questions (Patton, 2002) and procedures to match the respondents (e.g., interviewing adults vs. adolescents) and specific learning environment (e.g., the questions were tailored to the physical education program at each site). During the interview, I used an interview guide to ensure that I asked similar questions across interviewees and also demarcated questions I wanted to use with particular students/teachers. I wrote down any points or additional observations (e.g., actions and comments on drawings) on an interviewee summary sheet on my writing pad. All interview data were captured using technology (digital recorder and mp3 player) to obtain the exact words of the participants.

Student interviews. The purpose of the first student interview was to gain deeper access into students' knowledge and ontological and epistemic beliefs (e.g., value, source, stability, structure) about the target fitness concepts that were not accessible through the sole use of the questionnaire. The interview involved a protocol that combined performance, verbal, and visual elicitation techniques to permit students to demonstrate and explain their understanding about the target concepts. Interview data were necessary to build each interviewee's profile permitting the examination of each interviewee's as a unique case. The purpose of the accumulated profiles was to determine the existence of a coherent pattern in students' responses reflective of a particular mental model. To facilitate comparison, the student interview guide for both the first and second interviews comprised a common series of questions specific to each school. However, during the second interview, the guide was expanded to include additional open-ended questions that related to specific events I had observed during the lessons and additional clarification from students.

The first interview (early April) was completed within approx.20 min., while the second interview (early June) lasted approx 35-min. I conducted the student interviews when feasible for the teachers and students: early in the morning prior to the start of the first lesson, during their regular physical education class, and during their tutoring time on days when they were not scheduled to have physical education. All interviews were staged in a quite location in the school that was familiar to the students (e.g., counseling room, empty classroom, or fitness room). The space was large enough to permit students to perform their understanding about the target concept while verbalizing their ideas (e.g., demonstrating heart rate measurement). To help students feel comfortable with me as the researcher, I first asked each interviewee a few questions that require minimal recall (e.g., personal demographics and general comments about physical education). I then proceeded to ask each student a series of follow up and clarification open-ended questions related to their questionnaire responses and additional questions related to the target concepts. During the second interview, I also asked students questions related to specific events that occurred during the lessons. I annotated observations of students' performances and explanations of their drawings on the interview summary sheet for each student.

Teacher interviews. The physical education teachers were key informants in this study. I conducted informal interviews as they naturally occurred during the instructional setting and incorporated data obtained within the lesson descriptions developed from the field observations. I also conducted a one-hour formal interview after the instructional period in an appropriate quiet setting. The formal interview guide comprised questions related to specific events observed in the lesson with the purpose of obtaining the teachers' subjective perspective on their lessons, strategies, and their perceptions of how students learn fitness concepts. I conducted one informal and one formal interview with the science teacher at Beech middle school. The purpose of the one hour interview conducted towards the end of the school year was to learn about science concepts that overlapped with fitness concepts. Specifically, I asked questions related to what and how she taught concepts related to human body functioning and the effects of exercise on the human body.

Interview data management. In preparation for analysis, I transcribed and saved the formal interviews as a separate file with the interviewee's pseudonym. All files were saved in a word-document format and rich-text-format to facilitate their import into the qualitative software MAXQDA 2. All data were secured in a locked cabinet.

Field Observations

I conducted field observations at the respective sites for four weeks observing 12 lessons at each site. Beech Middle School sixth grade physical education lessons were conducted in the mornings from 8:00am to 9:30am. Oak Middle School lessons were conducted in the afternoon from 1:30-3:00pm. This scheduling set-up permitted me to visit both schools within a day. On the few occasions when student interviews conflicted with my observation of the lesson of the target class, I observed the same lesson the teachers conducted with their second sixth grade class the following day.

I adopted primarily the role of non-participant observer (LeCompte & Preissle, 1993) to obtain detailed descriptions of participants' actions and verbalizations within the extant learning environment. From an unobtrusive position, I took down field jottings and recorded teachers' and students' actions and verbalizations during the lesson, and where possible, captured the emic perspective by recording participants' precise wording (Patton, 2002). Since the nature of the physical education class was dynamic, I focused my observations on salient events and interactions that informed my research questions. I observed the nine interviewees and their teacher but did not exclude other students from the observation process. I also recorded information obtained during informal conversations with students during the lessons and the teachers between the lessons. In order to ensure continuity of lesson development, when student interviews conflicted with lesson observations, I observed the physical education lessons conducted with another sixth grade class.

Field observation data management. As soon as possible after the lesson, I elaborated and typed the lesson observations and teacher informal interview information into full-field notes (LeCompte & Preissle, 1993). Detailed observations were important to enhance the validity and subsequent interpretation of the findings. I detailed my observations to the extent possible and documented my questions and reflections in a data column separate from the observational data column as recommended by Patton (2002). Where relevant, I incorporated the informal conversations held with the teachers and students during or after the class into my lesson descriptions. My goal was to obtain a thick data description to address the internal validity and external reliability of my design (LeCompte & Preissle, 1993). I saved each lesson observation (including associated reflective stems or memos) as files in both word document format and rich text file format to facilitate import into MAX QDA2.

Data Analysis

I utilized constant comparison (LeCompte & Preissle, 1993) and the levels of qualitative analysis (open, axial) identified by Strauss and Corbin (1998). To facilitate this process, I used MAX QDA2 qualitative software as a coding tool. This software permitted the creation of data categories, including dimensions and properties, enabling coding from all data sources into specific or multiple categories, and facilitated the development of additional hierarchical structures that facilitated axial coding. Once codes were developed, I printed and cut them out and manipulated them into patterns on an artists sketch pad to identify salient emerging themes.

Document Analysis

All written documents collected during this research were analyzed using content analysis (LeCompte & Preissle, 1993). School district physical education curriculum documents were read and specific concepts identified. Teacher unit plans, the *Fit for Life Teaching Manual* (Corbin & Lindsay, 2005), instructional posters, power point presentations, web-based instructional resources, science textbooks and Brain Pop instructional videos were compared with the school district documents for consistency. They also were analyzed to identify the particular concepts emphasized and document the nature of the instructional messages. Student products included their physical education fitness portfolios and science work sheets and text books. These documents were analyzed to identify the concepts that were both common to science and fitness and identify variables related to students' mental models.

Data from the document analyses during phase one were used to develop the first corresponding student instrument. Content analysis of teacher and student products during phase three followed the same content analysis process and were used to develop the second student instrument and teacher interview guides. Data were triangulated with other sources and used to support the properties of each interviewee's profile and the generic models.

Case Development: Constant Comparison and Open and Axial Coding

I used inductive analysis techniques to examine students' mental models at the individual student and across student level. The process occurred prior to, during, and after the instructional period. I then re-analyzed all sources to identify personal and contextual variables related to each student case.

Questionnaire analysis. I used open coding on the first questionnaire to analyze the data inductively from each class. I examined students' textual and visual responses to each question and compared responses across all questions to establish the range of students' responses. I developed a rubric that represented the patterns reflective of students' understandings of the target domain concepts. I then used the rubric(s) to develop a total score for each student. The initial questionnaire findings were used to select interviewees. I categorized each student's responses using the rubric into three categorical levels, low, middle, and high. Then I purposefully selected students from each level to obtain a sample of students that represented the range of abilities in each class as well as demographic and gender representativeness. I worked in consultation with the classroom teacher to finalize interviewee selection.

Interview and contextual data analysis. The interview data were merged with the questionnaire data to develop a rich picture of each student. I also triangulated interview data with students' portfolio entries and summarized them into a profile for each interviewee. Examinations of each interviewee's profiles permitted me to identify patterns within students' responses from which I inferred the generic mental models and underlying domain specific beliefs about the target concepts (Vosniadou, 1994). This process also enabled me to identify similarities and variations both within and across mental model groups. Because the first process in developing the generic models was an inductive subjective process, I conducted another analysis of each student at the model level to verify my categorization of students' into the respective model groups. I also conducted a check for the internal consistency of the primary characteristics of the generic mental models in relation to students' responses to the range of questions associated with the target concepts. After, I triangulated the findings with examinations of the context and learning opportunities from the field observations, teacher data, and document analysis. I used the thick descriptions of the learning environment, document content, and the teacher interview data to corroborate data sources and, where relevant, used these information sources to build further each generic mental model.

Trustworthiness and Transferability of the Research

Adopting an ethnographic research design within this multi-site case study affected the trustworthiness and transferability of my study. There were embedded validity and reliability threats related to my credibility as a researcher and the technical rigor of the design, data collection, and analysis. In this section, I used the recommendations by LeCompte and Preissle (1993) to identify and address some anticipated threats. These qualitative scholars noted that validity and reliability are overlapping constructs. In some instances, the adoption of pre-emptive strategies can minimize both validity and reliability concerns and ameliorate the trustworthiness and transferability of a study.

Validity

Accurate representation of participants' perspectives is critical to the validity of this study. LeCompte and Preissle (1993) explained that validity is concerned with the accuracy of findings and the extent to which researchers represent participants' realities. They distinguish two types of validity concerns that affect accuracy, researcher-as-instrument and procedural validity. Below I describe the design strategies adopted in the current study to address these issues.

Researcher-as-instrument. LeCompte and Preissle (1993) explained that as researchers gain entry into natural settings and access to participants' subjective worlds, their own identity, experiences, biases, and personality affect the natural ecology of the setting and their own perceptions and interpretations of that context. They advocated that researchers perceive themselves as additional key-informants involved in the ethnographic case study. To this end, in the methods section, I provided a description of my personal background, research interests, biases, and experiences/limitations, and roles and responsibilities in conducting this research.

Procedural validity. My role and experience as researcher also affected the procedural validity of the study in terms of my decisions regarding the selection of the sites, research design, participant, and data collection and analysis protocols. I provided a detailed explanation regarding the selection process and criteria used in this research. I substantiated my findings/interpretations through systematic data collection and analysis protocols that accurately represent the setting and participant perspectives

Internal Validity

Internal validity refers to the extent to which researchers accurately observe and interpret participants' perspectives. To strengthen the internal validity in my research design, I used multiple methods for eliciting students' mental models and purposefully triangulated data sources prior to, during, and after the instructional unit. In addition, I documented the learning environment and teachers' perspectives. Below I describe the strategies embedded in the current research design and data collection/analysis protocols to address the five internal validity threats identified by LeCompte and Preissle (1993): observer effects, history and maturation, spurious conclusions, selection effects, and mortality.

Observer effects. These effects relate to how the researcher's entry and presence in the setting disturb the natural environment such that participants behave atypically in the presence of the researcher. Additionally, observer effects relate to my own innate biases. Earlier in this section, I described my consciously held biases. I continued to be vigilant throughout the data collection and analysis to monitor my judgments and decisions for potential bias. Additionally, to minimize the power structures between interviewer and interviewee (Parker, 1984; Patton, 2002), I adopted a stance of empathic neutrality and avoided a judgmental stance during the one-on-one interviews. I spoke to students at their level and demonstrated a genuine interest in what they said. I also adopted the *stance of naïveté* (LeCompte & Preissle, 1993) with students and teachers and avoided any judgments during my informal and formal interactions with them.

History and maturation effects. History effects are unexpected events that occur during the instructional period that may affect students' learning, where as, maturation effects are physical, intellectual, and emotional changes that naturally occur within individuals over time and may affect their learning (Gay, Airaisan, & Miller, 2006). According to LeCompte & Preissle (1993), these threats are an internal validity concern in studies examining process and change of a particular phenomenon over time. The multi-site case study design could have permitted a comparison of student growth documenting any maturational effects across the sixth grade classes in different schools.

Spurious conclusion effects. These effects refer to the possibility that my conclusions as researcher may be flawed. Not withstanding how thoroughly an ethnographer accounts for internal validity threats, LeCompte and Preissle (1993) stressed that there always is a possibility that researchers' interpretations may not reflect participants' subjective realities. To reduce this possibility, I analyzed the data obtained both within and across data sources (methodological triangulation) to locate evidence to verify and validate my assertions and findings. I sought confirmatory and disconfirmatory evidence and subsequently developed awareness for bias or contamination sources that confound the patterns and themes that I perceive to emerge from the data. After transcribing students' and teachers' interviews I sought confirmation of the accuracy of the transcripts and after developing coding protocols/initial themes, I conducted member checks and peer review (as detailed in the internal reliability section below) to circumvent this threat.

Selection effects. These effects refer to distortions in the data caused by the researchers' criterion-selection protocols to identify sites and participants (LeCompte &

Preissle, 1993). I established explicit rubrics to select participants across the range of abilities in the class, in parallel with the methodological guidelines articulated by conceptual change scholars. In the final report, I detailed students as a unique case or group of cases. Selection effects also relate to the selection of the learning context. I described in detail the selection process used in this research in the final reports (Chapters 4 and 5). I described the learning settings using thick descriptions (LeCompte & Preissle, 1993) to examine the influence of context variables on the development of students' mental models.

Mortality effects. These effects occur when individuals drop out of a study and modify the composition of a group in ways that jeopardize the continuation of the research (Gay et al., 2006). LeCompte and Preissle (1993) clarified that ethnographic case studies "preclude the interchangeability of human informants and participants" (p. 346). Researchers address this threat by selecting multiple sites and participants and attending carefully to baseline data. I did not face this threat in this study. However, had it occurred, I would first determine the severity of this effect. For example, the loss of an interviewee would be more severe than the loss of a non-interviewee. Second, by selecting and collecting a full data set on a few more students than might otherwise be necessary, the research will not be as negatively affected by the loss of one or two students. Third, while acknowledging that I could not exactly "replace" a student, having obtained the baseline knowledge of all students had a student dropped out early during the study, I would have had time during the instructional period to select another pupil of "similar" conceptual level for the second interview. Additionally, if such a replacement occurred early during the instructional period, I could incorporate this new student within focused lesson observations. Then to examine his/her profile, I would have used the first questionnaire data and scrutinized field notes for vignettes that depicted his/her involvement in the lesson.

External Validity

External validity is concerned with the applicability of the findings of my study in other contexts. LeCompte and Preissle (1993) describe *comparability* as the ability to provide sufficient detail such that other researchers can compare the results to those found in other contexts. In my final report, I defined the constructs and terms and provided descriptive details of the settings, participants, and methods used for data collection and analysis. These strategies also addressed threats to external reliability.

LeCompte and Preissle (1993) use the term *translatability* to define the extent to which researchers use theoretical frameworks and research methodologies that are familiar to other researchers. In Chapter 2, I described in detail the conceptual change approach that formed the basis of this study. This was necessary because conceptual change as a process of mental modeling has not been applied extensively in physical education. Furthermore, bearing in mind that several qualitative experts have defined qualitative methodologies differently, I specified the references used when describing methods so that readers could understand the qualitative protocol and philosophy that underpinned my study.

Both comparability and translatability are necessary for the usefulness and applicability of my findings to different sites and disciplinary domains. My decision to conduct a multi-site case study design increased the opportunity to study students' mental models in diverse settings and with different participants. I used criterion-based selection procedures to select the schools and participants. Although sites were similar on some criteria, each site was unique because sites and participants were different and teachers were teaching different sports based units in the middle school physical education curriculum.

Reliability

LeCompte and Preissle (1993) explained that reliability is concerned with the replicability of scientific findings and is dependent on internal and external research design factors that can be replicated by other scholars to obtain the same results (p. 331). They noted that no scholar could wholly achieve reliability in an ethnographic case study because each study comprises unique settings, time-periods, and participants that cannot be recreated by others. Instead, they discuss strategies researchers can utilize to address reliability at an internal and external level.

Internal Reliability

Internal reliability refers to the degree to which the instruments and analysis are reliable in reflecting participants' perspectives. LeCompte and Preissle (1993) suggested researchers should conduct member checks and peer review to ameliorate research reliability. In this study I sought clarification of the interview transcripts from some students during ensuing lessons. Additionally, I conducted member checks with the teachers and asked them to review transcriptions of their interview data and sought clarifications to detail my descriptions of their lessons. I asked them to assess the extent to which I had captured their views reliably and interpreted the events observed during the lesson correctly. Further, I sought the assistance of an external expert-peer reviewer to control for my bias in interpreting data or analytic themes. I asked the reviewer to read data segments and themes and discuss differences with me. Through these strategies, I was able to assess the reliability of my interpretations and minimized biased conjectures.

External Reliability

External reliability refers to the degree to which other scholars can replicate my study in other settings, identify the same constructs, and reach similar conclusions (LeCompte & Preissle, 1993). In my final report, I increased the external reliability of my study by describing in detail five aspects of this study (a) my position at each site, (b) the criteria I used for selecting sites and participants, (c) the specific contexts in which I collected the data, (d) the definitions and constructs I used in the study, and (e) the methods and protocols I used for data collection, reduction, and analysis.

As elaborated earlier in this chapter, I sought sites where physical education teachers emphasized students' conceptual learning of fitness domain concepts. In the final report, I specified, for example, whether I obtained data from a physical education teacher during an informal conversation or the formal, one-on-one teacher interview. I described all the operational definitions central to this research (see chapter 2) and described sensitizing concepts that emerged though the data collection process. I also detailed the protocols used for each method (e.g., jottings in situ and full-field notes completed post hoc) and explained the steps taken during systematic data analysis. Addressing these five issues were central to my research design and consistent with strategies described to address validity concerns.

CHAPTER 4

SIXTH-GRADE STUDENTS' MENTAL MODELS OF EXERCISE INDUCED PHYSIOLOGICAL CHANGES.

Examining learning as a process of mental model building has potential to provide insight in the conceptual changes students experience during the learning process, and hence, inform instructional design that is sensitive to the way children think and learn (Greca & Moreira, 2001; Vosniadou, 1991). *Mental models* are domain-specific knowledge structures learners use to build their idiosyncratic conceptions and understand phenomena in a specific academic domain. As the mechanisms underlying conceptual change, mental model building describes a process through which learners enrich and restructure their existing conceptions as they move from novice towards principled conceptualizations of a domain. Current perspectives on mental modeling assume that learners' underlying *beliefs about knowledge* are intertwined with their *knowledge,* and hence, can facilitate or constrain mental model development (Alexander, 2006; Vosniadou, 2002).

Examining students' *mental models* permits researchers to gain insight into how students are constructing their conceptual understandings and organizing their knowledge and beliefs about specific concepts. One goal of this research is to assist students to enrich and restructure their existing conceptions to parallel scientifically accepted views (Vosniadou, 1991). Scholars have examined students' mental models on a variety of physical and chemical science topics (e.g., Chiu & Lin, 2005; Vosniadou, 1994). However, they have focused less intently on students' mental models of biological phenomenon (e.g., Venville, 2004). Chi, Chiu, and DeLeeuw (1991) and Teixeria (2000) in particular noted that research on topics related to the human body is limited.

The significance of examining students' human biological conceptions lies in the fact that it can reveal how students are constructing their knowledge about their body and how it functions. Thus far, scholars have primarily examined students' mental models of one body system in detail (Chi, deLeeuw, Chiu, & LaVancher, 1994; Teixeira, 2000; Tunnicliffe, 2004) whereas others have examined an overview of human body organ systems (Reiss & Tunnicliffe, 2001). Their findings suggest learners have little awareness for the anatomical and physiological complexity of the human body (Reiss & Tunnincliffe, 2001; Rowlands, 2004). Grounded in initial approaches to model building these scholars have not yet examined how both epistemic and ontological beliefs about knowledge influence students' developing mental models of human-body related phenomenon.

Framework Theory of Conceptual Change (FTCC) is a hypothesis that describes how learners' ontological and epistemic beliefs about knowledge enhance or limit mental model development and the conceptual change process. Scholars have increasingly applied this theory to examine student learning in the physical sciences (e.g., Chiu & Lin, 2005; Mazens & Lautry, 2003), biology (e.g., Venville, 2004) and other domains (e.g., Greca & Moreira, 2001). However, it has not yet been applied to examinations of human biology concepts. The purpose of the current study was to apply FTCC within the area of human biology to an examination of students' mental models of exercise-induced physiological changes. The research questions guiding this study were: How do sixth-grade students develop their understanding of physiological adaptations to exercise?

What is the nature of their underlying epistemic and ontological beliefs associated with exercise induced physiological adaptations?

Contemporary Approaches to Conceptual Learning

Scholars recognize that cognitive learning involves a domain-specific process of conceptual change (Vosniadou, 2007a). Conceptual change denotes the learning pathways learners follow as they move from novice toward more sophisticate conceptualizations of a specific domain (Duit &Treagust, 2003). It is a knowledge construction process whereby learners' gradually and continuously enrich and restructure their existing conceptions are as they seek to integrate new information (Alexander, 2006; Vosniadou, 2007a). As learners create idiosyncratic conceptions to understand phenomenon, they may also develop naïve conceptions that contain some knowledge misrepresentation (Vosniadou, 1991). Rather than regarding less sophisticated conceptions as unilaterally negative, some scholars recognize that naïve conceptions act as "scaffolds that support the construction of all future learning" (Alexander, 1996, p. 89). Current research perspectives recognize that conceptual change involves changes in learners' knowledge and beliefs and the significant role beliefs about knowledge play in conception development (Alexander, 2006; Vosniadou, 2002). I first review beliefs about knowledge and then describe the Framework Theory of Conceptual Change (Vosniadou, 1994; 2007b) that articulates how beliefs about knowledge mediate the mechanisms involved in conception development.

Beliefs about Knowledge

Alexander (2006) summarized that *beliefs about knowledge in a domain* comprise learners' assumptions or perceptions about knowledge of specific concepts and are intertwined with that knowledge. Murphy and Mason (2006) explained these beliefs reflect all that learners accept to be true without the need for external verification assumed with domain knowledge. Further, learners generally attribute a valence of importance to beliefs and hold to them even when confronted with more scientifically correct externally verified knowledge.

Scholars (Buehl & Alexander, 2001; Hofer, 2000; Vosniadou, 2007b) discriminate beliefs about knowledge into kinds. *Ontological beliefs* reflect learners' perceptions about the categories and properties of specific phenomenon in the world. *Epistemic beliefs* relate to how individuals perceive the process of knowledge development and the nature of knowledge; they include several dimensions such as *justification of knowledge* (e.g., causal explanations) and *source of authority* (e.g., self vs. external) dimensions. According to Vosniadou (1994), both ontological and epistemic beliefs play powerful roles in conceptual change because they mediate the organization of the mental mechanisms involved in knowledge development.

Scholars have sought to hypothesize the mechanisms that underlie naïve conception development and modification (e.g., Chi et al., 1994; Vosniadou, 1994). Recently, Greca and Moreira (2001) noted that the Framework Theory for Conceptual Change (Vosniadou, 1994) offers powerful theoretical constructs and methodological recommendations to examine and describe conceptual change. Indeed, FTTC can guide research and thought on conception development in various domains such as science and mathematics (e.g., Venville, 2004).

Framework Theory for Conceptual Change

FTCC developed through a series of empirical studies conducted by Vosniadou and her colleagues (1994; Vosniadou & Brewer, 1994) to examine students' mental models of several physical science concepts (e.g., force, the shape of earth, day/night cycle, and heat). Vosniadou (2002) emphasized the complex nature of learners' conceptions, theorizing they comprise a coherent multi-component system that integrates their knowledge, beliefs about knowledge, perceptions, and mental models. Vosniadou (2007c) explained that FTCC has potential to describe how individual cognitive, social, and contextual variable influence learners' mental models and beliefs about knowledge.

Mental models. Vosniadou (1994) characterizes learning as an active process in which dynamic, evolving mental models denote the mechanisms fundamental to mediating conceptual change. Mental models are recursive domain-specific knowledge structures that learners create and use to think, reason, and represent their knowledge about the world. She hypothesized that learners "create them [mental models] on the spot to deal with the new demands of specific problem solving tasks" (p. 48) and either store or retrieve mental models from long-term memory. Vosniadou (2007c) emphasized the ability to generate mental models is a basic characteristic of the human cognitive system and children from a young age utilize them to build and revise their conceptions of particular phenomenon. Within FTCC, mental models originate from three sources; individuals' perceptions, social interactions, and social-contextual experiences.

Vosniadou (1991) theorized mental models exist in three forms that depict an emerging learning continuum. Learners transition from intuitive to scientific mental models through a series of intermediary synthetic models. Intuitive models develop during infancy from children's direct experiences in the cultural context. Synthetic models develop during the instructional years and reflect learners' creative, coherent, active, but sometime ineffective, attempts to reconcile scientific information within their existing models. When scientific information is not directly observable or is counter-intuitive to students' direct experience, students unconsciously distort or misrepresent it as they try to internalize the new information either without revising or only partially revising their existing ontological and epistemic beliefs. Students are unaware of their tacit beliefs and the fact that their mental models, although internally coherent, may be distorted and not externally coherent with accepted scientific views. Scientific models develop when learners modify their existing mental models such that they parallel the accepted scientific perspectives and hence become both internally and externally coherent knowledge structures. Mental model development is influenced by epistemic and ontological belief shifts within learner's naïve theories about the domain.

Naive theories. According to Vosniadou epistemic and ontological beliefs about a particular topic develop during learners' instructional and cultural experiences and can promote or limit transitions in learners' mental models. These beliefs are not static but rather can change and evolve as learners learn to adapt to social and contextual life influences (1991; 2007). Vosniadou (1994) theorized that these beliefs coalesce to form two types of naïve theories, global and specific, that are hierarchically organized to form the coherent frameworks that embed learners' perceptions and knowledge. Global theories comprise ontological and epistemic beliefs about the domain that learners unconsciously develop during their early experiences in the lay culture. They affect the organization of both learners' specific theories and mental models. Specific theories comprise an interplay of ontological and epistemic beliefs that derive from their global theories and perceptual (e.g., object falls to the ground) and observational information (e.g., gravity is a force that pulls objects down to the ground) received within the existing socio-cultural context. They represent the explanations students use to describe a particular phenomenon within a domain (e.g., the concept of gravity) and directly facilitate or limit the development of learners' mental models. Unlike other perspectives on conceptual change, Vosniadou (1994; 2002) suggested that the enrichment and restructuring of learners' conceptions occur at the belief level (within their global and specific theories) rather than at the mental model level. Modifications in the organization of either or both naïve theories influence mental modeling because both may be involved in shaping students' mental models during the learning process.

Methodology recommendations. Vosniadou and her colleagues (e.g., 1994; Vosniadou & Brewer, 1994) provided methodological guidelines to examine students' mental models. Since naïve theories influence mental models, students' ontological and epistemic beliefs can be inferred from an examination of students' mental models. Qualitative methodologies involving the one-on-one interview method with a range of open-ended questions combined with various elicitation tasks (e.g., drawings, play dough) are recommended as particularly effective in helping students externalize their mental models. They also delineated procedures to facilitate the inductive inference of "generic" model features, emphasizing the need to code student data individually, across students, and also at the model level. Further, Vosniadou, Ionnides, Dimitrakopouou, & Papademetrios (2001) recommended that researchers document the learning context in which students' mental models develop to gain insight into sources that may influence students' developing mental models.

Summary

Vosniadou and her colleagues (1991;1994; Vosniadou et al., 2001) suggested that knowledge development is cumulative process. In FTCC they theorized that students' initial conceptions (intuitive and synthetic) evolve from simple to complex. Additionally, they maintained knowledge growth is influenced by learners' academic beliefs (ontological and epistemic) and the setting and richness of the learning environment in which students learn. Scholars have not yet applied FTCC to examine complex relationships among biological systems. Current studies of human biological concepts have been limited to examinations of children's conceptualizations of one body system with the body at rest (daily functioning). They did not examine students' integrated knowledge and beliefs nor did they document how the contextual influences mediated the development of students' developing conceptions. The purpose of the current study was to apply FTCC to a contextualized examination of students' perceptions, knowledge, and beliefs about various body systems as they adapt in response to physical exercise.

Methods

Research Design

I conducted a descriptive study using a qualitative, multi-site case study design (LeCompte & Preissle, 1993) to examine students' mental models of exercise induced physiological changes. I examined student learning during physical education classes because health-science concepts were an integral part of the fitness curriculum and were taught concurrently with human biology concepts in the regular science education class.

Because students were physically active throughout the physical education class, stressing body systems in response to exercise in physical education, I assumed they experienced the physiological changes that occurred in their bodies in a way that was concrete and real to them.

Setting and Participants

I conducted this research in an affluent sub-urban school district in the United States with a student enrollment of 41,000 (~72% Caucasian, 12% African American, 8% Hispanic, and 4.6% Asian/Pacific/Native American). Teachers were highly qualified and students consistently surpassed state and nationwide test averages in reading and mathematics. The school district physical education curriculum emphasized the need for students to be physically fit and learn cognitive concepts (including health-science concepts) necessary to make decisions and solve problems associated with personal health and fitness.

Beech and Oak Middle Schools (pseudonyms) with student enrollments of 762 and 554, respectively, served as the sites for this study. I selected these schools because the physical education supervisor had recommended an exceptional teacher at each site who emphasized cognitive concept teaching. Additionally, school policies allocated adequate instructional time for physical education, with lessons scheduled in 90-minute blocks, two times each week and every other Friday. The physical education program at both schools consisted of personal fitness units and sport based units with fitness and health-science content integrated with the sport content. Two sport-based units were the focus of the observations in this research.

This study was conducted with two sixth-grade (11-12 year olds) classes, one at each school. I selected this age group because I assumed students would be able to articulate their conceptions of body system functioning more clearly than younger students Further, I assumed an examination of sixth grade students' conceptions constituted the prior knowledge foundational to seventh grade and beyond. The 18 student interviewees were a representative sample of nine students from each class. They were selected after the preliminary analysis of students' responses on the first questionnaire (described in the next section). All students approached gave assent and returned signed parental permission forms.

Adult key informants included one science teacher, Sandy, at Beech Middle School and two physical education teachers, Sue and Pam, who taught at Beech and Oak Middle Schools, respectively. All three teachers were active professionals, holding masters degrees with 9, 28, and 18 years of teaching experience, respectively. All teachers provided informed consent to participate in this study.

Data Collection

I collected data for this research between April and June 2008. I used a combination of qualitative techniques to elicit students' mental models through questionnaires and interviews that I field tested prior to administration with students in different classes. Examples of the instruments are presented in the dissertation appendix (p. 271). I also collected instructional documents, and completed field observations and teacher interviews to develop a contextualized understanding of the learning environment in which students' mental models developed (Patton, 2002).

Student questionnaires. I administered two 15 min-questionnaires before and after instruction. They served as pre-interview tasks and were administered to students in each class during their regular physical education lessons. I administered the first questionnaire in early April to obtain baseline data to examine students' beliefs about the nature of fitness and their knowledge about fitness concepts (e.g., cardiovascular endurance). It comprised primarily open-ended questions that permitted students to write and draw their responses. I used the questionnaire responses to examine the range of responses in each class, identify the representative sample of nine student interviewees from each class, and generate questions during the first follow-up interview.

I administered the second questionnaire to each class in early June following the instructional unit. The purpose of the second questionnaire was to examine the range of responses by all students in each class regarding their understandings of physiological indicators associated with moderate to vigorous exercise and their ability to apply concepts to practical applications of exercise intensity within the basketball unit and the track and field unit at Beech and Oak Middle Schools, respectively. Again, I used the questionnaire responses of the selected interviewee's to create probing questions on the second follow-up interview.

Student interviews. I conducted 30-min., one-on-one, formal interviews with the 18 students following the administration of questionnaires in April and June. The purpose of the interviews was to elicit students' knowledge and beliefs about fitness concepts and the effects of exercise on the human body in more depth than possible through the sole use of the questionnaire. A semi-structured format enabled me to ask the same questions to each student and permitted the flexibility to create probing questions specific to each student and learning environment. During both interviews, I also asked students to identify their knowledge sources (e.g., Where did you learn this? or How did you learn this?) to identify the contexts that shaped their conceptualizations.

In addition to verbal elicitation, the interview guide included visual and behavioral elicitation techniques. During the first interview, for example, I used picture cards (Placek et al., 2001) depicting people performing various physical activities (e.g., swimming, lifting weights) to probe for students' understandings of fitness components. Additionally, I asked students to demonstrate how to locate their pulse and compute their heart rate as they explained how to check activity intensity.

The purpose of the second interview was to elicit students' explanations about the effects of exercise intensity on the human body. I asked students to describe and demonstrate how pairs of muscles worked (e.g., when performing the bicep curl) and to draw and explain the physiological changes they experienced when participating in aerobic activities (e.g., mile run). All student interviews were audio taped and transcribed. I sought informal clarification from some students' during ensuing lessons to seek additional clarification and ensure accuracy of the interview transcripts.

Document collection. I examined four types of documents associated with students' conceptual development of fitness knowledge using content analysis (LeCompte & Preissle, 1993). First, I analyzed the district's physical education and science curricula to determine the concepts presented and the processes recommended to facilitate student learning. Within this step, I also reviewed the content presented in science textbooks, supplemental video clips, and the resources that science and physical education teachers used to complement instruction. Finally, I examined students' physical education portfolios and science workbooks to provide additional information regarding students' conceptions.

Field observations. I documented the nature of the physical education lessons for four weeks, observing 12 lessons at each school. I observed mostly as a non-participant, writing field note descriptions after each observation (Patton, 2000). I paid special attention to the teacher's content delivery and students' responses and actions. Where possible, I informally interviewed students (e.g., why did your teacher ask you to measure your pulse?) and teachers (e.g., why are the students using heart rate monitors today?) and incorporated data thus obtained within the lesson descriptions that were reconstructed after class.

Teacher interviews. I conducted one 90-min. interview in mid-June with each physical education teacher using a semi-structured format, involving open-ended questions to examine teachers' perceptions of students' learning and rationales for strategies used during the lessons. Although my original research design did not involve interviewing science teachers, during the course of the first student interview many students indicated their science class was another source of information they tapped to understand physiological changes. Hence, given the emerging nature of this study, I sought permission and interviewed Sandy (the science teacher) using a semi-structured format to learn how she explained the effects of exercise on the human body and body systems in science. All teacher interviews were audio taped, transcribed, and reviewed by the teachers for accuracy.

Data Analysis and Trustworthiness

The preliminary analysis of the first questionnaire was conducted to identify interviewees across the range of cognitive ability in the class. Previous research by Venville (2004) had recommended the purposeful selection of students with a range of ideas. Therefore, I examined students' responses to the fitness concepts and developed a rubric organizing them into three groups from which I then purposefully selected three students to represent the high, middle, and low range of cognitive understandings associated with fitness and health-science concepts. I sought confirmation from the physical education teacher that the nine students selected were representative of the class and would be willing to verbalize their ideas

Following the first interview, I analyzed the students' responses as unique cases and then analyzed the data across students to identify "generic mental models" (Vosniadou, 1994, p. 48) they used to explain a range of questions associated with exercise induced physiological changes. This involved an ongoing multi-level analysis process that first used open codes (Strauss & Corbin, 1998) to categorize students' verbatim responses and then triangulated data from the questionnaires, interviews (including descriptions of their actions), and drawings. I followed this process for each student as a case, re-organizing the data across the students as I began to note similarities and differences in their responses to emerging categories. This initial coding process helped me understand that students had varying conceptualizations to explain and describe their body and associated physiological changes. I inferred students' beliefs through the careful analysis of words and phrases they used to describe their conceptions about the human body's physiological changes, structure, and function.

I next conducted a second round of analyses using axial coding procedures

(Strauss & Corbin, 1998) to identify the characteristics that defined variations in student conceptualizations across students (e.g., site of oxygen need). This led me to identify unique features defining five generic mental models held by these students. Ongoing inductive analysis sensitized me to variations in other mental models students' held embedded within the generic models of exercise induced physiological changes that were somewhat similar to findings that emerged in previous research (e.g., body organ organization Reiss & Tunnincliffe, 2001; blood pathways Chi et al., 1994; and chemical awareness Rowlands, 2004). Hence, I conducted a second literature review which informed the ensuing axial coding process. Since the first attempt to define the generic mental models was conducted as an emerging subjective process, I then re-analyzed each student at model level (Chi, deLeeuw, Chiu, & LaVancher, 1994; Vosniadou & Brewer, 1994) to verify that they demonstrated the major characteristics of the generic mental model I had defined. This process served as a validity check, and I sought both supporting and disconfirming examples in students' responses across the triangulation of student data sources, teacher data, and contextual data.

Results

The purpose of this research was to examine students' mental models of the human body's physiological adaptations to physical exercise from the perspective of the Framework Theory of Conceptual Change (FTCC) (Vosniadou, 1994). I inferred five mental models students used to explain how the body adapted to exercise. In this section, I first elaborate students' opportunities to learn about the physiological changes associated with exercise in their schools. Next, I describe two beliefs students held within their naïve global and specific theories that undergird the mental models inferred. Finally, I describe the five mental models to illustrate how students organized their conceptual knowledge systems differently.

Learning about Physiological Adaptations to Exercise.

Contextual and interview data revealed that all sixth-grade students at Beech and Oak Middle Schools had many opportunities to learn about the physiological effects of exercise during their physical education and science education classes. During physical education, for example, students were involved in a variety of aerobic activities to develop their cardiovascular endurance (e.g., running the mile, cycling, and rowing). Pam explained:

> These [aerobic] activities are exercises in which they typically use the large muscle groups of the body for a stretch of time…they increase the need for oxygen, overloading the heart and lungs, causing them to work harder just so that they can keep on exercising.

Consistent with the district curriculum, both teachers stressed students' physical participation and cognitive understanding associated with the effects of exercise on the human body. They used various instructional strategies and educational resources (e.g., posters, power point presentations, heart rate monitors, pedometers) to help students experience and examine the effect of exercise on their bodies. During the basketball unit, for instance, Sue frequently asked her students to "take a pulse check." Students measured their heart beat manually by feeling for a pulse at their carotid artery at the neck or radial artery at the wrist. She then asked them to compute the heart rate in beats per minute and check whether they were exercising at an appropriate intensity level. During the track and field unit, Pam used technological resources and provided her students with heart rate monitors to measure their heartbeat variations and pedometers to measure the number of steps taken throughout an entire class.

Students at both schools also completed written assignments during physical education. For example, they used their pedometers to record data to examine the relationship between the number of steps taken and the number of calories consumed. When the researcher asked how such instructional tasks helped students understand the effects of exercise, Ian, a sixth-grade student explained:

> It's because I can really feel these things happen to my body in physical education. I can really feel my muscles working. I feel my heart pumping faster. When I read it [heart rate] off the heart rate monitor, the numbers tell me how fast my heart was working and pumping to get the oxygen to the muscle so that they can work harder.

He further explained:

> Now that I'm at the end of sixth grade, I understand things better about what's happening inside my body and why my body is trying to get more oxygen, because I can connect what I get in my science and my physical education class.

Beliefs about Knowledge

Students' naïve human biology theories seemed associated with their need to attribute causal explanations (epistemic belief) and infer internal mechanisms (ontological belief) that explained the physiological changes they experienced during exercise. These beliefs represented major themes common within students' global and specific theories across the five mental models identified.

Justification of Knowledge Epistemic Belief: A Cause-Effect process. Vosniadou (1994) explained that students' use of causal explanations reflects an epistemic belief related to the justification of knowledge. All students' responses reflected the belief that physical exercise has a cause-effect on the physiological functioning of the human body. Many believed this cause-effect relationship existed between "exercise" and the "human body" and some also noted it could also occur between different body systems (e.g., skeletal and muscular systems). For example, Ray explained:

> Things in your body are connected and complex, like a cause and effect, or an action–reaction. When you are running, you are moving more, so your muscles need to work harder. So your body needs more oxygen. So then your heart is pumping more, you're breathing more, and more oxygen goes to your muscle. If your muscles move a certain way, then your bones will move according to that, because muscles contract and pull on bones. And that's how you can bend your arms and legs. So exercise is like that, a cause-effect type of thing.

However, I noted variations in students' explanations of the cause-effect process. They perceived it as either a linear chain of events, concurrent parallel events, or concurrent but integrated events. I detail these variations in their specific theories when I discuss the respective mental models.

Ontological Belief: A Human Machine. Students held the ontological belief that the human body functioned as a machine that worked harder during exercise as compared to daily functioning. Yana explained "when you are exercising, you are working with your heart and lungs even harder than you usually do." They consistently used mechanical work-related phrases such as muscles *work* faster by *pulling* on bones and the heart *pumps* faster when explaining how organs or body systems functioned during exercise. Others also used analogies (e.g., car and train) depicting the human body as a machine that heats up during exercise. For example, Jim explained:

> It is like a car. As it moves around a lot, [the car] starts to work harder, heat up, and gets hot. So as you start to move around and your muscles move around a lot, you start to heat up and get hot and sweat because your heart and muscles are working harder.

In order to meet the increased physical demands of the body during exercise, all students indicated that the human body required an increased supply of two resources: oxygen and energy. Some students demonstrated awareness that the human body machine had to remove an increased accumulation of waste products.

An increased need for oxygen. All students explained exercise caused the body to experience an increased need for a supply of oxygen to function effectively. For example, Liam explained “when you’re moving, you’re really trying to get a lot of oxygen in your body. That’s the top priority.” Students’ explained in diverse ways the structure of the human body and how it functioned to meet increased oxygen needs. I elaborate on these variations when I describe the respective mental models. Some students explained that *isolated body organs* such as the heart [e.g., Jim] or lungs [e.g., Linda] played a role in enabling the body to meet the increased need for oxygen. In contrast, others noted that organs were connected into various *body systems* that worked in synchrony to deliver oxygen and nutrients to the muscles. For example, Emma explained:

> Your cells *have* to maintain a certain level of oxygen! And when you’re running, your body needs *even more* oxygen. The circulatory system and other systems

> work inside to keep us moving. It is kind of hard to process it all together to understand how exercise makes different body systems work even more, to try to get a lot more oxygen and glucose to your muscles. It seems like it's happening all so fast!

Energy requirements. The majority of the students indicated that the human body utilized oxygen and nutrients as energy resources during exercise. Sally explained "nutrients and oxygen are like the energy your muscles need. They can't work without them." Similarly, Ray explained:

> The body gives the energy to the muscles, because the muscles… they can't give themselves food like plants can do with photosynthesis. So they need the energy from the body and they get that from the oxygen and food calories, and then you burn them.

The above extract revealed that students believed "power comes from eating food' (Inagaki & Hatano, 2006, p.178) and demonstrated "personifying tendencies" (Inagaki & Hatano, 2006, p. 178) in their attempts to explain how the human body components behaved and how processes occurred.

Waste production. Some students explained that the human body had to remove an accumulation of waste products. They explained muscles produced more wastes during exercise such as "carbon dioxide they give to the lungs to breathe out" [Yana]. Others noted that "urea and salt that come out in the sweat because your body is trying to get rid of them" [Sally].

In summary, it appeared all interviewees shared these belief themes within their global and specific theories associated with the exercising human machine. They explained the effect of exercise on the human body as a cause-effect process (epistemic). Further, during exercise the human machine (ontological belief) functioned harder, faster, required more oxygen and energy, and produced more wastes.

Mental Models of Exercising Human Bodies

Although students experienced similar responses to exercise (e.g., when I run my heart beats faster) were exposed to similar information (e.g., the heart is both a muscle and organ), and shared some beliefs about knowledge, they seemed to organize their mental models differently. In examining the different mental models, I inferred underlying diverse specific theory configurations and noted that students organized their perceptions, knowledge, and beliefs about the human body and exercise induced physiological changes differently on some aspects and similarly on others.

I present the mental models as an increasingly complex continuum of understanding about body organ/system adaptations to exercise. Each model represents a specific point on a learning continuum that is not necessarily linear in nature with each model evolving recursively one into the next. They simply illustrate snap shot descriptions of knowledge development associated with these 18 students' understanding of exercise induced physiological changes. I present data from a few students within each group who exemplified the characteristics of the respective models. It was not my goal to make students "fit" into a "generic" model. They are unique individuals following their own unique learning pathways. Where relevant I try to illustrate their unique variations in understandings within a generic model group.

The characterization of each mental model reflects a focus on variations in students' organization of their shared epistemic and ontological beliefs, perceptions, and knowledge about the human body. I based the development of each generic mental model on three criteria that emerged during the analysis process in regard to students' assumptions about the: (a) site of oxygen need, (i.e., which body component students' assumed needed oxygen), (b) the manner in which the cause-effect process occurred within the human body; including students' perceptions of how the human body was structure and functioned to deliver oxygen to reach the target site of need, and (c) process in which the body muscles met energy requirements.

To facilitate my description, I assigned a title to each model. The first part of the title denoted students' epistemic belief about *how* the cause-effect process occurred; that is, whether they assumed it was a sequential (MM1), parallel (MM2), or integrated (MM3, MM4, and MM5) process. The second part of the title following the colon denoted students' ontological belief about the human body structure and function to meet the increased need for oxygen during exercise. I first describe MM1, MM2, and MM3 models respectively. Then I review together the similar features of MM4 and MM5 together, followed by a description of their contrasts.

Sequential Process: Independent Organs Model (MM1)

Defining features. Students I categorized within MM1 (n=3) perceived the heart was the site of oxygen need. They explained independent body organs were involved in a sequential chain of events to meet the increased need for oxygen during exercise. Muscles obtained energy through body movements and food.

Site of oxygen need. Karl, Sandra, and Jim perceived that the *heart* was the target site of oxygen need during exercise. Each explained that their heart rate and breathing rate increased during exercise. The following extract from Karl's interview illustrated this model:

> The heart has to work harder when the body is moving because the body is not getting enough oxygen. When the heart pumps faster, then, you breathe faster to get more oxygen going to your heart. And then, when the heart gets the oxygen, your muscles can work harder and you can bend and move to run.

Hence, MM1 students seemed to assume an increased heart rate *led* to an increased breathing rate. I inferred this suggested they believed the process involved a sequential chain of cause-effect events, where an effect became the ensuing causal agent.

Human body structure and functioning. These students perceived the human machine comprised body organs that were not connected to each other. I noted in their explanations and drawings the absence of a transport system between organs. Even though they indicated that oxygen moved from the lungs to the heart and that muscles obtained nutrients from food, they were unable to explain how these sources reached the heart/muscles respectively using any medium (e.g., blood) or pathway (e.g., blood vessels). They depicted the human heart as a valentine' heart and described muscles as having "the shape of the arms and legs" [Jim].

Meeting energy requirements. MM1 students identified two resources muscles used as energy to work harder, physical movement and food. Karl explained:

> Your muscles get the energy when you are bending your arms and your legs when you are moving …also ingredients from the food you eat. Because if you don't eat then you don't have enough energy to work your muscles [belief that power comes from food].

Parallel Process: Independent Organs Model (MM2)

Defining features. The defining features of this model are three fold. Students I categorized within this model (n=3) perceived the muscles were the site of oxygen need. Independent body organs that used separate one-way transport systems functioned concurrently as parallel events to meet the increased need for oxygen during exercise. Muscles used oxygen and food as energy resources.

Site of oxygen need. Victor, Linda, and Suzi perceived that the *muscles* were the target sites of oxygen need. Each explained that exercise caused a simultaneous increase in heart rate and breathing rate, enhancing the body's efficiency in delivering oxygen to the muscles. Their explanations revealed the belief that exercise led to a concurrent, yet parallel, chain of events to meet the increased need for oxygen through a process involving independent body organs that utilized separate one-way transport systems. Victor's explanation illustrates this model:

> When you're exercising you're hyperventilating to get the oxygen going quicker to your muscles so that they don't get cramps and they can work longer. You breathe in the oxygen and the lungs kind of transport it to the muscles using the blood. At the same time, your heart is pumping more to move the blood faster to your muscles and so your heart rate is up too. Because your muscles need both [oxygen and blood] quickly.

Human body structure and functioning. MM2 students believed the heart and lungs were carrying out separate and distinct roles. The cause-effect process entailed the concurrent functioning of two unrelated processes (hence my use of the term parallel to describe this model) associated with the heart and lungs, respectively. The students ascribed one function to the heart, to pump blood faster to the muscles. Interestingly, they credited the lungs with three functions, to take in the oxygen, oxygenate the blood, and pump the oxygenated blood directly to the muscles.

Distinct from MM1 students, MM2 students demonstrated awareness of a transport system within the human body. Their use of the terms “blood stream” [Suzi] and “blood” [Victor] demonstrated their awareness of a transport medium between the organs and muscles. However, they believed blood followed a one-way pathway from the heart and muscles and from the lungs and muscles, respectively. Interestingly, even though they talked about a transport system there was (a) no awareness of a return flow of blood from the muscles to either the heart or lungs, (b) no transport system between the heart and lungs, and (c) no explanation that described how food entered the blood vessels from the digestive system. In response to the researchers’ follow-up inquiry as to whether there was a connection between the heart and lungs, the three students indicated, “I don’t think so” (Linda) and “No” (Victor and Suzi). Figure 3 represents students’ drawings that depict the one-way parallel blood pathway and the disconnect between the heart and lungs. Evidence for the disconnect between the heart and lungs was also revealed in students’ written definitions of cardiovascular endurance on the first questionnaire: for example, Victor’s entry was “the ability of the heart to pump faster and get stronger; he made no mention of the significant role lungs play in cardiovascular endurance development.

[Insert Figure 3 about here]

Meeting energy requirements. Similar to MM1 students, MM2 students indicated muscles used food as a source of energy. For example, Victor explained “calories [from food] are like your energy to burn." In addition, however, they believed oxygen itself was another energy resource muscles utilized. For example, Suzi explained, "when you're being active, your muscles are getting more energy from the food… and the oxygen is like your secondary energy that they use so that they can keep going."

Summary of MM1 and MM2 and Introduction to MM3, MM4, and MM5.

Albeit simpler in comparison to the next models, the consistency in MM1 and MM2 students' responses reflected that the internally coherent nature of their understandings was plausible to them. As students' conceptions became more complex, their increasingly coherent perspectives were reflected in the next three models. The next three models emphasized students' belief that the cause-effect process involved the concurrent and integrated function between different body systems. Human body systems were connected via a circulating blood transport system that delivered oxygen and nutrients to the muscles and, moreover, removed carbon dioxide from the muscles.

Integrated Process: Body Systems Model (MM3)

Defining features. Students' categorized within this model (n=6) perceived the *muscles* were the site of oxygen need. Various *body systems* functioned in integration simultaneously via the blood circulatory system to meet the increased need for oxygen during exercise. They demonstrated awareness for the production of carbon dioxide and its removal from the body. The body muscles used/consumed oxygen and food as energy resources.

Site of oxygen need. Similar to MM2 students, the six MM3 students perceived the muscles were the target site of oxygen need. For example, Carly explained:

> The muscles, they’re working hard because you are pushing them to run faster to get a better time so your body is working more. So your muscles use a lot of oxygen, you’re going to sweat more and then they’re going to get tired.

Human body structure and functioning. In contrast to MM1 students, MM2 students explained that exercise (causal agent) has an effect on several body-systems. They shared awareness that the human body was made up of several organs systems integrated in function and connected via the circulatory system. Al’s explanations illustrated this model:

> The respiratory, circulatory, and digestive systems are working together to get the oxygen and food there [muscles].When you’re exercising, the blood gets pumped faster by the heart through the arteries and veins. And you’re also breathing faster through your mouth and nose so that your lungs can get the oxygen from the air into your body. So the oxygen gets into the blood and it becomes oxygenated and it gets moved to the muscles that need it and even food parts are going into the blood faster…. Because the food goes from your mouth gets broken down into smaller parts, like, sugars and vitamins and proteins that get pumped into the blood by your intestines. So your muscles get the oxygen and the sugars and use them as energy to contract and expand….Muscles pull on tendons and ligaments that pull on your bones in a certain way to make you move.

Distinct from the previous models, students categorized as MM3 shared awareness of systemic circulation. They assumed the circulatory nature of blood and the return flow of the blood to the heart, explaining that “blood flowed in a cycle that started all over again”

[Liam]. Others used the analogy of a train on a circular track. For example, Ray explained:

> It's like a train. The blood in the arteries and veins will pass by the intestines and glucose goes on board. Then it will go again and it will then stop at the heart. And then at the muscle the glucose and oxygen get out and the carbon dioxide gets on board and then it [blood] moves and keeps going all over again to pick up more oxygen and glucose.

Al's data draws attention to the fact that students within this group also indicated awareness that exercising muscles produced wastes that *must* be eliminated from the body through the integrated role of the circulatory and respiratory systems. For example, Carly explained:

> When your muscles work normally, they produce carbon dioxide. It's a natural gas they make. When you're exercising your muscles are working so hard and make too much of that …and it can cause cramps especially if you cannot keep up with your breathing. So when you do this [student demonstrates exhalation], it's helping to get that carbon dioxide out of your muscles.

Figure 4 demonstrates three drawings and schematic representations that show variations in students' explanations of the direction and flow of circulation for oxygen delivery and carbon dioxide removal at the muscles. Liam's, Yana's, and Al's descriptions of blood pathways indicated different sites of blood oxygenation, perceived to occur at the lungs [Liam], heart [Yana], and blood vessels [Al]. Pointing to the arrows in his picture, Liam explained:

> The heart [valentine-shape] pumps the blood *to* the lungs along the arteries and veins here. Then the lungs oxygenate the blood…there are two of them [lungs] on the right side and left side [of the body] and they pump out blood carrying the oxygen to the muscles…At the muscles, the red blood cells pick up the carbon dioxide and then return to the heart which pumps them to the lungs again to get rid of the carbon dioxide and pick up more oxygen.

Yana's model reflected a similar circulation in the reverse direction. She explained, "oxygen moved from the lungs *to the* [bag-shape] *heart…* blood is oxygenated in the heart, pumped out to the muscles, and goes back to the heart."

[Insert Figure 4 about here]

In contrast, Al's drawing represented a circulation system wherein the blood oxygenation occurred in blood vessels and there was no structural relationship between the heart and lungs. He explained the function of the heart "was just to pump the blood along faster to the muscles." Unlike other students in his group who perceived a valentine [Liam] or bag-shaped heart [Yana], Al explained that his drawing of the valentine-shaped heart actually was a four chambered organ sectioned into a top and bottom pump that moved blood from the top chambers to the bottom chambers, and then out into the arteries and veins. He explained:

> Your heart has four chambers. The bottom ones are your ventricles, the top ones the aorta or something. The blood will flow into the top layer and then the lub would push it down to the bottom layer. And then dub would push blood up out through the veins and arteries to your body muscles. So it's like the lub is like the top pump and the dub is the bottom pump.

Further, he assigned the site of blood oxygenation to blood vessels, explaining:

> When you breathe in fast, the blood in the veins and arteries in your neck and near your lungs pick up the oxygen, but I don't remember what it's called, but I learned it in science [gaseous exchange]. Because the heart is also pumping the blood along, it will also push that blood with the oxygen to the muscles…And once the red blood cells give the oxygen and glucose to the muscle, then the blood turns sort of bluish because it picked up the carbon dioxide. And it will go back to the heart, so that the heart pushes that blood along until its in the veins and arteries at the neck and lungs again, and it will pick up oxygen and turn red, get the carbon dioxide out, and go back to your body, get the glucose, then go give the glucose and oxygen to your muscles again!

The blood pathway variations were intriguing because each reflected diverse explanations these students found plausible and coherent from their perspective to explain how oxygen was delivered to the muscles and carbon dioxide removed from the body during exercise. However, similar to MM1 and MM2, MM3 students' descriptions of these pathways lacked an accurate scientific understanding of the internal structure of heart (septum separate right and left side of heart to prevent mixing of oxygenated and deoxygenated blood), arteries and veins, and awareness for pulmonary and coronary circulation.

Meeting energy requirements. Similar to MM1 and MM2 students, the MM3 students assumed the body muscles *used up* or *consumed* energy. They identified energy resources as oxygen and food. Many explained specific nutrients including glucose [Ray], protein [Ian] and fats [Yana]. Some students used hand motions and gestures to explain how this process occurred. For example, Ian using personifying tendencies, explained:

> …the muscle *takes* the glucose and oxygen from the blood….like this [student demonstrates hand movement to imitate reaching out to grab items from blood] and *it* puts them into its mouth and so then they'll go into the muscle.

MM1, MM2, and MM3 students seemed to lack awareness of cellular respiration, a process through which the body cells produce energy that is the distinguishing feature within the next two mental models I describe conjointly.

Integrated Process: Cellular Level Body Systems Models (MM4 and MM5).

Defining features. Students categorized as MM4 and MM5 held a cellular level awareness of body functioning and perceived the human body as both a mechanical and biochemical machine. I structured the presentation of the next two models somewhat differently than the previous models because students within these models shared awareness for cellular respiration and a cellular level awareness of the human body distinct from the previous models. However, there were slight variations in their explanations of these features. The two variations I named the *Red Blood Cell Model* (MM4) and the *Muscle Fiber Cell Model* (MM5), respectively, were similar in several attributes, save, the identification of the "cell" they identified as the site of oxygen need and cellular respiration. I first describe MM4's and MM5's shared attributes followed by their model-distinctive attributes.

Site of oxygen need and the body as a mechanical and chemical machine. Students categorized within these models, MM4 (n=2) and MM5 (n=3) perceived that *individual cells* were the site of both oxygen need and energy generation. They demonstrated awareness that the human body was mechanical machine. Additionally they perceived it was also a biochemical machine that could generate energy at the cellular level.

Human body structure and functioning. The five students espousing integrated process models assumed exercise led to a concurrent chain of events to meet the increased need for oxygen through a process involving the coordinated function of several body organs connected via a circulating transport system. Similar to MM3 students, MM4 and MM5 perceived exercise entailed a cause-effect process involving the synergistic relationship between diverse body systems, functionally connected via the circulation system, to deliver nutrients and oxygen to the muscles and remove carbon dioxide. Additionally however, they shared a cellular-level awareness of body-system synergistic functioning and were able to describe underlying physical and chemical processes. For example, they described the underlying physical science processes involved (e.g., diffusion) and were aware of the body's capability to carry out chemical reactions that change the properties and form of substances to facilitate their transport and usage. For example, John explained, "digestive acids *change* the food you eat into sugars and because sugars are so much smaller than the food you eat, it's easier for them to pass from the digestive system into the circulating blood." Students also seemed aware of the process of gaseous exchange, whereby, oxygen and carbon transferred in the lungs along a diffusion gradient. For example, in explaining her drawing (pictured in Figure 5) Dina said:

> Basically, when you're exercising, your carbon dioxide and oxygen just switch faster. There are red blood cells moving in the vessels going around your lungs

> and what happens is the red blood cells switch carbon dioxide for the oxygen…because there's more oxygen on this side [in alveoli in lungs], than this other side [capillaries carrying de-oxygenated blood circulating alveoli]. And it's the opposite for the carbon dioxide. There's more carbon dioxide on this side of the lungs [i.e., in capillaries surrounding lungs], so it crosses over and goes into the lungs and that is what you breathe out.

[Insert Figure 5 about here]

The same process also occurred at the muscles as Aldo described:

> When the red blood cell carrying the oxygen come here [muscles], it just exchanges the oxygen for the carbon dioxide….it's the other way [i.e., there is greater concentration of oxygen in the blood capillaries around muscle than within the muscle]. There's more carbon dioxide in the muscles and you have to remove that because it causes cramps and lactic acid.

Meeting energy requirements. In contrast to the previous models, MM4 and MM5 students specified that cells combined oxygen and glucose to create energy that was then used by cells. For example, Dina stated, "glucose and oxygen are *combined* and *turned* into energy muscles can use to work." MM4 and MM5 students' comprehension of the human body's energy needs is characterized by an awareness that glucose and oxygen are not energy sources in themselves, but rather are two substances cells combine and "recycle into energy" [Emma]. John also explained the process of chemical transformation: "Cellular respiration is when cells in your body cells combine sugar and oxygen to make energy, water vapor, and waste gases like carbon dioxide." Unlike the previous models, MM4 and MM5 students' understandings of cellular respiration permitted them to explain how muscles produced the carbon dioxide.

The contrasting features between MM4 and MM5 models was students' (a) identification of the target "cell" of oxygen need where they assumed cellular respiration occurred and (b) their perception of the blood pathway and structure of the human heart. This in turn led to variations in their specific theories regarding the flow of the circulatory system and the pathway oxygen and carbon dioxide followed through the circulatory system.

Red Blood Cell Integrated Process Model (MM4.). Students categorized as MM4, Dina and Evan, identified the *red blood cell* as the site of oxygen need. They indicated that cellular respiration occurred *outside* the muscle tissue. Red blood cells in the blood vessels combined oxygen and glucose to make the energy that the blood then transferred into the muscle. Dina explained:

> Your red blood cells need the oxygen actually because they need it to make the energy and take that energy to where the body needs it…It depends on what type of exercise you're doing. Like if you're doing bicep curls, then the red blood cells take the oxygen there and combine it with nutrients to make that complex sugar …to provide the muscle fibers in your biceps with the energy they need.

Hence, MM4 students ascribed the red blood cells with four functions: (a) transport oxygen to a site of energy need, (b) combine oxygen with nutrients to make an energy source at the site of need, (c) transfer the energy source into the muscle for usage by the muscle fibres and pick up the carbon dioxide from the muscle, and (d) circulate blood back to the heart and then the lungs to eliminate the carbon dioxide and pick up more oxygen. Dina and Evan were the only students who, in addition to systemic circulation, held an initial awareness of pulmonary circulation and understood the fact that the heart muscle was a four-chambered organ that needed oxygen directly to sustain living. For example, Evan explained:

> Your heart is constantly needing that oxygen too. It doesn't matter what exercise you're doing. Your heart still needs oxygen because it has to constantly keep beating to keep you alive. Because your heart's always beating. The organ part shoots out the blood....The heart is a muscle too and it's always going to be working and so it's needing oxygen from the lungs [awareness of pulmonary circulation] to beat harder and pump the blood faster so that your body can work better. There are two arteries from the lungs that bring oxygen from the lungs into the heart. I think they are on each side [right side and left side of heart].

Muscle Fiber Cell Integrated Process Model (MM5). Students I categorized as MM5, Aldo, John, and Emma, demonstrated awareness for the microstructure of muscles. In contrast to MM4 students, they identified the *individual muscle fiber cells* as the site of oxygen need for both energy production and usage. Upon delivery of the glucose and oxygen into the muscle, John explained that, "each individual muscle cell in your muscles makes its own energy from combining of oxygen and sugars." Emma emphasized that muscles "are actually tissue made up of many cells called muscle fibers. *They* need the oxygen because they use it with the glucose intake to create energy in your muscles so your muscles can keep up with your body movements." In explaining the circulation pathway, MM5 students revealed limited awareness for the internal structure of the human heart that separated the flow of oxygenated and deoxygenated blood. Figure

6 illustrates John's awareness for systemic circulation between the heart and the body. He distinguished the specific roles of arteries and veins in systemic circulation. However, he depicted a bi-directional pathway between the heart and lungs through which both carbon dioxide and oxygen flowed. Similarly, Aldo depicted a one-way pathway carrying deoxygenated from the muscles to the lungs directly, but by passing the heart.

[Insert Figure 6 about here]

Summary of Findings

The five mental models illustrate the distinctive and developmental nature of students' conceptual understandings of the physiological events occurring in the human body during exercise. Each model illustrates varying degrees of accuracy in students' explanations, however, from the students' perspective, their views were plausible. The diverse mental models articulated the diverse ways students integrated their perceptions, knowledge, and beliefs about human anatomy and physiology. The mental models depict distinct and diverse specific theories students used as the basis for their explanations of how the human body functioned and adapted during exercise.

Discussion

I concur with Rowlands' (2004) observation that students have different ways of thinking about and describing what they know about their bodies and body mechanisms. FTCC appeared to be a viable hypothesis to gain access into mental model building mechanism and infer how students organized their conceptions about exercise induced physiological changes. The findings from this study revealed a spectrum of five mental models. They draw attention to two aspects essential to educators' understanding of conceptual change as a process of mental model building. First, students' mental models derive from internally coherent conceptual systems that are diversified and developmental in nature. Developing sophisticated understandings about a human biological phenomenon is an emerging process. Second, students organized their mental models according to diverse configurations of their beliefs, perceptions, and knowledge within their conceptual knowledge system associated with an understanding of the human body and exercise induced physiological changes. I hypothesized a conceptual structure that charts how students in this study might have developed each generic mental model. I conclude by suggesting that identifying where students experience conceptual difficulties can be a useful sensitization to the challenges students face in interpreting what is going on in their bodies during exercise (Rowlands, 2004).

Seeking Coherence: An Emerging Process.

The diversified mental models identified in this study reflect students' attempts to seek mental coherence. Students spoke with confidence and expressed their ideas consistently, thereby suggesting they were operating from underlying conceptual structures that were internally coherent, irrespective of how different they might be from conventional understandings (Vosniadou, 1994). In parallel with previous research (e.g., Chi et al., 1994) the different models identified in this study, for example, reflected diverse ways students sought to explain their perceptions of "increased heart rate" and "breathing hard" to bring in oxygen into the body and remove carbon dioxide. Students seemed unaware their explanations contained some misrepresentation or inaccuracy about human biology knowledge Vosniadou (1994) explained that lack of awareness occurs because students do not possess metaconceptual awareness of their beliefs and do not notice that their conceptions do not match conventional understandings. Vosniadou

(1994) and Sorzio (1994) emphasized that diverse students' mental models reflect their idiosyncratic, active, and creative attempts to understand a phenomenon and keep their cognitive system free from contradictions necessary to establish mental coherence.

Alexander (2006) explained that developing expertise and principled knowledge in any academic domain, in this case human biology, entails students undergoing a conceptual change process whereby they are helped to develop alternative internally coherent systems that evolve and become increasingly externally coherent with the principled understandings associated with a domain. Developing sophisticated conceptualizations of exercise induced physiological changes occurs gradually and may take several years to be understood deeply (Vosniadou, 2007b). Perceived in this manner, conceptual change is an intricate process necessitating that learners' continually reorganize their conceptions whilst maintaining internal coherence of their personal views.

The findings from this study suggest that promoting both internal and external coherence is an emerging process. Developing sophisticated coherent conceptions of exercise induced physiological changes entails developmental, application-oriented, and integrated processes that evolve into relational conceptions.

Developmental processes. The spectrum of mental models identified in this research may reflect a continuum associated with developing expertise in understanding the human body and exercise induced physiological adaptations. Mazens and Lautry (2003) explained that distributions of generic mental models across different contexts reflect a development trend. Their observation seems plausible for data within this study because I too identified diverse mental models that were shared by students in both schools. Additionally, I noted that aspects of my findings were comparable with previous research conducted in the USA and elsewhere. For example, Reiss and Tunnicliffe (2001) found that UK students across all levels of schooling have difficulty understanding the human body. Although students' drawings revealed increasing detail with age; many students' conceptions remained incomplete. In their research, children and some adults typically drew an external view of an organ or organ system and many drew the heart in a non-anatomically correct fashion (i.e., valentine shape). Similar to the children in our study, many UK participants seemed unaware of the heart's internal structure, its organization within the circulatory system, and its relationship with the respiratory system. These scholars indicated that the students held a limited appreciation for how organs existed as related structures within a system because "they assumed their insides consist of a scattered assemblage of isolated body organs and incomplete organ systems" (p. 396). Further, they concluded that "it takes a while for children to understand that organs are joined within and across body systems to constitute the entire human body" (p. 397).

Students in our study also demonstrated varying degrees of detail and accuracy in their understandings about the structure and function of the human body machine (ontological beliefs). The contrasts I found, for example, between MM1 and MM2 versus MM3, MM4, and MM5 illustrate that students' ontological belief sophistication was shifting from perceiving the human body as being comprised of isolated body organs towards an appreciation of the fact that it comprised integrated, synergistic body systems. Students' epistemic beliefs of the cause-effect process also demonstrated a transition from perceiving the process as sequential (MM1) to concurrent and parallel (MM2) to concurrent but integrated (MM3, MM4, and MM5). I believe this reflected an emerging shift in epistemic sophistication that needs to occur if students are to appreciate the complex, integrated, and coordinated function of the human body.

The above transitions in ontological or epistemic beliefs are shifts one would expect to see if students are to become increasingly principled in their knowledge base and modify their conceptions such that they become both internally and externally coherent. It is not, however, a flawless process and students' are unaware of the distortions they make when they interpret scientific phenomenon. The variations identified indicated that students' mental models still held scientific unawareness (e.g., pulmonary circulation) and inaccuracies (e.g., blood oxygenation or cellular respiration sites; bidirectional blood flow in veins and arteries). Naïve conceptions need to be appreciated as learners' ongoing attempts to seek coherence and not simply labeled as inaccurate conceptions. Both Alexander (1996) and Vosniadou (1991) have reiterated the developmental nature of the learning process, emphasizing that naïve conceptualizations are scaffolds supporting future learning.

Application processes. Students in this study attempted to maintain internal coherence of their ideas by applying their knowledge of the human body to construct their explanations of exercise induced physiological changes. For example, all students elaborated that normal physiological functioning was occurring much faster during exercise. For example, the heart, lungs, and muscles had to work faster [e.g., Emily]; carbon dioxide and oxygen had to switch faster [e.g., Dina]; and the digestive system had to send glucose into the blood pathway faster [e.g., Aldo].

Students also used other mental models they held to explain physiological changes. Vosniadou (1994) explained that students can retrieve other mental models they hold in long term memory to explain and predict a new phenomenon. In this study, students used, for example, existing circulatory system mental models to explain how oxygen and carbon dioxide travelled through the human body during exercise. Students described blood pathways that matched variations already identified by Chi et al., (1994): “no loop” (Victor, MM2); “single loop with no lung” (Al, MM3); ‘single loop with lungs” (Yana and Liam, MM3), and “double loop 1” (Dina, MM4). Some students’ circulatory mental model seemed in transition; for example, MM5 students (John and Aldo) used a combination of Chi’s et al. (1004) models with the “single loop with loop lungs” for systemic circulation and a “no loop” involving a blood pathway between the heart and lungs carrying both oxygenated and deoxygenated blood, unaware that the bidirectional flow of blood was inaccurate. This may demonstrate an emerging initial awareness for pulmonary circulation. They may be able to enrich or restructure their “no loop” transitioning toward the “double loop” variation if the curriculum purposefully targeted this shift in understanding. Clearly, seeking coherence is an emerging process. Targeted belief and knowledge change through purposefully designed curriculum and instruction is essential to facilitate external coherence with scientifically accurate explanations and may assist these students’ to reach these conceptions (Vosniadou, 1994).

Interactional processes. Developing sophisticated mental models of a multifaceted phenomenon, such as exercise induced physiological changes, involves a complex interaction of several phenomena that may not be directly observable.

Vosniadou and Brewer (1994) explained that student mental models of the day and night cycle are influenced by their mental models of the earth, sun, moon, and stars. Understanding the interactions of the various pre-requisite concepts was challenging for students because they required understanding phenomena that were either not directly observable or were counter-intuitive to their direct experiences.

In parallel, I suggest that developing principled understandings of exercise induced physiological changes involves students' understandings of both observable and unobservable phenomena. For example, although physical education lessons offered students opportunities to receive sensory and perceptual information related to physiological adaptations (e.g., feeling their increased heart rate) and science education lessons provided information about human biology concepts. However, students could not actually *observe* how blood was flowing through their heart, blood vessels, and valves nor *feel* the cellular respiration processes occurring in their bodies (Texiera, 2000). In line with Vosniadou's observations in the physical sciences, Chi et al., (1991) noted that students experience conceptual difficulties with understanding biological phenomena, such as the circulatory system, because of the complexity of processes involved that are causally related and not readily observable.

Sorzio (1994) explained that students use their imagination to construct their mental models of unobservable or incomprehensible events when they cannot comprehend phenomenon directly from their perceptions. Some students in this study demonstrated this propensity through their use of metaphors to explain the relationship between the circulatory system and other systems (e.g., train on circulatory path) and what Inagaki and Hatano (2006, p. 178) describe as "personifying tendencies" (e.g., Ian demonstrating how muscles “take” oxygen from the blood). Hence, students’ use of metaphors and gestures reflects their use of imagination to explain the unobservable exercise induced physiological changes fuelled by their underlying beliefs and need to seek coherence.

Seeking internal and external coherence also can be hard to achieve because it requires complex, interdisciplinary understandings (Michael et al., 2002). Within this study, only MM4 and MM5 students demonstrated an emerging awareness for body system interactions and the underlying mechanisms (e.g., cellular respiration, gaseous exchange) occurring at the whole body, tissue, and cellular level. In line with Michael et al.’s (2002) comment understanding exercise induced physiological changes necessitates a conceptual understanding of the physical science concepts (e.g., diffusion) and chemical processes (chemical transformations) that underlie the biological phenomenon (e.g., cellular respiration). Further, there is a developmental trend associated with these complex interdisciplinary understandings. In examining students’ mental models of the digestive system, Rowlands, (2004) and Teixera (2005) noted that students’ understanding of chemical reactions and awareness that the human body was both a mechanical and biochemical entity only begins to emerge at the middle school level.

The interactional process may also be hard to understand because the human body is a complex phenomenon. Modell et al. (2005) noted that understanding human biology concepts was more complex than physical science concepts because human biology concepts involve mental models at different levels within the human body. Hence, understanding exercise induced physiological changes necessitates students having an integrated understanding of the various coordinated relationships within and across body systems (e.g., Chi et al., 1994). Further, students also need to appreciate the multi-level organization of the human body: whole organism, body system, organ, tissue, cellular, and molecular levels (Michael et al., 2002; Modell et al., 2005).

The spectrum of mental models identified in this research demonstrated that students experience conceptual difficulties in understanding the human body and how it functions. Modell et al. (2005) noted that even adults have conceptual difficulties with understanding the circulatory system because their mental models of the integrated function between body systems and underlying chemical and physical process were underdeveloped or were correct, but integrated inappropriately. The general trend of MM1 towards MM5 reflects the direction of developing increasingly principled knowledge. However, the data provide only a snap shot description of five specific points along a learning continuum that may take several years to develop (Vosniadou, 2007b). It is challenging for students to integrate and organize their various mental models into a coherent whole (Vosniadou & Brewer, 1994; Model et al., 2005). Rowlands (2004) described two challenges that educators face: first, identifying where students experience conceptual difficulty, and second, designing simpler but scientifically correct instructional tasks that simplify complex processes in order to target conceptual difficulties. I suggest that FTCC may help address the first challenge because it can help identify where students experience conceptual difficulty.

Charting Emerging Coherence

Rowlands' (2004) first challenge could be addressed by examining students' mental models and charting their emerging coherence. In Figure 7, I hypothesized a conceptual structure underlying students' mental models of exercise induced physiological changes. I try to demonstrate how students' mental models emerged from the diverse ways in which students organized their perceptions, knowledge, and beliefs of the human body and exercise induced physiological changes into a coherent system. According to Vosniadou (1994), it is the specific configurations of these knowledge elements within learners' conceptual systems that limits or facilitates students' mental models development. I used previous FTCC models of physical science concepts (Chiu & Lin, 2005; Vosniadou, 1994) and other research in the domain of human biology (Chi et al., 1994; Inagaki & Hatano, 2006; Reiss & Tunnincliffe, 2001; Rowlands, 2004; Teixeria, 2005) to develop this structure.

[Insert Figure 7 about here]

In Figure 7, I adapted Vosniadou's (1994) depiction of a FTCC schematic conceptual prototype[3] that illustrates how students' mental models are influenced by their underlying global and specific theories. I assumed that because learners' mental models are shaped by underlying naïve theories, they could be indirectly inferred. Hence, the left vertical rectangle (dotted grey area) depicts students' global framework theory; it comprises students' ontological and epistemic beliefs about human biology that develop since infancy (Inagaki & Hatano, 2006; Vosniadou, 1994). The figure is dominated by specific theory (wide, white rectangle enclosed in dashed-line border) that directly influenced students' mental models of exercise induced physiological changes. Specific theory develops through learners' everyday experiences and educational experiences through their sensory and motor access within the embedded cultural context (Chiu & Lin, 2005; Mazens & Lautry, 2003; Vosniadou, 1994). In this figure, specific theory represents an overview of all interviewees' data sources, responses, and key features in

[3] I use the *conceptual prototype* instead of *conceptual model* to avoid confusion.

their explanations they used to explain how their body adapted to participation in exercise. It comprises two sections: the top section contains examples from the data that indicates students' access to perceptual information (e.g., increased heart rate) and knowledge (e.g., an increased need for oxygen). The lower section contains data categories that illustrate students' emerging ontological and epistemic beliefs associated with exercise induced physiological changes. The data suggest the epistemic beliefs comprised one dimension associated with need for causal explanations (Hatano & Inagaki, 2006). The ontological beliefs associated with the human body machine comprised eight dimensions. I indicate the variations I noted within each dimension across all the mental models. The bidirectional arrow in the figure illustrates the interplay between learners' beliefs and perceptions and knowledge within specific theory.

The bottom section of the diagram schematically illustrates how each of the five mental models could have been shaped by the specific theory through the mapping of perception, knowledge, and beliefs using specific key codes within the general specific theory area (vs. creating a specific theory box for each mental model). By way of illustration, I try to demarcate how MM2, MM4, and MM5 (shaded boxes) students could have organized their perceptions, knowledge, and beliefs. I use a particular symbol to denote each mental model (e.g., ♦ = mental model 4 etc.). I demarcate the code that corresponds to each mental model throughout the global and specific theory areas to illustrate how particular beliefs/observations/sources of information were configured differently by students and influenced the development of MM2, MM4, and MM5 models.

Rowlands (2004) explained that identifying students' mental models is a useful sensitization to the conceptual challenges students face in interpreting what is going on in their bodies during exercise. The merit of the hypothesized prototype is three fold. First, it may enable educators/researchers to gain insight into how students are organizing their conceptions and, moreover, to identify the dimension(s) where students experience conceptual difficulty (Modell et al., 2005; Rowlands, 2005). Second, it illustrates that beliefs about knowledge are multi-dimensional in nature, and they interact with other elements within learners' conceptual systems (Buehl & Alexander, 2001; Vosniadou, 2002). Finally, this prototype can serve as a diagnostic tool (Modell, et al., 2005) to identify where students need help to enrich and restructure the naïve theories that underlie their mental models. I use three examples to illustrate how schematic representations like Figure 7 serve this purpose. First, MM4 students need to be helped to enrich their understanding of the site of cellular respiration to advance their conception towards the more scientifically accurate location. MM1, MM2, and MM3 students demonstrated that they still did not have a conceptual understanding of cellular respiration necessary to understanding how muscles produce carbon dioxide as waste. It would be necessary to check if their understanding is due to "lack of knowledge" (Chi et al., 1991, p. 9) and hence students need to enrich their existing conceptions. Alternatively, it is important to determine whether students knowledge about the concept, it is stored as "inert knowledge …in a separate knowledge structure" (Vosniadou, 1994 p. 50). If so, it is understandable why they cannot apply it to their comprehension of exercise induced physiological changes. In either case, students need ongoing curricular and instructional support to assist them to enrich or restructure their naïve theories to modify their mental models.

Similarly, MM2, MM3, and MM5 students may need to enrich and restructure their generic mental model of the circulatory system to progress their mental models to match the external coherence of the scientifically accepted description of the circulatory system. Enrichment, alone, that is simply acquiring additional facts and adding them to their existing conceptions without re-organizing their beliefs, would still lead to distorted mental models. The use of models, such as Figure 7, should be implemented with researchers' /educators' sensitive and appreciative awareness that students' mental coherence is still emerging. For example, because chemical awareness is still emerging around age 10, students' may experience difficulty in understanding how their body is structured, and may struggle to integrate the various levels of organization of the human body, in addition to trying to explain and predict how adaptations to exercise occur.

Gradual and incremental shifts in specific theory beliefs can help students *reinterpret* their observations and knowledge of the exercise induced changes they seek to understand while enabling them to maintain mental coherence (Vosniadou, 1994). Additionally, helping students redress one element that is inaccurate may help students understand other aspects with which they had conceptual difficulty. Chi et al., (1991) noted that because human body components and processes are connected, changes in students' understanding of one part may have repercussions for other conceptions or other aspects of the human body. Thus, for example, I could envision that if students are able to understand the nature of chemical reactions, they can understand a variety of other chemical transformation that occurred in the body (e.g., cellular respiration, the process of food break down etc.) during normal physiological functioning and during exercise.

In conclusion, in permitting an examination of learners' knowledge and beliefs as an integrated system, FTCC provides a very rich picture of conceptual development. Vosniadou (1991) explained that educators' awareness for *how* students develop internally coherent conceptual systems is critical to the design of instructional experiences that promote the evolution of students' synthetic mental models towards the externally coherent models of scientific phenomenon. She emphasized that a key criterion to facilitating model development is helping students first develop awareness for their conceptions. Educational experiences that facilitate students' opportunities to externalize their conceptions are essential to help students become aware of their naïve conceptions, recognize the conflict with accepted understandings, and, finally, recognize the need to enrich and restructure their beliefs. Vosniadou and Brewer (1994) clarified that it is not students' observation of the phenomenon that changes, but rather, their interpretation of the phenomenon. Hence, examining students' mental models of exercise induced physiological changes can help researchers understand how students can be helped to reinterpret their sensory experiences and develop a more advanced conceptualization of this complex phenomenon.

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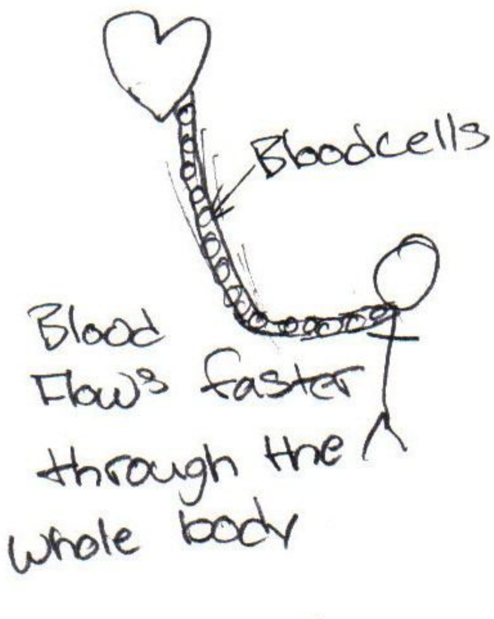
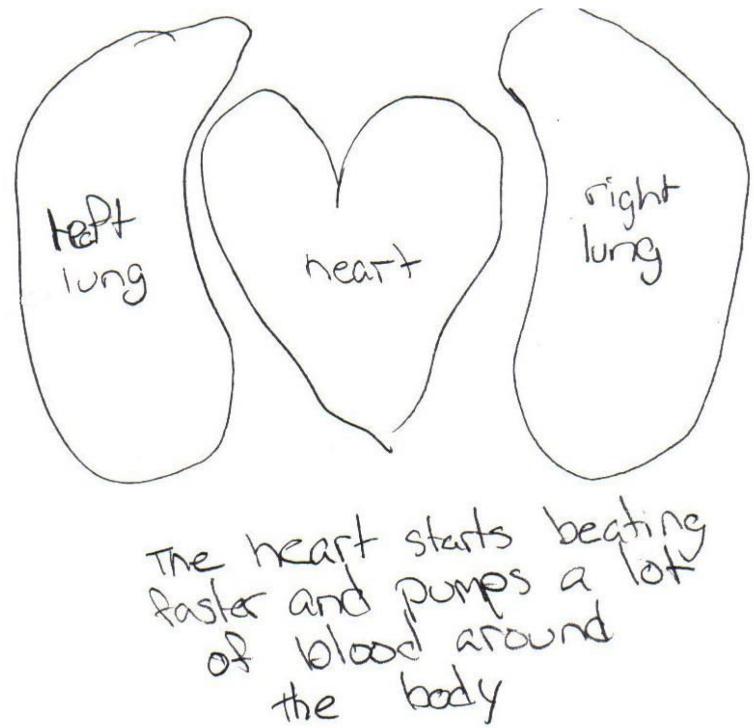
Figure 3. Examples of MM2 students' drawings that illustrate the one-way blood pathway and the disconnect between the heart and lungs.



Victor (MM2)



Linda (MM2)

Figure 4. Examples of MM3 students' drawings that illustrate blood pathway variations.

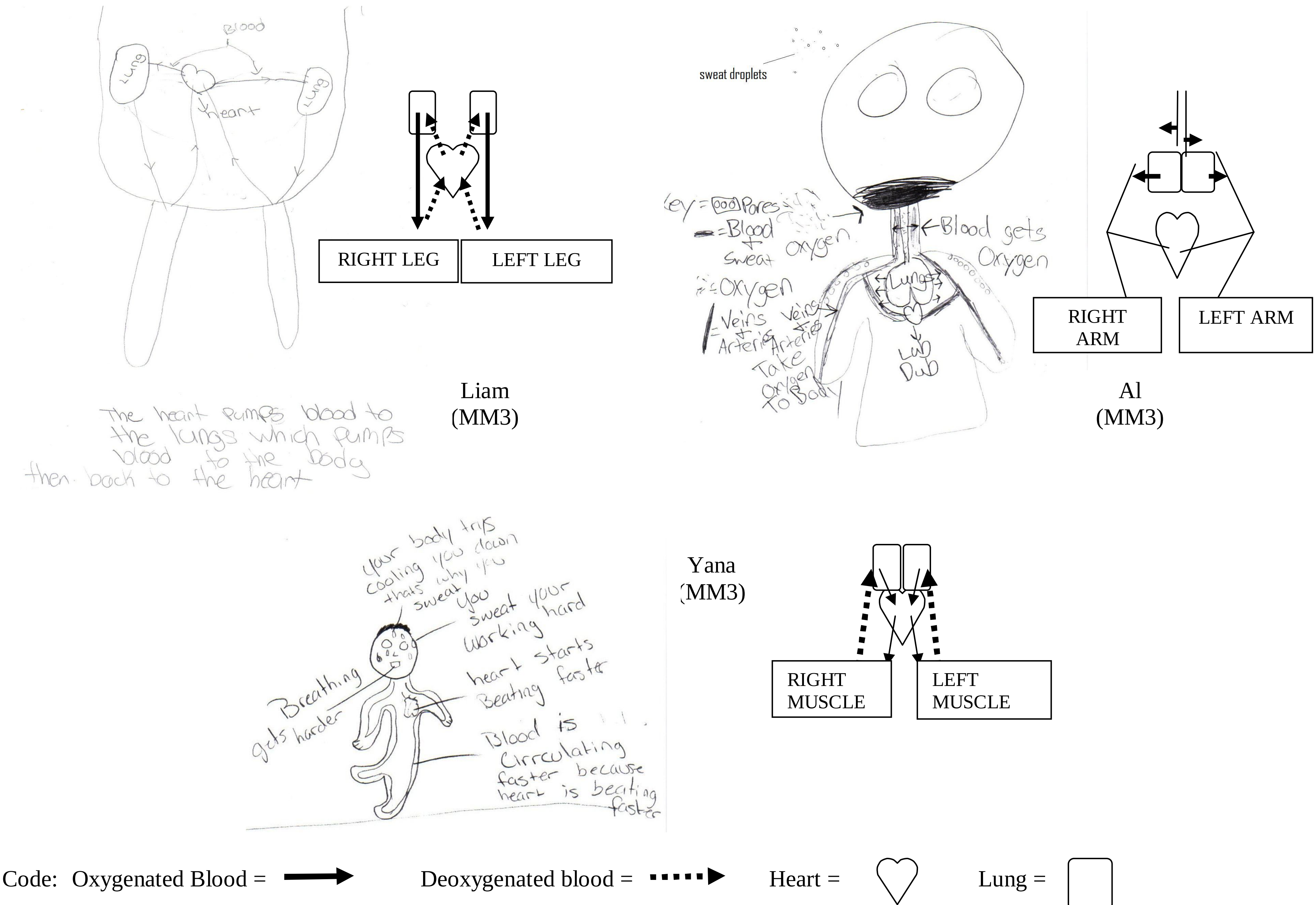
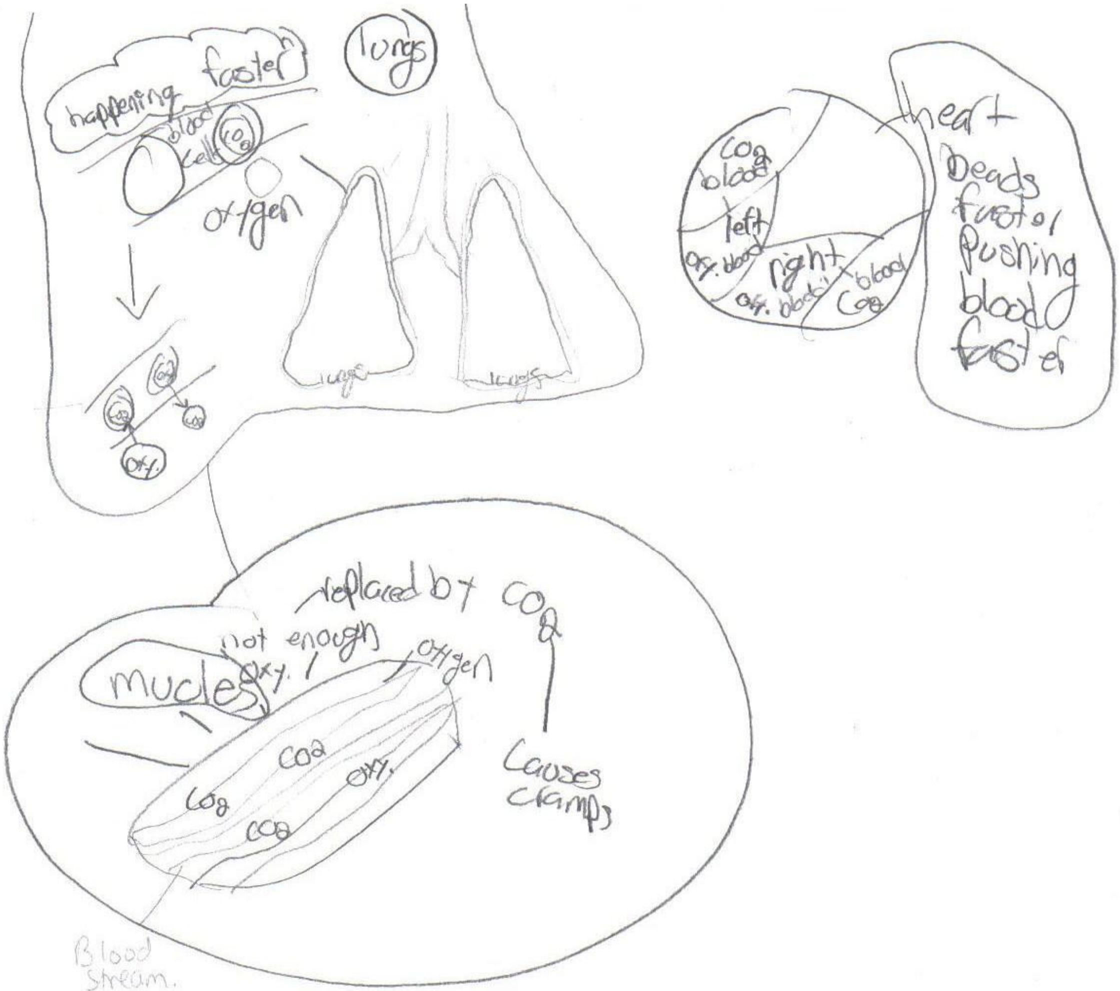
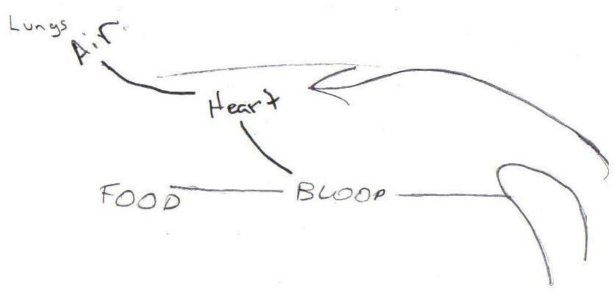


Figure 5. Examples of student drawings categorized as MM4 and MM5 representing the gaseous exchange process



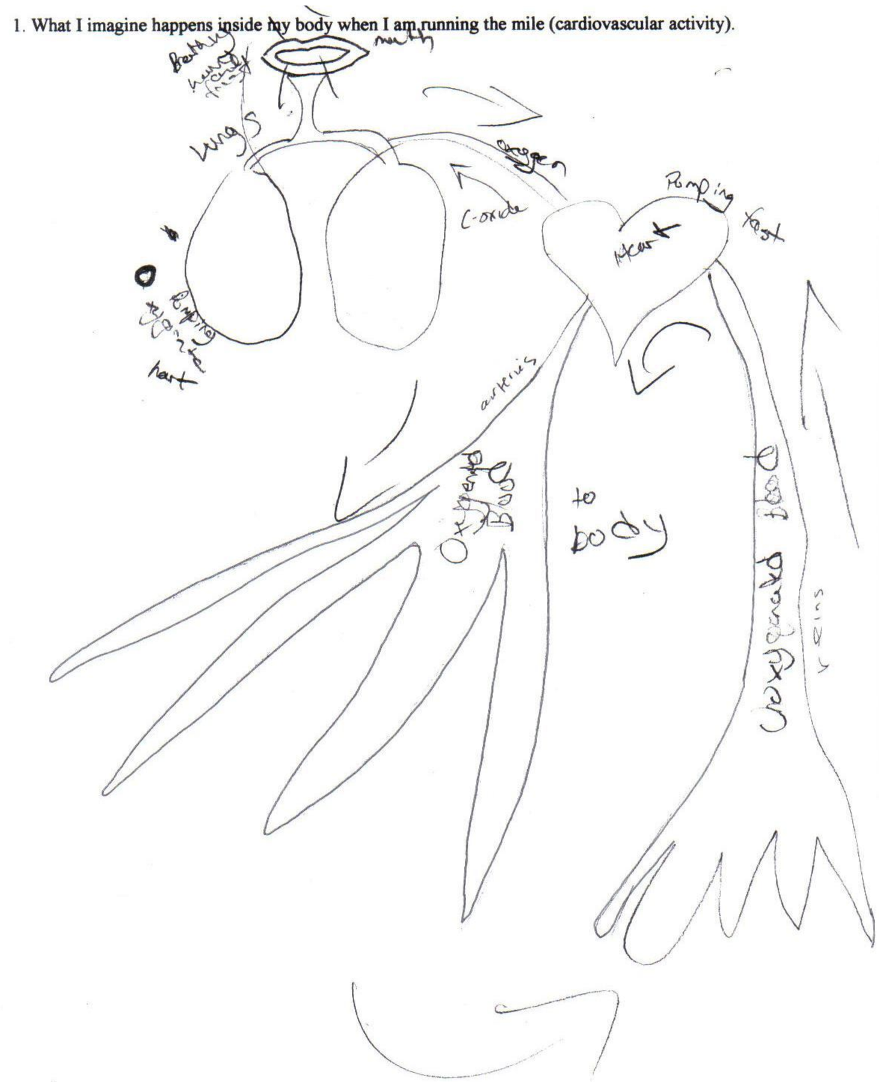
Dina (MM4)

Figure 6. Samples of students' drawings of the blood pathways categorized in MM5.



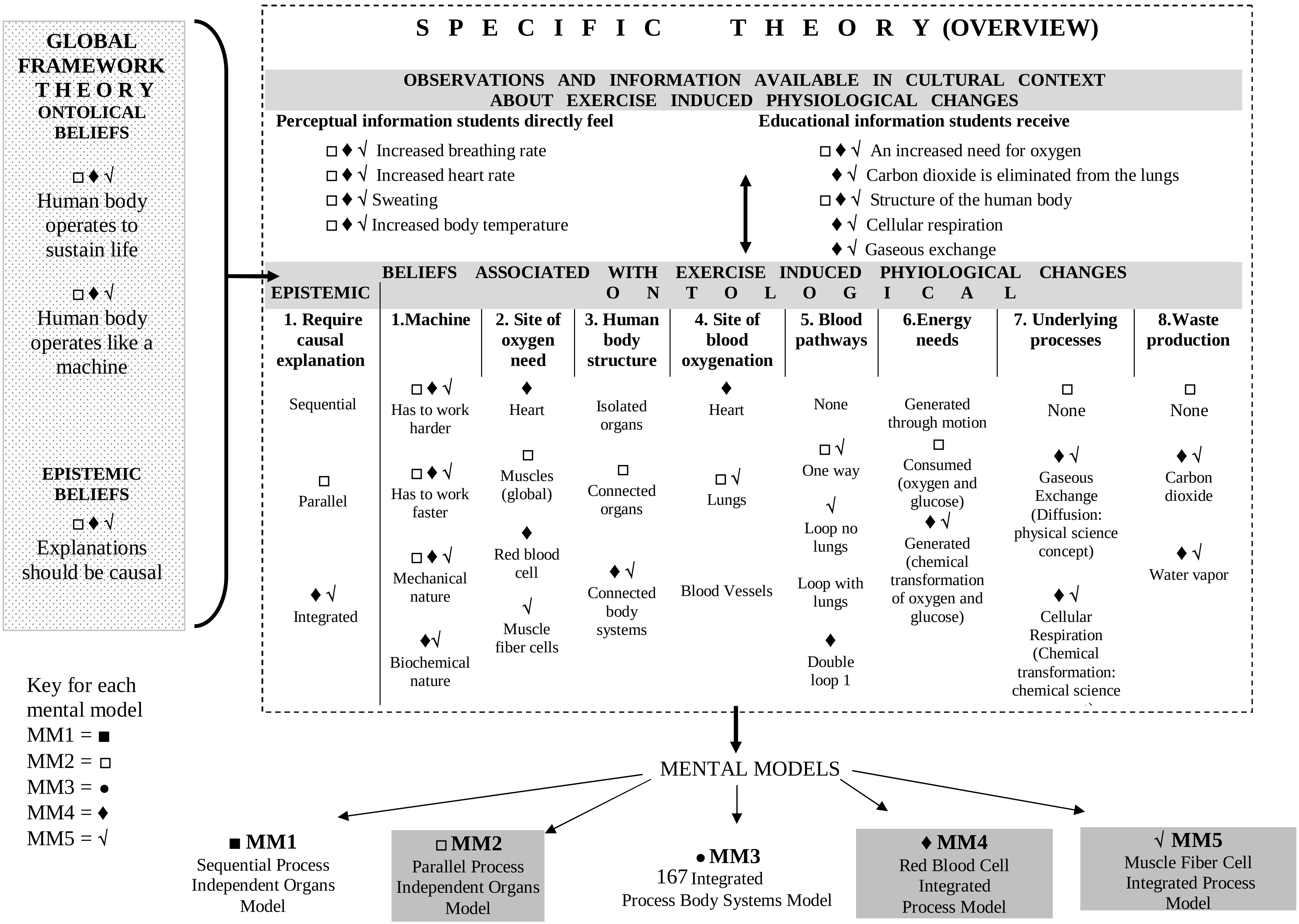
Muscle takes food

Aldo (MM5)



John (MM5)

Figure 7. Conceptual prototype underlying MM2, MM4, and MM5 students' models of exercise induced physiological changes



CHAPTER 5

SIXTH-GRADE STUDENTS' MENTAL MODELS OF EXERCISE INTENSITY

Recently, federal agencies and professional organizations have produced reports calling for increased opportunities for children and youth to participate in physical activity (Pate et al., 2006). For example, the Surgeon General's report suggested a flexible approach to increasing enjoyable physical activities at moderate-to-vigorous intensity levels to accrue health benefits (U.S. Department of Health and Human Services [USDHHS], 1996). Additionally, the National Association for Sport and Physical Education [NASPE] content standards emphasized the need for students to develop a conceptual understanding of health-related-fitness concepts (2004). There are a number of fitness domain concepts, such as those related to the FITT principle[4] and the fitness components,[5] that can contribute to students' cognitive understanding, habits, and performance abilities that increase the adoption of physically active and healthy lifestyles (Corbin, 2002). Fitness domain concepts represent *externally* verified forms of knowledge reflecting experts' interpretation and agreement on what knowledge constitutes the essential fitness concepts students should learn and master through systematic instructional experiences. The meaningful learning of fitness concepts enhances students' willingness to use and apply them in personal fitness decision making (Ennis, 2003a; Mohensen, 2003; Murphy & Mason, 2006; Placek et al., 2001).

Placek et al. (2001) reported students hold a number of naive fitness conceptions that are far removed from expert understandings. They are inaccurate because they contain errors and misrepresentations of fitness knowledge. Researchers have used diverse research designs to

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[4] FITT principle or the FITT formula is an acronym that represents four factors essential to develop a fitness program, that is, frequency, intensity, time, and type (Corbin & Lindsay, 2005).
[5] The fitness components comprise the "*type*" element of FITT, that is, activities, that promote the development of cardiovascular endurance, muscular strength, muscular endurance, or flexibility (Corbin & Lindsay, 2005).

examine and describe students' naive fitness conceptions. Using a qualitative research design conducted at the middle school level, Placek et al. (2001) reported that sixth grade students' (n=39) conceptions about the fitness components and the FITT principle lacked the foundational declarative knowledge (i.e., factual information sometimes described as "knowing what", Alexander, Shallert, & Hare, 2001, p. 332) necessary to design personal fitness plans. For example, interview data revealed students had "no idea" about the concept of intensity. Further, Placek and her colleagues reported students' culturally based naive conceptions about fitness related to appearance (e.g., fitness = being thin) rather than health benefits. The researchers concluded many students enter physical education with distorted or incomplete conceptions about the nature of fitness and fitness knowledge that are developed through information sources derived through experiences in the lay culture (e.g., media). They also hypothesized students' inaccurate knowledge could be related to teachers' lack of pedagogical content knowledge to teach fitness effectively, a curriculum that did not focus on teaching fitness, or the lack of facilities, resources, and equipment necessary to provide quality fitness experiences (Placek et al., 2001).

Students may continue to hold naive conceptions even in fitness oriented physical education curricula. For example, using a quantitative research design, Stewart and Mitchell (2003) reported findings of naive conceptions in high school fitness classes. While knowledge surveys demonstrated students (n=270) possessed declarative knowledge about the components of fitness and the FITT principle, the majority of their responses demonstrated confusion in their procedural fitness knowledge, that is, "knowing how" (Alexander et al., 1991, p. 333) to use and apply their declarative knowledge about these concepts to make fitness decisions. In particular, students struggled to apply the FITT principle when designing a fitness plan. More specifically, within the FITT principle, intensity was the most problematic concept. The majority of students reflected vague notions about appropriate intensity levels and their responses reflected confusion between the FITT elements (e.g., between intensity and time, by describing intensity as running for 20 minutes). Additionally, several students described measures of intensity that did not match the type of physical activity (e.g., using heart rate for muscular strength).

Placek et al.'s (2001) and Stewart and Mitchell's (2003) research has been instrumental in drawing attention to continue examining students' conceptions of health related fitness. Ennis (2003a; 2007) and Stewart and Mitchell (2003) emphasized the importance of examining how students develop their fitness conceptions, rationalize their responses, and gain insight into the variables that facilitate and constrain conception development. These include documenting the curriculum content and implementation including teachers' use of instructional resources.

Recent advances in cognitive theory have provided new approaches, such as the *Framework Theory of Conceptual Change* (FTCC; Vosniadou, 1999; 2007a) to explain and describe conceptual learning research, permitting new insights into the complexity of the learning process. The central element within FTCC is that students' knowledge is embedded within naive theories that are academic belief-based internally coherent conceptual knowledge-systems that are useful when constructing or scaffolding future learning.

The purpose of this study was to apply FTCC as a theoretical framework to examine cognitive learning of fitness concepts. This theory has not yet been applied to examine student learning in physical education. FTCC can offer an opportunity to describe students' knowledge and academic beliefs about fitness in tandem. Because learners' academic beliefs develop unconsciously through their experiences both within and outside the physical education lesson, FTCC is useful when examining the complexity of the knowledge-beliefs-context relationships.

In this research, FTCC was applied to an examination of students' conceptions of intensity. Previous research (Placek et al., 2001; Stewart & Mitchell, 2003) indicated that students experience particular difficulty in understanding the conceptual complexity inherent in scientific conceptions of exercise intensity. Current fitness prescriptions recommend moderate to vigorous intensity levels of exercise to accrue health and fitness benefits, placing the intensity concept central to students' ability to design and implement effective personal fitness plans. Because adolescence is a pivotal time for fostering active lifestyle habits (Ennis, 2003), it is essential that middle school students focus on concepts associated with exercise intensity and apply them accurately and flexibly to their personal fitness (U.S. Department of Healthy and Human Services [USDHHS], 1996). The specific research questions guiding this study were:

1) What are sixth-grade students' conceptions of exercise intensity and its relation with the other elements in the FITT principle?
2) How do students develop their knowledge and beliefs about fitness?
3) What variables influence students' developing conceptions?

Conceptual Change Theory

Recent perspectives on conceptual learning view learning as process of conceptual change that depict the pathways learners follow as they move from novice to more sophisticated understandings (Duit & Treagust, 2003). Vosniadou (2007a) emphasized that a theory of conceptual change needs to recognize that learning involves acts of personal and social cognition. Further, that learners' knowledge and academic beliefs constitute different yet overlapping constructs. I first review academic beliefs and explain the significance of their examination in this study. Then, I review the Framework Theory of Conceptual Change (Vosniadou, 1994; 2007a) that is driving current thought and research in other academic areas (e.g., Venville, 2004). FTCC describes how academic belief shifts and personal and social-contextual variables come to bear on the mental mechanisms that underlie knowledge development.

Academic Beliefs

Academic beliefs comprise learners' understandings about knowledge and concepts in a specific domain. They reflect assumptions that learners accept to be true without the need for external verification required by externally defined forms of knowledge (e.g., fitness domain concepts). Generally learners attribute a valence of importance to academic beliefs over externally verified knowledge (Alexander, 2006; Murphy & Mason, 2006). According to Vosniadou (2007a), academic beliefs play a powerful role in conceptual change because they develop through learners' daily experiences in instructional and cultural settings. Additionally, they mediate the organization and structure of the mental mechanisms involved in knowledge development. Scholars (Buehl & Alexander, 2001; Hofer, 2000; Vosniadou, 1994, 2007a) differentiated academic beliefs into two types. *Ontological beliefs* reflect learners' assumptions about the categories and properties of specific phenomenon in the world. They reflect the attributes learners ascribe to specific concepts. *Epistemic beliefs* relate to how learners perceive the nature of knowledge and the process of knowing. They include at least four dimensions: structure of knowledge (simple vs. complex), stability of knowledge (fixed vs. evolving), justification of knowledge (e.g., causality), and source of knowledge (self vs. external authority). Murphy (2007) noted they also include learners' value for particular topics.

Little is known about the academic beliefs students hold about fitness and the role they play in fitness knowledge development. Physical education scholars (Ayers, 2004; Stewart & Mitchell, 2003) have explained students' incomplete knowledge from a deficit perspective typical of information processing theory (IPT). The IPT perspective can mask students' idiosyncratic attempts to construct their conceptions including their perceived relationships among concepts or their academic beliefs. For example, Stewart and Mitchell reported students' "confusion" between *intensity* and *time.* In contrast, if one reinterprets students' declarative knowledge about *intensity* and *time* as integrated with their academic beliefs, the confusion identified may potentially reflects students' ontological belief about the properties of intensity (i.e., they perceive a connection between the properties of time and intensity) and an epistemic belief associated with the structure of fitness knowledge (i.e., the complexity of knowledge, e.g., perceiving relationships among FITT principle elements).

Physical education scholars also seem unclear about defining knowledge and academic belief constructs and have used the terms interchangeably. Another team of scholars (Dodds et al., 2001; Placek et al., 2001) working within earlier conceptual change approaches that were also IPT-based, reported naive conceptions from a deficit perspective. Moreover, they reported students' academic beliefs as knowledge, noting that researchers typically use the terms knowledge and beliefs interchangeably since the distinctions between the two were fuzzy. In reporting students' beliefs about fitness as knowledge they did not differentiate between ontological and epistemic academic beliefs nor describe how they were related with students' fitness knowledge.

Conversely, more recent approaches explicitly distinguish knowledge and beliefs (e.g., Murphy & Mason, 2006). Adopting the current views on knowledge and beliefs, Placek et al.'s (2001) findings on students' views about fitness, such as "exercise increases muscle size" or "sweating burns fat," may reflect students' epistemic (e.g., causality) and ontological (properties ascribed to fitness) beliefs about fitness knowledge, respectively. Thus, from the contemporary conceptual change theory perspectives, students' knowledge and academic beliefs may represent different, yet integrated, constructs (Murphy & Mason, 2006).

Ennis (2007) recommended future examinations of naive fitness conceptions be grounded in "new and more complex conceptualizations of learning and the learning process" (p. 139) that have been increasingly adopted in other domains. Developmental psychologists' (e.g., Vosniadou, 1994, 2007a) perspectives on conceptual change are based on constructivist learning theory tenets and address the limitations inherent in IPT approaches. Vosniadou assumed that knowledge and academic beliefs were related constructs and re-conceptualized the process of learning as the Framework Theory of Conceptual Change (FTCC). This alternative learning theory has been instrumental in guiding current thought and research methodologies in many academic domains including science (e.g., Venville, 2004). Given that knowledge and belief based cognitive fitness concepts share close ties with science concepts, they lend themselves to this contemporary learning perspective. FTCC can offer insight into the rationales behind students' correct and incorrect responses and clarify variables that mediate the development of fitness knowledge.

Framework Theory of Conceptual Change

Vosniadou and her colleagues (1994; Vosniadou & Brewer, 1992; Vosniadou, Ionnides, Dimitrakopouou, & Papademetrios, 2001) described learning as a knowledge construction process. Based on students' interpretations of their everyday experiences, this process involves acts of personal and social cognition that begin early in infancy. The central element within FTCC is that students' knowledge and perceptions are embedded within naive theories that are academic belief based. Hence, learners' conceptions represent internally coherent conceptual knowledge *systems* irrespective of their degree of naïveté. Emphasizing the complexity of learners' conceptions, Vosniadou described them as a multi-component system composed of many knowledge elements including mental models, perceptions, academic beliefs, and knowledge presuppositions that learners organize in complex ways. FTCC assumptions and key features provide important insights into the development of conceptual understanding (1994; 1999).

Vosniadou (1994) defined conceptual learning as the ongoing enrichment and restructuring of the learners' existing conceptions through their everyday and formal schooling experiences. These experiences are sources that fuel the development of learners' perceptions, knowledge, and academic beliefs. Vosniadou (2007b) explained that when learners' existing knowledge and beliefs parallel scientific understandings, they construct conceptions that reflect scientific thought. Students' participation in the local culture or school environment can enable them unconsciously to gradually internalize, enrich, and/or restructure their ideas. Sometimes, however, students' develop naive conceptions that contain some distortion or misrepresentation of scientific information. These distortions occur because learners' experiences in the lay culture differ from the accepted domain or scientific knowledge. For example, scientific content about the health benefits of fitness may run counter to children's everyday perceptions and observations of fitness benefits in the lay culture (e.g., media portraying that fitness = being thin). Alternatively distortions occur because the fitness concept presented during instruction may entail a complex counter intuitive phenomenon that is not directly observable or perceivable to students (e.g., exercise induced physiological changes). In either case, students may struggle to reconcile conflicting perspectives or unfamiliar phenomenon, developing naive conceptions that comprise a hybrid of their existing conceptions and domain information. Vosniadou denotes that naive conceptions develop both before and during formal instructional experiences.

Moreover, she does not regard naive conceptions as unilaterally negative, but rather views them as necessary initial steps towards more elaborate and advanced scientifically correct conceptualizations of externally verified domain concepts (1991; 1994; 2007b).

In FTCC Vosniadou (1991) articulates a developmental perspective through which naive conceptions grow in sophistication and complexity through their interactions and experiences. Although they seem incoherent and simplistic when compared with scientific forms, they comprise an internally coherent knowledge system when viewed from the learners' perspective. Cognitive learning is a gradual emerging process whereby students' can be helped through instruction to modify the internal coherence of their conceptions to adopt the external coherence of conventional scientific theories (e.g., fitness domain concepts). Through the gradual incremental enrichment and restructuring of learners' ontological and academic beliefs, students' conceptions can change and evolve towards more complex and sophisticated conceptualizations. Influenced by the work of Hatano (2003) within FTCC, Vosniadou (2007b) recently reiterated the purpose of instruction is to provide ongoing social and cultural support that is sensitive to the way students think and reason about specific topics.

Mental model building. FTCC (Vosniadou, 1994) offers a complex hypothesis that identifies mental models as constructs depicting the mental mechanisms underlying conception development. Mental models are domain-specific knowledge structures learners create during cognitive functioning to represent their knowledge (Vosniadou, 1991). They are dynamic, recursive, evolving structures that can exist in three forms, representing a learning continuum. When mental model development is conceptualized as a continuum, learners transition from intuitive to scientific model forms through intermediary synthetic models. *Intuitive models* represent the knowledge structures learners create in their everyday experiences prior to schooling. As students are introduced to formal knowledge in school, they generate hybrid combinations of lay and scientific knowledge described as synthetic models. *Synthetic models* reflect students' efforts to reconcile counter intuitive information using varying amounts of adaptation and re-organization of the configurations of their existing academic beliefs. Although they may contain some distortions, synthetic models reflect learners' attempts to seek mental coherence and keep their cognitive systems free from contradictions (Vosniadou, 1991). Vosniadou (2007a) sustained that because mental models are not static, they can change as students gradually understand and accept scientific understandings. As this occurs, students' mental models grow in complexity and sophistication to parallel the external coherence of scientific theories and develop to more accurate *scientific models*.

Influences on mental model building. According to Vosniadou (1991; 1994; 2007a) mental model transitions from intuitive to scientific are influenced by the symbolic systems (e.g., language) and cultural artifacts (e.g., instructional resources) learners are exposed to and use in their social interactions at home and school. Additionally, transitions in mental models are influenced by learners' ontological and epistemic beliefs as they coalesce to form two types of hierarchically organized naive theories, global and specific, that provide the coherent framework within learners' conceptions. They also mediate the creation and modification of learner's mental models. *Global theories* are the ontological and epistemic beliefs about knowledge in a specific domain, (e.g., fitness), that develop from infancy through learners' informal experiences in everyday culture. *Specific theories* reflect learners' explanations and rationales about specific phenomenon (e.g., the concept of intensity) and develop from learners' everyday interactions and educational experiences. They comprise learners' ontological and epistemic beliefs derived from their culturally influenced global theories, perceptions, observations, and knowledge. Vosniadou maintained that ontological and epistemic belief enrichment and restructuring within global and specific theories can facilitate or hinder mental model development towards paralleling scientific views. For example, when learners hold advanced epistemic beliefs they view knowledge as complex and evolving, and hence, they are more open to modifying their existing conceptions (1994; 2007a).

Methodological guidelines. In addition to offering an alternative theoretical perspective to learning, Vosniadou (1994) offers methodological guidelines to examine students' mental models. Access to students' mental models is facilitated through qualitative methodologies, in particular, the one-on-one interview involving a combination of elicitation techniques (verbalizations, drawings, textual, and actions/performances). These diverse methods permit learners to externalize their subjective understandings in ways that are sensitive to their expressive capabilities. Further, they overcome the inherent limitation of using only one method (e.g., written responses only). Since mental model construction is influenced by students' naive theories, the rationales students use to explain their domain knowledge enable researchers to infer their ontological and epistemic beliefs within their naive theories. Vosniadou (1994) also provides recommendations on how to analyze and infer mental models. Consistent patterns of explanation about a specific concept enable researchers to identify inductively features that characterize "generic mental models" (Vosniadou, 1994, p. 48). Once generic models have been constructed, researchers can then infer the global and specific theories that provide their coherent structure through the careful analysis of the way learners express their views. Since students' conceptions develop in relation to specific contexts, mental models are specific to factors or variables within learning environments that facilitate or limit their development. Hence, researchers need to document the learning contexts in which students' mental models develop

(Vosniadou, et al., 2001).

Summary

In FTCC, Vosniadou and her colleagues (1991; 1994; Vosniadou, et al., 2001) suggested that knowledge development is cumulative process; students' initial conceptions (intuitive and synthetic models) grow from simple to complex. They also emphasized that knowledge growth is influenced by learners' ontological and epistemic beliefs and the richness of the learning settings in which students learn. FTCC provides researchers with a window into student knowledge and academic belief constructions as an integrated conceptual system. Because FTCC emphasizes a contextualized and developmental understanding of students' developing knowledge, the theory facilitates a view of learning that is sensitive to students' way of thinking about domain concepts, such as intensity and the mechanisms they use to gain greater knowledge understanding (Vosniadou, 1994; 2007a).

Methods

Research Design, Setting, and Participants

I conducted an ethnographic descriptive study (LeCompte & Preissle, 1993) involving two sites in an affluent suburban school district located in the Eastern region of the United States (enrollment 41,000; 72% Caucasian, 12% African American, 8% Hispanic, and 4.6% Asian/Pacific/Native American). The physical education curriculum in this district emphasized fitness education k-12 and students' physical and conceptual learning necessary to develop personal fitness. Curriculum learning outcomes included the fitness components, the FITT principle, and understanding the effects of exercise on the human body. Students across all grades took part in written cognitive and physical tests both informally and formally during each quarter of the scholastic year.

Two middle schools, I renamed Beech (enrollment, 762) and Oak (enrollment, 554) served as sites for this research. The district physical education supervisor recommended these schools as quality physical education programs developed by master teachers who emphasized students' cognitive understanding of fitness. School policies allocated 90-minute blocks of instructional time two or three times on alternate weeks for each class. School facilities included outdoor areas (e.g., tennis courts, basketball courts, running track) and indoor areas included fitness and weights rooms and large spacious gymnasia. Each physical education department was comprised of three (Oak) and four (Beech) physical education teachers, respectively. A team of teachers in each physical education department shared the facilities and equipment. In this study, each participating teacher conducted her lessons with one class in a specific facility based on a rotating schedule during each lesson period. The curriculum consisted of integrated sports and fitness-based units. This data collection occurred during the track and field and basketball units at Oak and Beech Middle Schools, respectively.

One co-educational sixth-grade class (approx. 34 students; ages 11 & 12) at each school participated in this study. I selected this grade level because students at this age can experience difficulty understanding the intensity concept (Placek et al., 2001). Sixth grade is the "transitional" grade between elementary and middle school, and student views constitute the prior knowledge for 7th grade and beyond. Further, previous research has documented that physical activity participation begins to decline during early adolescence (Pate et al., 2006). I purposefully selected a representative sample of nine students from each class (n=18) to serve as key informants. Selection was based on class gender and demographic representativeness and the preliminary analysis of students' responses on the first written survey, as detailed in the next section. All students gave assent to participate in this study and returned signed parental permission forms. Teacher key informants included one science (Sandy) and one physical education teacher (Sue) at Beech Middle and one physical education teacher (Pam) at Oak Middle. All were Caucasian and experienced professionals involved in curriculum writing projects within their school district. Sandy, Sue, and Pam held master degrees, had 9, 28, and 18 years of teaching experience, respectively, and provided informed consent.

Data Collection

I collected data between April and June, 2008. Data to elicit students' mental models were collected using written surveys and interviews that were peer-reviewed and field tested prior to administration (Patton, 2002; Vosniadou, 1994). Given the difficulty in posing academic belief questions, I used a scenario strategy (Buehl & Alexander, 2001) presenting students with the scenario that they were teaching their ideas about fitness to a new student, Brendan, visiting their school from a foreign county who never had the opportunity to learn about fitness. In order to develop a contextualised understanding of student's mental models, I also conducted document collection, field observations, and teacher interviews (Patton, 2002; Vosniadou et al., 2001).

Student survey. Two 15-min. surveys that served as pre-interview tasks for the selected interviewees were administered before and after each sport unit to all the students in each class during their regular physical education periods. I administered the first survey in early April to obtain baseline data examining students' beliefs about fitness value and benefits and their knowledge of fitness components and the FITT principle. I primarily used open-ended questions that permitted students to write and draw their responses. I also included a matching item question and two closed-ended true or false items while providing space for students to explain their choice. I used the survey responses to identify the interviewees and as probes during the first follow-up interview.

I administered the second survey to both classes at the conclusion of the unit in June, adapting the content to reflect the track and field and basketball units conducted at each school. Examples of both questionnaires are provided in the dissertation appendix (p. 271). Open ended questions focused on examining interviewees' (a) understandings of physiological indicators associated with exercise intensity and (b) applications of the fitness components and the FITT principle within the track and field or basketball units.

Student interviews. I conducted one-on-one semi-structured open-ended interviews (approx. 30-min.) with the 18 students following the administration of each survey. Examples of the interview questions are presented in the dissertation appendix (p.271). I conducted the teacher and student interviews in the health or counseling room when feasible (e.g., during "tutoring time" on non-PE days and during their physical education lessons). A semi-structured format enabled me to ask each student the same questions, yet permitted me flexibility to ask questions specific to the student and learning environment. During both interviews, I asked questions to determine the cultural and academic sources of students' responses (e.g., Where did you learn this? or How did you learn this?) to identify the contexts that shaped their conceptualizations. I sought informal clarifications from some students' during ensuing lessons to ensure accuracy of the interview transcripts.

The first interview was intended to elicit students' domain knowledge and ontological and epistemic beliefs (value, structure, stability, and source of knowledge) about fitness in general, the fitness components, and FITT principle. The interview protocol included visual prompts in the form of picture cards (Placek et al., 2001) depicting different physical activities to probe for students' understandings about the fitness components represented on each card.

Performance prompts also were used to allow students to demonstrate how to perform fitness tasks, such as measuring their heart rate to check cardiovascular endurance intensity.

The second interview elicited students' applied explanations of fitness components and the FITT principle in relation to the sports unit they had just completed. Additionally, students were asked to elaborate the effect of exercise intensity on the physiological changes they reported on the second survey and explain their direct experiences of intensity during their participation in physical activities I had observed during their lessons (e.g., mile run, shot put, and spot shoot).

Document collection. I conducted a content analysis (LeCompte & Preissle, 1993) of many types of documents associated with students' learning of fitness concepts. To determine the concepts teachers presented and instructional resources they used to facilitate learning of fitness, I examined the district physical education and science curricula, the physical education teachers' manual for *Fit for Life* (Corbin & Lindsay, 2005), instructional resources such as posters, and web-based instructional resources (e.g., power point slides, lesson plans; heart rate monitor instructional material) teachers used at both the elementary and middle school levels to examine how these concepts were instructionally aligned between these school levels. Additionally, I conducted a content analysis of students' physical education fitness portfolios, science textbooks, and sample work sheets to understand information sources that may have influenced students' developing fitness knowledge.

Field observations. Primarily in the role of non-participant observer (Patton, 2002), I observed 12 lessons at each school during the 4-week sports unit to document the nature of the physical education class. On days where lesson observation conflicted with a student interview, I observed the same lesson teachers conducted with other sixth grade classes. I focused on detailing teacher's content delivery, use of instructional resources, and students' responses and actions. Where possible, I also posed informal questions to students about events or content I observed being taught during the lesson (e.g., students: What does "pulse check" mean? teachers; Where did you get that poster? How do you use the poster in this lesson?) These data were incorporated within the lesson descriptions I reconstructed and detailed after each observation.

Teacher interviews. In mid-June I conducted semi-structured interviews (approx., 90-min.) with all three teachers. The interview protocol I used with the physical education teachers comprised open-ended questions to examine how they taught the fitness components and FITT throughout the year. I asked them to explain how they introduced and spoke about these concepts with sixth graders. Further, I asked about their perceptions of student learning and sought clarification on their instructional strategies. During the first interview, many students remarked that they connected what they learned about the effects of exercise intensity and the muscles with their science education experiences. Hence, although my original research design had not envisioned interviewing science teachers, given the emerging nature of this study, I sought permission and interviewed Sandy to learn about her instruction in science associated with the effects of exercise and human body systems.

Data Analysis

The preliminary analysis of the first survey enabled me to categorize interviewees across the range of cognitive ability in the class. Recently, scholars in science recommended the purposeful selection of students with a range of ideas to examine students' mental models (e.g., Venville, 2004). I organized students' questionnaires into three groups from which I purposefully selected three students to represent the high, middle, and low range of cognitive understandings of fitness concepts, while also considering demographic and gender representativeness. I sought confirmation with Pam and Sue that the selected students were representative of their sixth grade classes and would be willing to participate on the interview.

I was involved throughout the data collection process in ongoing multi-level data analyses. First I used open coding procedures (Strauss & Corbin, 1998) to categorize students' verbatim responses and triangulated data from their portfolios, the surveys, and interviews (including descriptions of their actions and drawings). I next re-examined the data, using each student as a case, contrasting similarities and distinctions in their knowledge and epistemic belief responses, and organizing data into different emerging categories. I inferred students' ontological beliefs through the analysis of words and phrases students used to describe their conceptions about intensity. This initial coding process led to axial coding procedures (Strauss & Corbin, 1998) that helped me identify inductively contrasting features in students' explanations and the range of variation in their knowledge and academic beliefs associated with the concept of intensity and its relation with other FITT elements. This led me to build the generic mental models (Vosniadou, 1994) students used to answer the range of questions associated with intensity. Because my first attempt to create the generic mental model was an inductive process, as a validity and reliability check I re-analyzed each student case at the model level to check my categorization of students' into the model groups and verify the match between their responses and model I inferred (Vosniadou, 1994). Then, I reexamined all contextual data (document collection, field observations, and teacher interviews) in conjunction with another examination of students' epistemic beliefs associated with the source, stability and structure of knowledge about fitness in general (in addition to the intensity concept). This permitted an examination of variables that could be related to students' developing understanding of intensity and FITT. To ensure trustworthiness I conducted negative case check, peer review, and teacher member checks.

Results

The purpose of this study was to apply Framework Theory of Conceptual Change (Vosniadou, 1994) to an examination of students' mental models of exercise intensity. I present the results in four parts. First, I describe the opportunities students had to learn about the FITT principle. Second, I review teachers' views on teaching and learning the concept of intensity. Third, I review students' shared knowledge and academic beliefs about intensity upon which the inferred mental models were based. Finally, I detail three generic mental models students used to explain intensity.

Students' Opportunities to Learn the FITT Principle

Vosniadou et al. (2001) stressed that students' conceptions should be examined in the context in which they develop because this environment can reveal sources of students' knowledge, perceptions, and academic beliefs. The student data revealed that all students in both schools were familiar with the fitness components and the FITT principle. They described their declarative knowledge about the FITT elements correctly as frequency, intensity, time, and type. When asked to explain these, they consistently used short descriptor questions, such as "how often you should exercise," "how hard," "how long," or "what kind of physical activity?" to define each respectively. Brian explained, "FITT is a template to get to all the fitness components." Others elaborated that the purpose of FITT was "to help you know all you need to do to make sure you're exercising right without over doing it," [Carly] and "to help you make sure you work on a variety of fitness activities so you balance things out" [Yana].

It was clear from the students' explanations, their teachers' remarks, and the school district curricular documents that students began learning about the fitness concepts and FITT principle during their elementary school physical education experiences. The teachers explained that students entered middle school already accustomed to the “language of fitness” [Sue] and to using “fitness tools” [Pam] such as heart rate monitors and pedometers; “We build on that prior knowledge and review the same concepts but in more depth” [Sue] and “extend and apply them throughout out sports units” [Pam]. Working on the FITT principle both physically and cognitively was integral to these teachers’ programs. At the middle school level, students were exposed to the FITT principle information in a variety of ways, including teachers’ explanations, posters affixed on the gym and fitness room walls, and their fitness portfolios. Portfolios comprised reading information and written tasks about FITT (brief constructed responses, true-false, and matching tasks items) across the four academic quarters of the school year.

[Insert Figure 8 about here]

Figure 8 illustrates examples of instructional posters and portfolio entries used in these two schools. In addition to the school district FITT poster, Pam created additional posters to help her students visualize how FITT could be adapted to different physical activities (see ii in Figure 8). She explained:

> They have this [school district] poster (see i in Figure 8) also in elementary. [But] I try to break it down [for them] so that they can understand each part of it and see how it changes depending on the component [i.e., type] they’re working on. Each time they come in here the posters are there in their face kind of. So they get the FITT message constantly without realizing it’s coming at them.”

Both teachers projected a flexible, life span approach to applying the FITT principle to develop a personal fitness plan. They wanted to help students realize that “they can tweak the formula to fit their own needs because everyone is going to be different” [Pam], and that “FITT is something essential they can use and adapt to their lives. FITT is not a rule but a general guideline. We have to make it specific to ourselves because fitness is something personal" [Sue]. Pam and Sue also helped their students develop awareness that fitness information, including the FITT principle recommendations, change. Sue explained:

> I've told them "Frequency" used to be three days a week, and instead now the most recent poster says: "on all or most days of the week." But I want them more to understand that we have to differentiate between someone who is just starting out and can do 2 or 3 days a week and someone who is already fit and can handle more.

Conceptual Complexity Inherent in the Intensity Concept

Both teachers remarked that intensity was the most challenging concept in the FITT principle for sixth grade students to understand. "It's also the hardest one to teach. That is why I try to hit on it in every unit" [Pam]. The complexity associated with learning intensity appeared to be related to three factors. These were the (a) abstract and multifaceted nature of the intensity concept, (b) relationships among intensity, time, and type elements, and (c) variations in optimal intensity level based on individual characteristics, such as age, gender, weight, and health.

The abstract nature of intensity. The teachers explained that intensity was an "abstract concept" [Sue] that could be manifested indirectly in many ways. For example, during the basketball unit I observed Sue on several occasions called out to her students, "Pulse check!" signaling them to stop moving, measure their heart rate, and monitor whether they were "working with intensity." She also used phrases such as "If you can add one more curl up today, that's an example of intensity." When I inquired about her use of these different phrases Sue explained:

> There are just so many examples of intensity. How they are feeling, sweating, out of

> breath, feeling sore....The number of calories they read off on the treadmill or rower; those are all ways in which they can say "Oh! That's an example of intensity.

The document review indicated that students had participated in intensity experiments. Examination of their fitness portfolios and science lab books revealed students had measured, recorded, graphed, and discussed in writing the patterns in heart rate change during activities at varying levels of effort (e.g., lie down, sit, stand, march, run, jump, jacks sit, and lie down again).

The relationship among intensity, type, and time. The second factor that appeared to enhance the complexity of the intensity concept for students involved the relationships between intensity and both the type of exercise performed and the time or duration of exercise. Both teachers emphasized teaching these relationships in their units. Pam explained, that "intensity can be [described in terms of] heart beats on aerobic activities, the amount of weight for muscular strength or endurance, or tension you feel as you stretch." Sue explained that in elementary physical education students are most often exposed to cardiovascular intensity. In middle school students need to extend the intensity concept to other fitness components. She also noted that the level of intensity would differ depending on the position played in a game (e.g., the goalkeeper vs. field player) or the nature of the tasks within a sports unit. For example, during the basketball unit Sue explained to her students, "you're going to be involved in different stations; they have different intensities. In some you're going to run with short little bursts of energy, others, you'll stay in place and just shoot." Students then rotated through a series of active basketball stations involving dribbling skills interspersed with static stations where they took "spot shoots," walking up to an X taped on the floor to shoot from a side angle to the hoop.

I also observed Pam targeting the muscular strength component during the track and field unit. When introducing the shot put, Pam explained:

> The shot put is a strength activity; the intensity is in the weight of the shot. You're going to use 6 or 8 pounds. It gets heavier at high school.... [and] at the Olympic level. You have to use a lot of power in a short time on this one [event].

Both teachers also emphasized teaching that "intensity involves a balance between time and intensity level" [Pam]. Sue elaborated:

> I've told them intensity relates to *how long* you do something and *how hard* you do something and there's so many combinations you can do. I guess we could put columns for all the different kinds of ways in which you can look at intensity. That's why I stress with them that you can always find something that you can do for yourself with intensity. Because you can find a "how hard" that is right for you and a "how long" you can handle.

Pam and Sue indicated they did not emphasize a relationship between intensity and frequency as much as they emphasized the other elements. Sue explained:

> In their [fitness] portfolio, there's the distinction in *frequency* for each of the components, 3 to 5 days for cardio, strength and endurance, 2 days a week and so on. But for sixth grade I don't put too much emphasis on differentiating between what kinds of exercise you should do on which days. What I talk about most is not using the same body part every day and I go over the principle of recovery, overload, specificity, and progression.

Variations in intensity levels. The third factor that increased the complexity of teaching and learning the intensity concept was the variation in intensity level based on individual characteristics such as age, weight, and health. Both teachers commented that they tried to help sixth graders understand the need for variation in the intensity recommendations. They explained that the guidelines did not apply in the same way to all individuals because of many factors, including an individual's experience in an activity, current fitness level, gender, and age. For example, when introducing the first shot put practice, Pam asked her students to "feel and choose the [shot put] weight that's right for you so that you'll experience what putting the shot feels like without tearing any shoulder muscles." Pam also indicated she tried to counteract students' initial assumption that a low heart rate means that someone is out of shape or is overweight. She explained students received conflicting cultural messages about the "right intensity" and "being in the [healthy fitness] zone:"

> Because they hear so much about obesity! And it may not all be true. So I tell them, even the skinniest kid in the class can be below the zone. Obesity does not always mean the person is out of shape and being thin does not mean the person is always fit. I want them to see that even someone that's at a low intensity can have intensity in their work out.

Sue shared with her students that target heart rate range (THRR) changes with age. During the first term, students participated in a portfolio written task in which they computed their personal target heart rate range using a formula involving 65% and 85% of their maximum heart rate (assumed to be 220 minus age). Sue explained,

> I work it out with them on the board and we compute the THRR for a sixth grade boy and girl. Then I tell them what mine is because I am older. And we also compute what THRR would be for a 70 year old so they can see how the range moves down the older you are. And they go! Oh wow! Because 220-70 is a lot different from 220-11.

Sue noted that even recommended intensity guidelines for intensity do not apply to everybody within the same age group in the same way. She elaborated:

> It sounds so simplistic to say to them I want to see you working with intensity! You should work at least moderate. I want them more to understand what it means to feel that they've worked with intensity. [I want them to find] what is just challenging enough for them only because different people may need different things. THRR is just an approximation. The "right intensity" is something very personal. The 11 year old athlete needs to learn how it feels to be in the upper range of the target range, for my overweight student, being barely in the range may be the right intensity for her; for a child with asthma it will also be different.

Students' Shared Knowledge and Academic Beliefs about Intensity

These sixth grade students' shared knowledge associated intensity primarily with physical exertion. John explained, "Intensity is literally how hard you're working your body." Emma concurred emphasizing, "It is how hard your body has to work to keep up with your body movements during exercise." Students' shared academic beliefs appeared to be more influential than their shared knowledge in their conceptualizations of the intensity concept.

Shared Academic Beliefs

Some epistemic and ontological beliefs were common among all students. They formed part of a foundational coherent belief system for each mental model. Hence I assumed they formed part of students' global and specific theories. While I inferred epistemic beliefs related to the source, structure, and stability of fitness knowledge, because there were variations in these beliefs both within and across mental model groups, I present them later when I describe each generic model.

Epistemic Beliefs: Justification of Knowledge

Students described two beliefs associated with students' justification of knowledge.

Figure 9 illustrates survey responses reflecting students' belief that intensity existed and was a causal agent.

[Insert Figure 9 about here]

Intensity exists because it can be felt. Learners often believe something exists if is detectable through the senses (Vosniadou, 1994). In this research, Al explained, "you can feel intensity" and Emma explained that, "you can feel it [intensity] on your body when you exercise." Although intensity was not something students could see or observe directly, they were able to detect it through other perceptual sources of information. For instance, students' experienced the effects of intensity indirectly through their bodies during their physical education class. They reported an increased heart rate, breathing rate, and body temperature (e.g., becoming hot and for light skinned students, red in the face), sweating, having a dry mouth, and feeling tired and sore muscles.

Intensity is a causal agent. Vosniadou (1994) pointed out that students often use causal explanations to describe the effect of exercise intensity on the human body. In this research, Ray explained that "exercise is like a cause-effect type of thing." Others students, including Linda, perceived this relationship and reported that, "running the mile makes my heart beat faster. The faster I run, the faster my heart rate." When Emma explained her drawing presented in Figure 9, iii, she elaborated that intensity "makes it harder to breathe because I have asthma."

Ontological Beliefs: The Nature of Intensity and the Human Body

Students reported two ontological beliefs associated with the concept of intensity and the human body. They appeared to use their naive biological and physical science theories related to understanding human body functioning to explain fitness phenomena and physiological adaptations to exercise.

The nature of intensity. Students attributed three properties to the concept of intensity. First, all students ascribed intensity a form. Although many students' responses reflected a belief that intensity existed in one form, a few remarked it existed in multiple forms. I elaborate on this property when I present the three generic models. Second, students assumed intensity could be measured and described in diverse ways. John explained, "intensity can be measured by if you're sweating or by if your heart is beating faster than usual," and Al pointed out that when lifting weights "intensity is determined by the amount of resistance." Third, students noted intensity involved different levels of effort that could be controlled by the individual. Sally explained, "It can be at a high, middle, and low level. You can adjust it by slowing down or speeding up your pace so that you're within the target range." Also Dina remarked that "you *put* intensity on your muscles."

A human machine. Students viewed the human body as a machine and applied four properties to explain its adaptations to exercise. First, when exercising, the human machine had to work harder and faster than when resting. Jim used the analogy of a "car" to explain that as muscles start to work harder, the body begins to heat up with increased speed. Second, students perceived a proportional relation between the functioning of the machine components (e.g., heart) and intensity level. For example, Sandra wrote in her fitness portfolio, "The faster I was moving the faster my heart beat went up. And the slower I was moving, like just lying down, the slower my heart beat was. My heart rate went down." Third, the human machine had a "working limit" [Evan] in which it could function effectively. Linda explained that "there is healthy zone of heart beats you have to be in." In describing the target heart rate range [THRR] of 130-185 beats per minute (bmp), all students explained that a heart beat above the THRR was too high. Several including Victor recommended "slowing down into the range, so that you're sure you're not overworking your heart." Finally, the human body used a reserve of energy during exercise. For example, Ray explained. "When you work with intensity, your muscles get tired. Your body, it's like a battery. It loses energy and it needs to charge up by resting or going to sleep."

Mental Models of Intensity

Despite experiencing similar instructional lessons, students perceived or created different conceptual understandings. They internalized information about the FITT principle, especially intensity, in diverse ways. While students shared some knowledge and academic beliefs, they also differed in how they organized their academic beliefs, knowledge, and perceptions about intensity within their mental models. I inferred three consistent patterns in students' explanations of intensity, thereby, suggesting they were operating from different generic mental models. These models revealed the diverse specific theories students developed and used to explain intensity.

The distinctiveness of each generic model was based upon variations on three criteria within students' responses: (a) the nature of intensity, (b) fitness development intensity levels, and (c) the relationships of intensity with other FITT elements. These criteria emerged through the inductive analysis process. Students *within* each model group shared the characterizing features of the model based on criteria (a) and (c), above. I applied a fourth criterion, (d) epistemic beliefs related to the source, structure, and stability of fitness knowledge, after I categorized the students at the model level. There were distinct variations within a model group in students' explanations on some criteria. Likewise, there were some parallels on a particular criterion across model groups. Hence, while each generic model represented an overview of characterizing features shared by a specific group of students, the responses of students within that group were not always homogenous within each of the four criteria. The variations illustrate that both across and within the generic models, students organized their knowledge, perceptions, and academic beliefs differently on some aspects, while they were quite similar on others.

Although I present the models in an order of increasing conceptual complexity, they do *not* depict sequential phases. Instead, they reflect cross-sectional snap shot descriptions tracing knowledge development about intensity within specific environmental settings. While acknowledging that students are unique and thus following their own conceptual learning paths, I present data from a few students that I categorized into each model group to illustrate the characterizing features of each generic model and, where relevant, also variations within each generic model group.

To facilitate my description of each model I assigned a title that reflects a focus on criteria (a) and (c). The first part of the title denotes students' ontological belief about the nature of intensity, that is, whether they assumed intensity was one generic form that was unchanging (MM1), one generic form that changed according to the type of physical activity (MM2), or existed in multiple forms for each physical activity (MM3). The second part of each title, following the colon, denotes students' perception of a relationship between intensity and another FITT element(s).

Generic Fixed Cardio: Intensity-Time Model (MM1).

Defining features. Students categorized into MM1 (n=5) believed intensity comprised one generic form that they applied irrespective of activity type. For these students, fitness development required moderate to vigorous intensity levels. They perceived a relationship between intensity and time, and most held less advanced epistemic beliefs regarding the source, stability, and structure of knowledge.

Nature of intensity. All students held a fixed generic form of intensity associated with cardiovascular endurance. The following extract from Victor's interview illustrates this model:

> You want to exercise at a moderate [intensity] or until you sweat because it will help your cardio-endurance, and it helps you do stuff longer, and you won't get tired that easily. Also, when we're doing the weight machines for [muscular] strength and endurance, you want to do moderate or until you sweat. The same for the hamstring stretch [flexibility], moderate or until the sweat starts coming....You can check if you are working at the right level by checking if you are in the healthy target heart zone for cardio. It's 135-180 for muscular endurance… strength…and flexibility exercises.

While this quote demonstrates that Victor held a conception of intensity that was scientifically correct for cardiovascular endurance activities, his description was limited and did not explain accurately how the intensity concept was addressed in other fitness components. Although students categorized within this model were aware that THRR was 135-180 bpm [Victor, Suzy, Liam, and Sandra] for 11-12 year olds and represented a method to measure intensity, they applied the cardiovascular concept, THRR, irrespective of physical activity type. This perspective on intensity parallels findings in previous research conducted at the high school level (Stewart & Mitchell, 2003). These MM1 students seemed unaware THRR was not used to measuring intensity in physical activities promoting muscular strength, muscular endurance, and flexibility.

Fitness development. Each student reported that recommended intensity levels for exercise were either the school district poster message of "moderate or until you sweat" [Victor; Liam, Suzy] or "moderate to high/vigorous" [Jim; Sandra]. They remarked that low levels of physical activity would not promote fitness and health benefits. Their rationales included, "low is not going to do anything and you won't gain muscle" [Victor], "if you do low, then you'll be barely fit" [Liam], "low is not going to do anything because you have to push yourself more than usual" [Sandra].

Connections among FITT elements. Students' explanations reflected a relationship solely between intensity and time. They also assumed intensity related to energy usage. They articulated two different intensity-time-energy relationships and applied it irrespective of physical activity type.

In the first variation, two students assumed that a proportional relationship between time and energy could be used as a criterion to determine the intensity level of a physical activity. They assumed that the longer the duration of an activity, the more energy that is required, hence, the more intense the activity. In comparing diverse track and field events, Jim explained, "The shot put is less intense than the mile, because you only do it for a short time. It's the time that counts. You don't lose a lot of energy to do that [shot put]." Liam echoed the same rationale, but also remarked the number of muscles involved could be a criterion to determine the intensity level of a physical activity.

> The more your muscles are moving, the more intense the activity. The spot shoot is low [intensity] because I only use a few arm muscles for a couple of seconds to push the ball up into the ring....When I'm doing the bicep curl with a dumb bell, I'm only doing that for a short time, say 1 minute on each arm, so that's low intensity.

Jim and Liam's rationales illustrate that the time criterion was of primary importance, irrespective of the type of physical activity and the intensity level within the activity, itself. They seemed unaware that the amount of weight/resistance in the shot put or dumb-bell also plays a role in determining the level of exertion in muscular endurance and/or strength development events.

In the second variation, three students perceived a proportional relation between the intensity *level* within a specific activity and energy expenditure that could be inversely proportional with time (i.e., an activity can be a high intensity level, uses a lot of energy, but is performed for a short time). For example, Suzy explained:

> If you do high [intensity], like sprinting, you won't be able to go for a long time because you use up all your energy in a short time. If you use a moderate rate, it won't tire you out as much and you can go longer because you've saved energy. That's why you have to pace yourself for 800m or the mile.....That's why it's better to use a moderate rate when you are lifting weights, so that you can last longer.

Suzy's response reflects some MM1 students' awareness of a relationship between time and intensity level that is central to a scientifically accurate understandings of the concept of "pacing." However, she applied this relationship across all physical activity types, assuming that the "moderate rate of movement" she applied successfully to cardiovascular endurance tasks also applied to muscular endurance tasks (vs. weight or resistance).

Students within this model group did not seem to perceive a connection between intensity and frequency. Although they were aware of the frequency concept, they reported diverse rationales within their explanations. Four students indicated that physical activities that addressed all fitness components were necessary "on most or all days of the week" (echoing the instructional message from the school district poster and the first quarter FITT reading assignment in the fitness portfolio) because otherwise "you get sore" [Suzy], "run out of energy when you do things" [Jim, Victor], and "will be tired all the time" [Sandra]. These rationales reflect ontological beliefs they found plausible to explain frequency, such as batteries must be charged or physical activity prevents stiffness. In contrast, Liam explained that frequency should be, “3 to 5 days a week so that you can give your muscles a rest in between and [they can] charge back up stronger.” Like his peers, Liam’s explanation also reflected the battery concept. His rationale, however, reflected a specific theory that also reflected awareness for the scientifically correct fitness “principle of rest and recovery” (Corbin & Lindsay, 2005).

Source, structure, and stability of knowledge. All students categorized as MM1 relied on their physical education teacher as the primary source of fitness information. For example, Sandra explained, “I have to ask my physical education teacher. Adults know more than I do. And sometimes my brothers and sisters.” One student indicated he also sought information for himself. Victor explained that, although he asked his teacher most often, at times, he checked his portfolio or the internet to find the words and definition he could not remember.

Most students held less advanced epistemic beliefs regarding the structure and stability of knowledge. They argued that fitness information was simple to learn, reporting for example, “FITT is easy to learn, because you only need to know what the letters mean” [Victor]. Four students indicated that fitness information does not change. For example, Liam remarked, “FITT and the components have been the same since elementary.” Victor, in contrast, was the only students within the MM1 model group who indicated “maybe in the future FITT could change because scientists and doctors might discover more stuff.”

Generic Transformative: Intensity-Time-Type Model (MM2)

Defining features. Students (n=9) categorized into MM2 conceptualized a generic form of intensity that changed depending on activity type but held two diverse views on fitness development intensity levels. They all perceived a relationship between intensity, time, and type, and the majority assumed that different configurations of this relationship balanced out to achieve the same intensity and energy usage. Most held more advanced epistemic beliefs than did students categorized into MM1.

Nature of intensity. Students categorized as MM2 perceived one form of intensity that changed depending on the type of activity and the fitness component it promoted. Evan explained, "Intensity depends on type. It transforms depending on what you're doing." Also Al noted, "intensity changes according to the fitness component you want to work on."

All MM2 students varied their explanation of intensity and its measurement in relation to the type of activity. For example, they described three methods to determine and monitor intensity level before/during/after cardiovascular events, including: (a) counting the total number of steps on a pedometer, (b) measuring their heart rate (manually or using heart rate monitors) and checking whether it was in the THRR, and (c) reading caloric expenditure units and heart rates on the digital screens on fitness machine (e.g., rowers). In contrast to MM1, the MM2 students explained that the intensity of flexibility exercises is monitored through tension, by "checking how you feel as you stretch. I just go a bit farther than I usually do, but not too much" [Carly]. They noted muscular endurance and strength intensities were determined by (a) the amount of weight: "you want heavier weights for strength and lighter weight for endurance" [Ian], or (b) the body position you used: "you can modify… do full or kneeling pushups to change the amount of resistance you push against" [Al].

MM2 students' presented two different explanations of the THRR. Similar to MM1 students, eight MM2 students indicated that 130/135-180 bmp "was the healthy zone of heart rates. Because you can have many heart rates. You just want to be sure you don't go under 130 and over 180" [Linda]. However, one student, Carly explained that target heart rate should be one number (not a range):

> It's 180. Because you want a stable heart rate so then your body's going to be able to not worry about going up and down. Because if it is constantly changing, it's going to need different energies. But if intensity stays the same, the heart, it's going to be put into a routine so that it knows what to do and you can improve instead of [student demonstrates fluctuating movement up and down with right hand].

Carly's explanation revealed awareness of a proportional relation between intensity level and heart rate. Although she had computed her personal target heart rate range [139-182] in her fitness portfolio and had used heart rate monitors, she was operating from an ontological belief that a steady heart rate represented one number. She believed that 180 bpm would be more efficient to promote fitness development. Analysis of the contextual data revealed that the source of this belief could be related to the way her teacher [Pam] encouraged students during class exclaiming, "Keep a steady pace! An intensity that's right for you!" on the mile run. Pam also emphasized a steady pace associated with the time element: Pam pointed out:

> I explain that time, for aerobic activities, has to be constant. If you are watching a TV show and there are 6 commercial breaks at 2 minutes each, and you do jumping jacks during the commercial breaks… You can't count that time together and say okay I've done 12 minutes of work. Because your heart rate did not stay at a constant; you watched TV in between. Your heart rate needs to be at a constant so if you're doing it for 20 minutes, it needs to be a straight 20 minutes: not stretched out into little periods.

Fitness development. There appeared to be two variations in MM2 students' recommendations on intensity levels to promote fitness and health. In the first variation, students (n=4) explained that at least a moderate or moderate to vigorous level was necessary. Although this explanation was similar to that of the MM1 students, MM2 students' rationales were different. For example, they argued that this level was important because you have to challenge your body to reach fatigue so that you can rip muscle [John; Ian], "you have to push yourself so that your heart gets used to pumping faster with less effort" [Carly], and "only with moderate to vigorous you'll get more power into your muscles [Ian]. These varied rationales reflected varying degrees of scientific accuracy. For example, Carly's explanation reflected her awareness of the overload principle and the cardiovascular endurance benefits associated with regular participation in physical activity. In contrast, John's and Ian's rationale reflected a more naive belief derived from their science teachers' 'no pain, no gain' explanation. I elaborate further on this during the explanation of criterion (d), epistemic beliefs, within this model.

In the second variation, students (n=6) explained that, in addition to moderate and vigorous, low levels of exertion could facilitate health and fitness development. They explained that determining the right intensity levels depends on "the persons' base fitness level and experience on any activity" [Aldo]. Additionally, they indicated that age could be a factor in determining the intensity levels necessary to achieve health benefits. For example, Evan explained:

> I learned this year [in PE] that with intensity you can't work your heart too much because you have a maximum heart rate. I think that's why I see adults, like my grandma just walk and my mom jogs rather than runs. They have a lower maximum heart rate than us kids and they don't have as much energy. They need low and moderate [respectively] so they don't work their heart too hard.

These six students noted that low intensity levels could be foundational to higher levels for children and young adults. Their explanations echoed the scientifically correct principles of progression and overload. For example, Yana, explained:

> If you're just starting out, then you probably have to start at a low level, but then slowly, you need to build yourself up to moderate because you want your heart trained in the [target heart rate range] zone for cardio....You may want to do one light weight and as you get used to it add more [weight] to improve your muscular strength.

Connections among FITT elements. MM2 students perceived relationships between intensity, type, and time elements of the FITT principle. Depending on the type of physical activity, they indicated that intensity level could be either proportional or inversely proportional with time and was associated with energy usage. For example, John explained:

> Time does matter, depending on what you're doing. Choosing the right level of intensity for strength would be a heavier weight, say 60 pounds to push [imitates leg extension on leg press], and you'd do that for a short time, say 20 times. For [muscular] endurance, you'd only want 30 pounds and do it for 100 times, about 2 minutes or so. It's like you're dozing [using] a lower [amount of] energy for that time.

Seven MM2 students explained that different combinations of intensity levels, time, and activity type involved the *same* amount of intensity and energy usage. For example, Aldo explained, "if you run for one hour or walk for two hours, it's the same energy and intensity, so you can still get the same exercise benefit." Similarly, Linda explained:

> If you are lifting a heavy weight for a short time, it will like average out to, like, if you're lifting a lighter weight for a long time. It will be the same because the big one is harder [high intensity] and you need more calories [energy] to lift it, but the lighter one is easier [lower intensity] and you'd use less calories [energy]. But because you do it for a long time it gets harder like the big weight and uses the same number of calories.

Similar to MM1, the MM2 students did not appear to comprehend a relationship between intensity and frequency. They explained the recommended frequency was "most days of the week," "every other day," or "3-5 days" of the week, but differed in their explanations of how the fitness components should be targeted. Two students explained, "You need to spend at least one day on each component to become fit all round" [Linda]. Seven recommended targeting a combination of components on each day. Evan explained, "you can break it up and mix them up [component] in the same work out," whereas Ray suggested that "you can target muscular endurance and cardio one day, and flexibility and strength on another. It's flexible." Unlike the majority of MM1, the MM2 students spread out physical activity through the week showing awareness for the principle of rest and recovery. Carly explained the importance of rest:

> You'd need to do it [an exercise] every other day so that you can give your muscles a rest in between so they are not working constantly. On the off day, they build back up with more energy so they're stronger. If you don't rest, they'll be weak.

Carly's response may reflect the influence of the ontological belief that the human body must not be over worked and needs time to recharge (battery concept), whilst reflecting an increasing alignment with the principle of recovery.

Source, structure, and stability of knowledge. Like MM1, all MM2 students credited their physical education teacher as the primary source of fitness knowledge. Carly explained, "I need my teacher to help me learn fitness stuff. She gives me a lot of examples, explains things in different ways so I work off those." Ray explained, "I learn from my physical education teacher. She's an expert on fitness and physical education. She knows more than I will be able to find out on my own. I learn different things from different teachers." Others (n=5) additionally conducted research independently after class using their physical education portfolio, the internet, and library resources. For example, John explained that he also used his personal books about the human body for additional review when he was learning about the muscles during physical education and science.

Several students noted that their science teacher was another source at school from whom they learned about the effects of exercise intensity on the human body. Ian explained he “connects” what he learns in physical education with science. He indicated his science teacher also explained how the human “body has to work harder to get more oxygen during exercise.” He watched “Brain Pop” instructional videos during his science class “about how muscles are powered by a sugar called glucose and oxygen... Your muscles use them as energy to work harder.” Similarly, John explained:

> I learned in science why you need to use the principle of overload. It’s so that you can reach fatigue. When your muscle fibers reach fatigue, they will rip in half, so there is a really big tear. And then new muscles will come out of the parts that were ripped and then they will meet in the middle. That is how you get stronger and bigger muscles. If you use low intensity, it will take you a very long time to reach fatigue. But if you do moderate and high, you will reach fatigue faster.

The science teacher, Sandy, confirmed John’s explanation pointing out, “I also ask if they’ve heard coaches say ‘no pain, no gain?’ That’s what they are talking about. Its working hard and the pain in the muscles ripping so they can get stronger.”

Students (n=5) also learned about intensity in their home environment. For example, Al detailed “my dad told me how the muscle tissue gets little tears when you exercise hard and they need time to heal.” Evan explained that playing video games helped him understand time, energy, and intensity because “Pac Man has to balance them out to have stamina to last the game.”

Most students in MM2 held more advanced epistemic beliefs related to the structure and stability of knowledge than did MM1 students. They explained that fitness information had different levels of complexity. Some indicated that fitness information could be "easy to learn because I work at it" [Ray], while others explained, "some things are easy, but things like the names of muscles and how they work together is much harder" [Yana], and "seems easy, but when you go in depth, you begin to realize it is more complicated" [John]. Several students shared an evolving awareness about knowledge. They explained that the fitness knowledge one possesses changes and that fitness information itself could change. Carly explained, "I know more now than I did in elementary, and I know I will continue to learn more." Others, including Ray noted that his teacher explained "Time has changed! From 30 to 60 minutes, so I would not be surprised if it changed again." Similarly, Yana explained, "Fitness information changes. The [food] pyramid has changed, and they're always finding new ways to design fitness machines and workout routines."

Multiple Forms: Intensity-Time-Type-Frequency Model (MM3)

Defining features. Students (n=4) categorized into MM3 held a manifold conception of intensity. They all perceived a relational structure among all the FITT elements that they applied in flexible manner to design a fitness plan. They held the most advanced epistemic beliefs across the three models.

The nature of intensity. In contrast to other mental model groups, MM3 students conceptualized multiple forms of intensities, understanding that there "can be many different ones [intensity] for the different activities" [Sarah]. Brian elaborated:

> There's not one intensity because it depends on what you are doing. If you made a table, there are probably different columns. You cannot put every workout into one column.

> Like if you have cardiovascular endurance, it's a different intensity than like doing the shot put for muscular strength, because strength is more about your muscles.

Similar to MM2 students, MM3 students varied their explanations of intensity and its measurement/monitoring, depending on which fitness component the physical activity promoted. Additionally, they explained that recommended intensity levels could apply differently to different individuals. Dina explained that

> If you're an athlete, you'd probably need to work in the 170-180s [bmp THRR], but if you're not as fit, 140-160s may be right for you. You have to listen to your body to know what the right range is for you, for that specific activity. It could be a fit person can do 3 sets of 15 reps for strength, but you can only do 3 sets of 8.

Fitness development. Similar to the majority of students within MM2, the MM3 students explained the basic principles of intensity. For example, they understood that all levels of intensity could promote fitness development, could explain progression, rest, and overload principles, and mentioned considerations such as an individual's initial fitness level, age, and experience. Two MM3 students additionally noted that one's health condition could be a factor in fitness plan design. Brian mentioned that his Dad's diabetes affected his decisions about the kinds of physical activities in which he could participate, while Emma explained that she had "asthma, but I still can find activities I can do." MM3 students also remarked that one may be concurrently working at a low intensity level on one activity but at a moderate or high level on another. For example, Emma explained:

> It's like I use different intensity levels in different things I do. When I work on my skating, I'm usually at moderate and high because I have been training for so many years. But I find the mile very hard to do. I was at a really low intensity on that at the beginning

> of sixth grade, and I think now I am just kind of low to moderate because I still have to walk and jog [because of my asthma].

Connections among FITT elements: Students categorized within MM3 perceived a relationship among *all* the other FITT elements. Similar to MM2 students, they indicated that intensity levels may or may not be relative to time, depending on the activity. In contrast, MM2 students, however, MM3 students understood that various combinations of time and intensity cannot be averaged, nor do they involve similar energy expenditures. Rather, they explained that different physical activities involved different energy expenditures. Brian's explanation illustrated this characteristic of the model:

> They are just different intensities. The energy you use depends on what kind of work-out you're doing. When I am running the mile, it's a different use of energy than if I'm doing curl ups because that does not involve cardio as much because it's more muscular. They have different energies and even different times because one is in minutes and the other in sets and reps.

MM3 students were the only students interviewed to perceive that frequency was connected with intensity, type, and time. Moreover they differentiated frequency according to the type of activity. For example, Brian elaborated:

> [Because the intensities are different] that's probably why they say you should only do strength and [muscular] endurance not more than twice a week. Because probably you tear more muscles fibers doing those and the muscles need more time to reconnect and build back up. But they say you can do cardio and flexibility 3 to 5 times a week.

Hence, their rationales revealed awareness for the fact that all FITT elements are relational and each should be discussed with respect to others. Dina reiterated the relationships among the elements when she clarified that each FITT element recommendation was "just in general" for everyone and could be modified:

> When I was in elementary, FITT was like in general, it does not apply for one specific person... [Sue] explained to us that you want FITT to be specific to what is right for you. Because it depends on the component *you* want to improve, and *your* abilities, and starting fitness level. The way I see it, frequency, intensity, time, and type, work all together because they can't be separated. It all works together, that's why it's a formula.

Source, structure, and stability of knowledge. Although MM3 students credited their physical education teacher as the primary source of fitness knowledge, they also indicated they "connect what I learn in PE with my life at home" [Dina] and in science (e.g., muscular systems, body system functioning). They also sought fitness information for themselves in their portfolio, the internet, TV shows, and library resources. Additional sources of fitness information included family [Sally, Brian] and coaches [Dina, Emma].

MM3 students held the most advanced epistemic beliefs when compared with students categorized within the other two models regarding the structure and stability of knowledge. Emma explained, "FITT's not as simple as I used to think it was. You have to figure *how long* with *how hard* to decide how to balance things out." Further, Brian indicated information learned at school was the basis for future learning. Information learned in science and physical education was:

> Probably just basic facts that become a base for something complicated. What I am learning now is an extremely simplified from what it actually is so a 12-year old mind can be able to learn it. My PE portfolio is my guiding thing to learn the muscles and I use it for science too, but it's a much simpler anatomy than I'll learn when I become a

forensic scientist.

MM3 students shared awareness that knowledge evolved, referring to recent changes in fitness the NASPE fitness guidelines and the food pyramid. Sally noted that fitness information "stays the same for some things but change for others as our research and knowledge develops," whereas Brian's response reflected a futuristic perspective:

> I'm sure fitness information changes, because there are always people trying to find a better work out plan or a better cure. It may take 10, 20, 30 years to evolve, but yes information changes over time. And even physical education teaching itself could change… [Pam] told us many things have changed in PE since when she was in school.

Discussion

All sixth-grade students interviewed for this research were familiar with the concept of intensity, and the majority was able to differentiate and measure it correctly in different types of physical activities. According to Pam and Sue, the concept of intensity presented conceptual challenges for both instruction and student understanding. These students may have learned this concept because they experienced a sequenced conceptually-oriented curriculum, ongoing curricular support beginning at the elementary level, and fitness curricula that emphasized a conceptual and applied understanding of intensity.

Framework Theory of Conceptual Change appears to be a viable theoretical and methodological framework to examine student learning in physical education. Students' development of sophisticated conceptions of intensity (and FITT) is a gradual emerging process that is not flawless, and even in effective learning settings, students hold a range of conceptions. A myriad of variables appear to interact, facilitating and sometimes unintentionally limiting model development, reiterating the complexity of knowledge-belief-context relationships. In this section, I discuss how students' diverse mental models reflected their subjective constructions leading to the development of internally coherent knowledge systems, followed by a description of contextual factors that appear to mediate mental model development.

Mental Coherence

The three mental models that emerged from these data suggested that developing sophisticated understandings of the concept of intensity is a gradually emerging process. According to Mazens and Lautrey (2003) researchers can infer developmental trends when distributions of the mental models are observed across different classes/grades/context. Longitudinal studies, however, are required to verify these developmental trends. Students expressed their views with confidence and the consistency of their rationales reflects the *specific theories* they used to justify their responses and explain intensity. The diverse models represented students' attempts to seek mental coherence and maintain their cognitive systems free from contradictions (Mazens & Lautrey, 2003; Sorzio, 1994; Vosniadou, 1999).

Emerging Coherence Involves Conceptual Transitions

According to Vosniadou (1994), each generic mental model and underlying specific theories should be appreciated as learners' creative attempts to construct their meanings. Even the most naive model should not be labeled as faulty reasoning or incorrect responses by researchers (e.g., Merkle & Treagust, 1993). Adolescents seek to maintain mental coherence and form internally coherent synthetic models that reflect *different degrees* of external coherence with conventional scientific understandings. These models should be appreciated as scaffolds that support the construction of learners' future mental models (Alexander, 1996; Vosniadou, 1991).

The intensity mental models identified in this study portray cross-sectional snap shot descriptions along an evolving learning continuum. They represent three synthetic models that reflect the conceptual transitions sixth grade students may undergo to change their general/holistic initial models of FITT and intensity developed during their elementary physical education experiences. These models can be used to sensitize scholars to the conceptual challenges students face when struggling to understand abstract concepts like intensity (Rowlands, 2004) and assist teachers to address specific student concerns and design curricular and instructional scaffolds to facilitate mental model development.

Coherence Emerges in Diverse Ways

Students in this study articulated rich naive conceptions that reflected varying degrees of accuracy, complexity, and correspondence with their teachers' explanations. Their models reflect a differential balance between the internal coherence of their existing models and the external expert coherence of the curriculum as expressed by their teachers. For this research, I adapted Vosniadou's (1994) conceptual diagram to summarize the research findings and show how diverse configurations of learners' academic beliefs, knowledge, and perceptions can lead to different mental models of intensity. Figure 10 illustrates a hypothetical conceptual structure that charts how students could have constructed the different models. The figure elaborates the process students may use to organize their conceptual systems and emphasizes elements or steps within the process where some students' experience conceptual difficulty (e.g., identify MM1 students adapting a cardio-model to other fitness components).

[Insert Figure 10 about here]

Within each intensity mental model, students shared the primary features of the generic model, yet their models also reflected slight variations (e.g., majority of MM1 students held static epistemic beliefs whereas one student, Vincent, indicated knowledge could change). Although the variations *within* each generic mental model might at first indicate a lack of coherence, they reflect the different ways students organized and structured their knowledge, perceptions, and academic beliefs. Because understanding intensity involves a number of interacting concepts (Vosniadou & Brewer, 1992), students' *different* specific theories about intensity lead to the construction of similar generic mental models. For example, whereas some MM1 students used time and energy consumption as a single criterion to establish an activity's intensity level, other MM1 students theorized a more complex relationship between time and energy usage that relied on differentiated intensity levels. According to Chi and de Leeuw (1991) such variations highlight the nature of individual differences in learning.

Seeking Coherence Involves Making Connections

Students use many sources implicitly when attempting to make connections and internalize information into their existing conceptions. For example, they rely on perceptions and sensations experienced during their physical activity experiences to identify relationships between concepts learned in different subject areas and those learned at home and at school. These connections reflect their ongoing attempts to construct their understandings in diverse yet coherent ways.

Perceptual connections. Students actively make connections as they interpret sensory and kinesthetic information experienced during formal and informal physical activity experiences (Magill, 1998). From a young age, students' awareness for their increased heart rate, breathing rate, and other physiological indicators of exercise intensity are sources of perceptual information that fuel the naive fitness, biology, and physics theories they are developing to understand their physical responses to exercise (Inagaki & Hatano, 2006; Vosniadou, 1994). It is important for teachers and researchers to realize that even, "the "darnedest things they say" (McCullick, Metzler, Cicek, Jackson, & Vickers, 2008) makes sense from students' perspective. For example, the "number of muscles" criterion used by Liam (MM1) could reflect his naive theory, intuitively connecting intensity with the perceptions of body parts he felt working. Predicting intensity levels based on the quantity of muscles used during different tasks was a plausible rationale to him.

This perspective may provide an alternative interpretation to Placek et al.'s (2001) deficit interpretation of their findings. They reported sixth grade students had little knowledge of appropriate exercises that target the fitness components. Students in their study incorrectly explained that lifting weights strengthened the hands, perhaps confusing the pressure they felt on the hands with strength improvement. Conversely, if interpreted from within a FTCC perspective, the origin of students' rationales may have been their perceptions of pressure from the weight on the hands. Because perceptions are one of three sources from which mental models originate, they provide a critical perspective for initial mental model development and may be an essential source for students' constructions of fitness understandings. This parallels motor learning scholars' (e.g., Magill, 1998) observations of a coupling between children's' perceptions of their body parts, environmental variables, and their body movements that occurs regardless of students' level of conscious awareness.

Connections between physical education and other subject area concepts. A second source of student conceptions to explain intensity and predict its effects on the human body was the connection they perceived among concepts learned in different subject areas. Jim (MM1), for example, used his naive physical science model of a battery to explain energy levels, providing a rationale for daily exercise. Other students, including Carly (MM2) and Liam (MM1), who extended the battery metaphor to explain the principle of rest and recovery, used explanations that indicated their specific theories were becoming more coherent and aligned with fitness principles. Although Pam and Sue explained that they could not work collaboratively with science teachers due to scheduling conflicts, the sixth grade students made linkages between the common concepts used in science education and physical education, perceiving cross-disciplinary connections between these two subject areas (Ennis, 2003b).

Connections between physical education and students' home environments. These sixth grade students also were quick to make connections between their experiences in physical education and their home environments. This was evident, for example, in Evan's use of Pac Man to understand the interplay between intensity, time, and energy level and his understanding that THRR was lower for older adults. Although he probably misapplied his teachers' computation of THRR for a 70-year old adult, this information helped him re-interpret his observations that his grandmother chose walking instead of jogging as her physical activity. Unfortunately, it may have reinforced his belief that older people have less energy and move more slowly. Rather than understanding that the lower THRR of 97-127 beats per minute range represented the moderate to vigorous range for older adults, he noted that her range was below the THRR range typical of middle school aged students of 130-185. Hence, he interpreted the lower THRR to mean that older adults can only exercise at a low exercise intensity level. Again, such active constructions indicate that students use purposeful rationales to support their conceptions.

Seeking coherence is gradual

Vosniadou (1991, 2007a) explained that mental model transitions are gradual and require both the enrichment and restructuring of the ontological and epistemic beliefs within naive theories that undergird existing models. Belief transitions occur differentially for different students. In this research, the descriptions of the three intensity mental models suggested that belief shifts within students' naive theories may occur in different ways and at different rates for individual students. At the end of the scholastic year, students categorized within MM1 (n=4) still seemed closely aligned with an elementary level holistic/general conceptualization of FITT and intensity. In contrast, students' theories categorized within MM2 and MM3 appeared to become increasingly aligned with their teachers' differentiated conceptualizations of the FITT principle and intensity (albeit to varying degrees). Vosniadou (2007a) reiterated that the learning of some complex abstract concepts takes time, sometimes several years, to be understood by some students. Model development requires the use of many ongoing purposeful instructional interventions and scaffolds within and across grade levels that target concomitantly knowledge and academic belief changes.

The general direction of positive change in complexity from MM1 to MM3 reflects the qualitative shifts with increasing principled understanding as students' mental models become both internally and externally coherent with expert fitness perspectives (Alexander, 2006; Vosniadou, 1999). The data from this cross sectional study led me to observe three different levels of sophistication in students' mental models. Although the mental models are not necessarily sequential in nature, they illustrate an increase in students' ontological and epistemic sophistication. For example, whereas some MM1 students used time, alone, as the criterion to determine activity intensity level, others ascribed more complex properties, articulating an integrated relationship between time, type, intensity level, and energy usage, differentiating how these elements interact resulting in similar (MM2) or different (MM3) intensities and energy usage. Changes in students' perceptions of a relational structure among FITT elements may occur as their ontological and epistemic beliefs increase in sophistication (Ennis, 2007; Vosniadou, 1991; Vosniadou & Brewer, 1992). For example, most students using MM2 and MM3 held more advanced epistemic beliefs, acknowledging the evolving and complex nature of fitness knowledge. This may have facilitated the integration of new knowledge and promoted model development resulting in increased student willingness to revise their beliefs and mental models adopting thinking dispositions that facilitated their intention to learn, and, hence, revise their existing conceptions (Buehl & Alexander, 2001; Mason, 2002; Vosniadou, 2007a).

In contrast, analysis of the data from this research suggested that MM1 students seemed to internalize their middle school teachers' explanations of a differentiated concept of intensity and the FITT principle to a lesser degree. Vosniadou's research suggests that model revision is slower when (a) students' prior knowledge base is deeply entrenched, (b) they hold less advanced epistemic beliefs, and (c) they store information as inert knowledge (Vosniadou, 1994, 2007a; Vosniadou, et al., 2001). Thus, changing these sixth graders' elementary holistic models of FITT and intensity may have been more difficult for these students because their elementary models were developed and re-affirmed throughout several years of exposure during their elementary physical education experiences. Additionally, Sue's and Pam's continued use of the school district FITT posters also used by the elementary physical educators may have unintentionally reconfirmed these models at the middle school level.

The depth of entrenchment also may be related to students' less advanced epistemic beliefs. When students view fitness knowledge as simple and unchanging, they are less likely to restructure beliefs that underlie their initial models even when presented with contradictory information. Further, efforts at instructional enrichment may be ineffective in promoting increased sophistication in students' mental models. Additionally, students may have learned

FITT in a non-meaningful, rote manner, storing it as inert knowledge. Thus, it may be difficult for them to perceive the integrated relationship among the FITT elements. For example, although these sixth graders understood the concepts of frequency and type, they seemed unable to perceive these concepts in relation to intensity. This may suggest that students are storing this information in a separate knowledge structure unrelated to the conceptual system structuring students' mental models of intensity (Vosniadou, 1994, 2007a; Vosniadou, et al., 2001).

Seeking Coherence is Not a Flawless Process

Developing sophisticated conceptions about intensity is not a flawless process. The variations in students' responses indicated that some students held inaccuracies and seemed unaware their explanations contained misrepresentation of fitness knowledge. For example, MM1 students did not recognize that the guidelines associated with the cardiovascular system did not also apply to other fitness components (i.e., flexibility, muscular strength and endurance tasks). Vosniadou (1994, 2007a) explained that students do not notice the contradictions or distortions between their own conceptions and fitness information. They lack metaconceptual belief awareness and are not conscious of how they distort what they hear, feel, and observe.

Vosniadou (1994) maintained that teachers should first help MM1 students to become more aware of their conceptions and then assist them to restructure the academic beliefs that underlie their naive model. Providing these students with more factual information (i.e., enrichment), without targeting academic belief restructuring, is likely to result in their continuing use of their existing models, producing the same mistakes. The restructuring/re-organization of existing naive theories helps students re-interpret the new FITT/intensity information/knowledge they received. In turn, this may enable them to develop broader naive theories that have greater explanatory power and that more closely parallel their teachers' externally coherent models.

Recently, Vosniadou (2007a) explained that belief restructuring also helps students restructure their modes of learning, developing more flexible thinking that facilitates alternative conceptual perspectives, such as those required to comprehend intensity and FITT.

Mediating Influences on Students' Naive Theories

Vosniadou et al. (2001) stressed that researchers should seek to relate mental models to variables in the social and contextual factors that facilitate and limit their development. In this research, situational influences mediated how these 18 students' structured and organized their perceptions, knowledge, and academic beliefs into rich conceptions of intensity. Three mediating factors were (a) school district support, (b) language, cultural artifacts, and tool support, and (c) teachers' values and beliefs about fitness and learning. These factors illustrate the complexities involved in knowledge-belief-context relationships.

School District Support

In the school district in which this research was conducted principals, supervisors, and teachers were strong advocates of a conceptually based physical education curriculum that promoted personal fitness development. Administrators hired certified teachers and provided adequate instructional time, reasonable class sizes, and excellent facilities, resources, and equipment for each student. These supporting physical structures influenced students' opportunities to be engaged cognitively and physically with fitness content. Additionally, curricular support in the form of content alignment ensured that fitness concepts introduced at the elementary school were revisited in more depth at the middle school level (Ennis, 2003a, 2003b). Students were immersed in a physical education environment that cultivated and transmitted the language and value of personal fitness from a young age. Curricular support was evident through language, technical tools and scaffolds, and teachers' content emphases and practices.

The Role of Language and Cultural Artifacts: Pros and Cons

Students at these middle schools possessed a rich fitness vocabulary. They were accustomed to listening to and using the “language of fitness” [Sue] and were appropriating the meanings (Pea, 1993) of their teachers’ explanations within their vocabulary and understanding. Bae and Ennis (2008) noted that students’ ability to use curriculum related terminology is essential to helping them construct complex conceptual relationships across fitness concepts. Richly articulated explanations and flexible thinking were evident, especially among students categorized within MM2 and MM3. Their verbalizations pointed to the central role language plays in fitness knowledge and concept attainment in physical education.

Berti (1999) explained that mental model revision is facilitated when students are linguistically equipped with a rich knowledge base. Other scholars (Greca & Moreira, 2000; Roth, 1990) explained the centrality of language as a cognitive tool students use to internally manipulate their mental models. Language serves both a communicative and interpretative function. In this research, sixth grade students’ exposure to fitness language since elementary school physical education may have enabled them to develop the declarative and procedural knowledge base necessary to scaffold the learning of fitness concepts in middle school. Additionally, students’ use of fitness portfolios may have facilitated their ability to carry out cognitive procedures because “writing is a tool for thinking and domain content learning” (Mason, 2001 p. 308).

Mental model development also may be facilitated when students use cultural artifacts defined as tools external to the human mind that students use to reason and construct their mental models (Vosniadou, 2007c; Vosniadou, Skopeliti, & Ikospentaki, 2004). In this research, students were accustomed to using cultural artifacts in the form of instructional resources (e.g., posters) and technological tools (e.g., heart rate monitors). Consistent with Pam's and Sue's explanations, Vosniadou noted two merits of using artifacts. First, they help teachers clarify specific concepts that may not be apparent if explanations were solely linguistic. Additionally, visual and auditory qualities embedded in cultural artifacts helped students remember and understand teachers' explanations of concepts, like intensity, that are unobservable and abstract.

Language and cultural tools are, however, not always interpreted by students in the manner teachers intend. Vosnaidou et al. (2004) pointed out that:

> the process of internalization [of domain information] is not an act of direct cultural transmission, but rather a constructive act of interpretation that can lead to different forms of knowledge, ranging from the simple recognition of facts to the generative use of scientific concepts. (p. 221)

Further, they elaborated that, depending on the academic beliefs students hold, some may use new information to construct more advanced conceptions through the enrichment or restructuring of their existing naive theories (e.g., MM3; Vosnaidou et al., 2004). In contrast, others may revert to utilizing their prior conceptions to interpret new information without changing the beliefs in their underlying specific theories (e.g., MM1). Additionally, students' may receive mixed messages or experience ineffective conceptual capture, language-related variables that play unintentionally limiting roles on model development.

Mixed messages. Model revision is slower when students receive mixed messages during educational process. Scholars in science education traced the sources of some students' naive conceptions to the text/message/language used in curricula, textbooks, teaching models and other instructional resources (Modell, Michael, & Wenderoth, 2005; Vosniadou, 1991). In this study, some students using MM2 continued to explain that the “right” intensity was moderate or higher, even though their physical education teachers explained that low levels also could promote fitness development. Again, students’ naïve conceptions could be related to the several years of exposure to the mantra, “Intensity means how hard you should exercise,” and “Use a combination of moderate and vigorous activities during physical education.” Additionally, for some Beech Middle students (e.g., John), Sandy, the science teacher’s use of the “no pain, no gain” slogan also reinforced the “moderate to vigorous intensity perspective.” This explanation contradicted Sue’s more flexible explanation. Sandy was unaware that “no pain, no gain” reflected a fitness myth (Corbin & Lindsay, 2005) or naïve conception. Science scholars have documented teachers’ naïve conceptions as a potential source of students’ naive conceptions. In this case teachers, such as Sandy, were unaware that they, themselves, held naive conceptions, unintentionally promoting mixed messages (e.g., Kikas, 2004).

Conceptual capture. Students’ efforts at model revision also can be hampered by ineffective conceptual capture (Roth, 1990). Roth explained that as conceptual change occurs, some students actively seek to revise their conceptions. In some instances, they may organize and structure information inappropriately because they are unaware of misrepresented or misinterpreted information. In this research, Carly’s use of a single value rather than a range for target heart rate may reflect ineffective conceptual capture. Although she appeared to be actively seeking to internalize her teachers’ explanation, she apparently misconstrued the meaning. Roth noted that such learning frequently goes unnoticed by teachers.

Teachers’ Values and Beliefs about Fitness, Teaching, and Student Learning

All students in this study reported that they valued their teachers as the source of authority for fitness knowledge. Students’ diverse explanations across the three models demonstrated that they were seeking to internalize their teachers' scientifically-based explanations. Although there were varying degree of correspondence between their naïve conceptions and the fitness knowledge their teachers' conveyed (Buehl & Alexander, 2001), students' synthetic models reflected their efforts to accept and use more scientific explanations. These teachers did target epistemic belief change related to the complexity and stability of knowledge. In sharing the changing nature of fitness knowledge and challenging students' lay culture assumptions about "obesity" and "right intensity" level, Pam and Sue were influential sources who mediated the development of students' advanced epistemic beliefs. Through their interactions with students, they were able to monitor and intervene to address at least some of the conceptual difficulties students experience. Further, they conveyed a personal and flexible approach to fitness development that may promote student adoption of the Surgeon General recommendations (U.S. Department of Healthy and Human Services (USDHHS), 1996).

Ennis (2003a) explained teachers' values and beliefs for physical education, fitness, teaching, and student learning impact curricular decisions making. Mason (2002) remarked that the construction of students' mental models is influenced strongly by the ways teachers introduce and link concepts. Ennis (2007) summarized that students' ability to develop complex fitness conceptualizations is related to how effectively teachers help students make explicit connections among concepts that affect relational understandings. Pam and Sue emphasized the relationships among intensity, type, and time and used diverse instructional resources (portfolios, heart rate monitors, posters) to help their students learn these connections. However, they placed less emphasis on the relationships between frequency and intensity. This could have contributed unintentionally to MM1 and MM2 students' lack of awareness of a relation between intensity and frequency. "Breaking down FITT" [Pam] within various units reflects a teaching mode of disassembly that is helpful to assist students to understand how intensity changed with type. Curricular emphasis on all elements equally through the use of an assembly mode may be necessary so that students can continue to perceive the relationships among the various elements and how FITT functions as a whole (Ennis, 2007; Reiss & Tunnicliffe, 2001; Rink, 2001). Only students using MM3 (n=4) articulated awareness for an interdependent connection among all FITT elements. Unlike their MM1 and MM2 peers, they seemed able to internalize the teachers' infrequent explanations of frequency, conceptualizing relationships among all FITT.

Conclusion

Vosniadou et al. (2001) reiterated the need to understand the myriad of variables that facilitate and limit the development of students' mental models. When scholars examine students' mental models as part of an integrated conceptual system involving knowledge and academic beliefs, findings can provide rich access to students' thinking about fitness. Understanding students' ontological and epistemic beliefs about fitness influences how they interpret and construct their mental models. Because ontological and epistemic beliefs are not fixed, they can change when curricular interventions purposefully target both knowledge and belief revision consistent with the manner in which students learn (Alexander, 2006; Vosniadou, 2007b). In this research, students' active constructions across the three mental models illustrated that students' thinking about intensity is purposeful, systematic, and theory-like in nature. Vosniadou (1991) explained that it is only when researchers and educators understand how students reason and what they know and believe about domain knowledge can they "slowly lead them to forming increasingly more sophisticated mental models" (p. 230).

Listening more closely to what students say "can have a tremendous impact" (McCullick et al., 2008, p. 5) because it helps researchers and educators reconceptualize the assumptions they hold about learning. It encourages scholars to use caution in interpreting naive conceptions and avoid judging them to be unsophisticated and incomplete. Naive conceptions of fitness concepts develop for many reasons. There are influenced by a myriad of personal and situational variables that interact and influence student learning, limiting or enhancing students' developing fitness knowledge.

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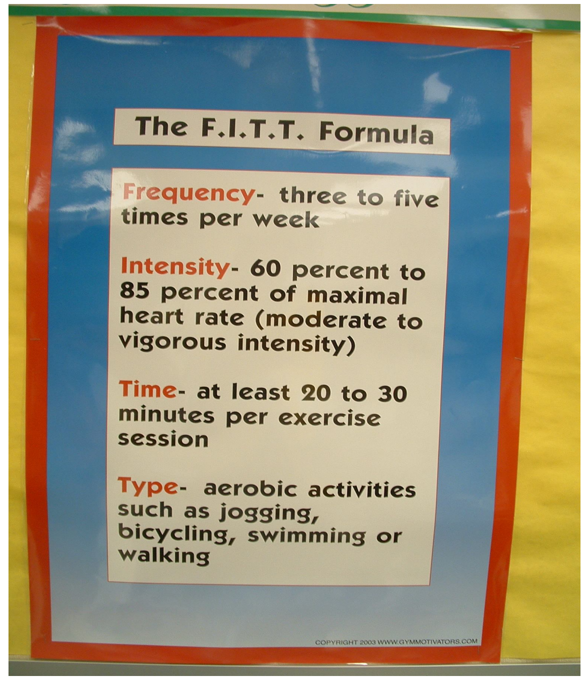
Figure 8. FITT principle resources used by teachers and students in this study

(i)
School district FITT Principle poster used at the elementary and middle school level

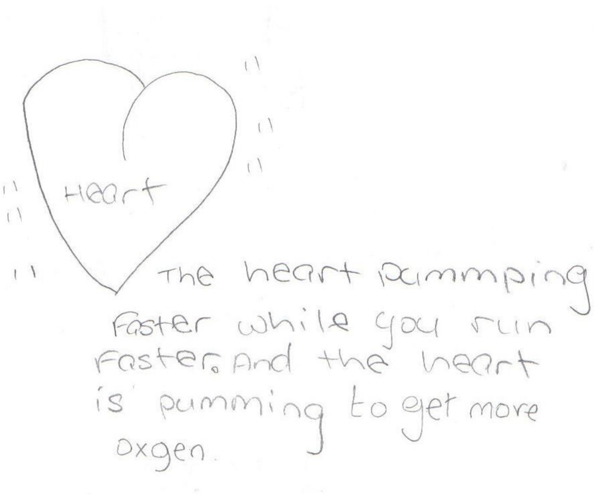


(ii)
FITT poster made by Pam for cardiovascular endurance activities.

Purpose of FITT			
What is the purpose of the FITT principle? *I think that the purpose of the fitt principle is to inform people the guidelines of good fitness*			
	What does the letter stand for	Write a two word definition	Answer your two word definition
F	*Frequency*	*how often*	*How many times a week I exercise about 5 times*
I	*Intensity*	*how hard*	*If I exercise at my ceiling heart rate*
T	*Time*	*How long*	*I exercise per day about 60 min.*
T	*Type*	*what kind*	*What kind of exercise I do on all fitness types*
Do you need to do all your work out all at one time? Explain why. *No because you need to give your muscles time to rebuild.*			

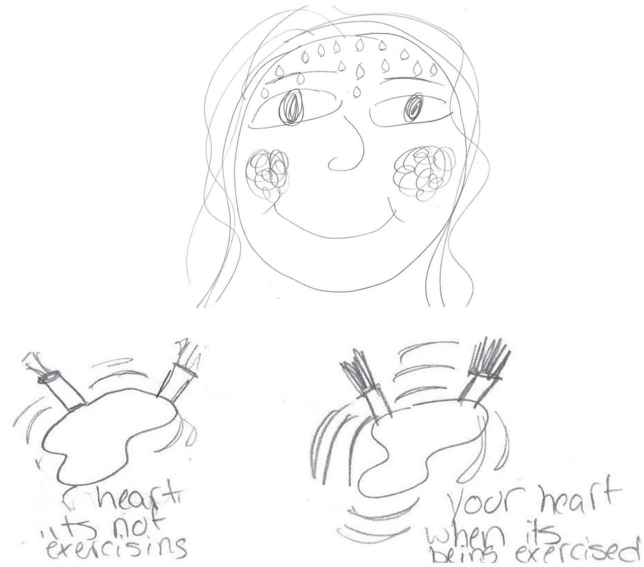
(iii) Reproduction of a sample of student's written responses about the FITT principle in the fitness portfolio.

Figure 9. Examples of students' drawings and written responses on second survey that illustrated how they feel intensity and explain its causal effect on human body functioning.



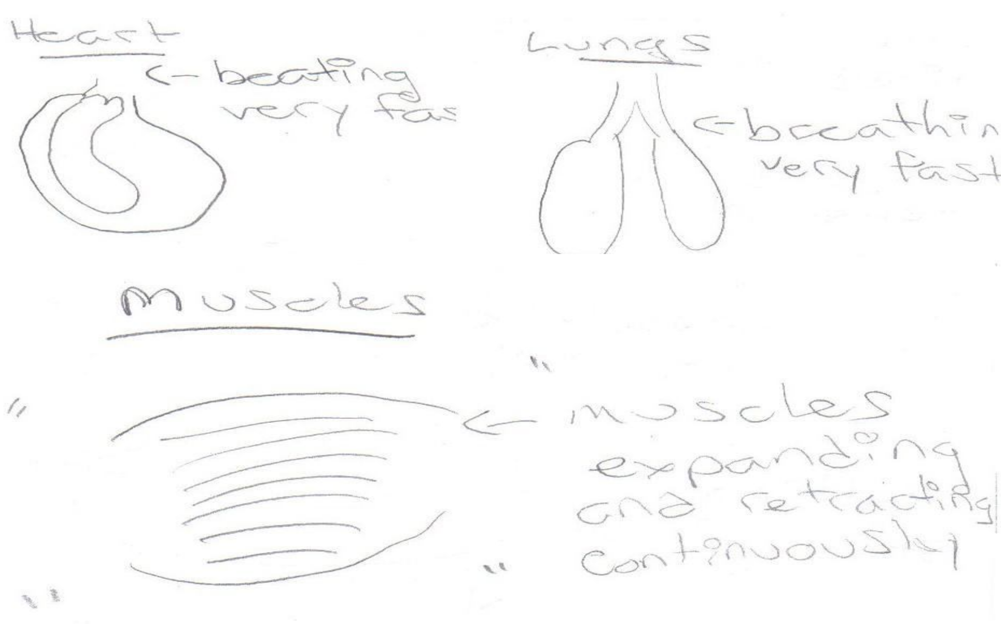
Sweating, gasping, and feeling a racing heart

(i) Sandra (MM1)



Sweating (too cool off), breathing hard, my legs feel very tired.

(ii) Carly (MM2)



Sweaty, heart rate increases, faster breathing. Harder to breathe. Fatigue.

(iii) Emma (MM3)

Figure 10. Hypothetical conceptual system underlying MM1, MM2, and MM3 students' mental models ntensity

GLOBAL FRAMEWORK THEORY

ONTOLICAL BELIEFS

□ ♦ √
The Nature of Intensity

□ ♦ √
Human body operates like a machine

EPISTEMIC BELIEFS (Justification)

□ ♦ √
Intensity exists can be perceived, measured, and controlled

□ ♦ √
Cause-Effect Process
Explanations should be causal

S P E C I F I C T H E O R Y

OBSERVATIONS AND INFORMATION AVAILABLE IN EDUCATIONAL CULTURAL CONTEXT ABOUT INTENSITY & FITT

Perceptual or observational information students directly feel/see/hear/

- □ ♦ √ Increased heart rate, breathing rate.
- □ ♦ √ Feeling muscles work during exercise
- □ ♦ √ Increased body temperature; sweating
- □ ♦ √ Technological tools and instructional resources

Information or observations students receive in educational and cultural settings

- □ ♦ √ Components of Fitness (PE)
- □ ♦ √ FITT principle (PE)
- □ ♦ √ Effects of intensity on human body (PE and Science)
- □ ♦ √ Energy and human body systems (Science)
- □ ♦ √ Cultural Messages e.g., Obesity stereotypes; Pac Man

BELIEFS ASSOCIATED WITH INTENSITY and FITT

E P I S T E M I C			O N T O L O G I C A L				
Source Authority of Fitness Knowledge	**Structure Of Fitness Knowledge**	**Stability of Fitness knowledge**	**Form of Intensity**	**Fitness Intensity Levels**	**Energy Usage**	**Balancing Energy-Time-Intensity Level**	**FITT connections**
□ ♦ √ Physical education Teacher	□ Simple	□ ♦ Unchanging	□ One fixed form	♦ √ Low	□ Proportional with *time* only	♦ Averages out across various combinations	□ Intensity-Time
♦ √ Science teacher	♦ √ Complex	□ ♦ √ Changing	♦ One form that changes	□ ♦ √ Moderate	□ ♦ Can be proportional and inversely proportional with time depending on intensity level	√ Different energies and intensities	♦ Intensity-Type-Time
□ ♦ √ Other: e.g., Family, Coaches	♦ √ Simple & Complex	♦ √ Mixed	√ Multiple forms	□ ♦ √ Vigorous			√ Intensity-Type-Time-Frequency

MENTAL MODELS

□ MM1
Generic Fixed Cardio:
Intensity-Time model:

♦ MM2
Generic Transformative:
Intensity-Type-Time Model

√ MM3
Multiple Forms:
Intensity-Type-Time-Frequency Model

Key for each mental model
MM1 = □
MM2 = ♦
MM3 = √

CHAPTER 6

Summary, Conclusions, Implications, and Recommendations

Summary

The purpose of this dissertation study was to examine sixth-grade students' knowledge and academic beliefs as implicated in their mental models about fitness concepts. Framework Theory of Conceptual Change was the theoretical framework used to analyze and interpret these findings. In Chapter 4, I inferred five distinct generic mental models students used to explain exercise induced physiological changes. Students explained their conceptions in diverse way and used other mental models, such as the circulatory system, to explain and predict physiological changes. An important finding from this analysis was the inherent inter-disciplinary and multi-level complexity involved in students' learning about the effects of exercise on the human body. In Chapter 5, I inferred three generic mental models students' used to describe the concept of exercise intensity. Again, students' conceptions were diverse. They tapped into perceptual (e.g., feeling heart rate) and contextual sources of information (e.g., language and cultural artifacts) at home (e.g. parents, video games) and at school (e.g., science and physical education classes) to learn and explain their conceptions of intensity and its relation to the other elements within the FITT principle.

In both studies students' described the relational complexity inherent in the respective concepts in diverse, yet coherent ways. Results affirm the importance of examining students' mental models as part of an integrated knowledge conceptual system in which learners' beliefs about knowledge play significant roles. The use of FTCC within a contextualized examination of students' mental models has enabled not only descriptions of students' knowledge and beliefs about fitness concepts but also data revealing the rationales, processes, and sources associated with perceptions, knowledge, and academic beliefs about fitness concepts (Alexander, 2006; Vosniadou, 1994).

The findings from this research confirm the viability of FTCC as an effective theoretical and methodological framework to examine student learning of science-based physical education concepts. Because FTCC articulates model development as a domain-specific phenomenon (Vosniadou, 2007), it has facilitated the examination of student model development associated with concepts shared between a science and a movement domain. According to Vosniadou (1994), the knowledge acquisition process is a journey that starts at infancy as learners' explore and understand their world.

Application of FTCC to the physical education domain has potential to tap into a major source of learning: students' movement experiences. These data confirm that students' kinesthetic movement experiences play important roles in conceptual change (Allison & Barrett, 2000; Magill, 1998; Rink, 2003). Thus, students' simultaneous participation in physically and cognitively oriented instructional activities enhances the development of perception, knowledge, and beliefs about fitness. Findings from this research suggest the value of a curricular and instructional emphasis on both belief and knowledge change. Teachers can help students interpret and re-interpret their knowledge and perceptions (e.g., faster heart rate) through their movement experiences. Thus, the internal coherence of their conceptions increasingly parallels the external coherence of conventional understandings. Ruth Abernathy (1964) emphasized this multi-dimensional focus for physical education when she explained:

> Physical education is concerned with facts [knowledge] and beliefs derived from the meaning of movement in human life and with the foundations for and the conditions of significant application of such facts and beliefs in the process of education (p.2).

It is critical to examine the contributions that a multi-sensory experience can play in cognitive conceptual change. Students use their experiences and perceptions to understand cognitive fitness concepts, internalizing how their body responds to exercise in physical education and science. Students can apply their conceptual understandings of fitness concepts to their personal fitness plans. Students also enhance and apply literacy skills as they learn to appropriate fitness terminology to communicate their experiences within different physical activities (Ennis, 2003; Gallahue, 1996; Magill, 1998; Placek, 2003).

Conclusions

The findings from this research may have pedagogical implications for the presentation of curricular materials and teaching of domain specific concepts. Traditionally, curricular approaches in physical education focused solely on physical skill development. When knowledge development has accompanied physical skill and sport goals, Ennis (2007) noted that knowledge enrichment has often been the curricular and instructional focus. A criticism of this approach has been its ineffectiveness in promoting behavioral changes thought necessary to adopt healthy and active lifestyles. Conclusions emanating from this research include the value of teaching for belief change, the instrumental role of language, the limiting role of misrepresentations, and the emerging nature of fitness knowledge.

Teaching for Belief Change

Vosniadou (1994) reiterated that the purpose of instruction should be to target both knowledge and academic belief change from a young age. It is necessary to provide instructional experiences that help students both enrich and reorganize their conceptions by targeting concomitantly knowledge and ontological and epistemic belief shifts. This process needs to occur progressively across school levels because the learning of complex abstract concepts can take several years to occur. Mason (2002) noted that when instructional interventions target both knowledge and belief enrichment and integrative restructuring, it is more likely that students' behaviors will also change. Further, Murphy and Mason (2006) reported that meaningful learning is facilitated when students both know and believe in the positive benefits of fitness.

When designing physical education curricula and planning lessons, it is necessary to *purposefully* target academic belief shifts in addition to knowledge change. Currently, most physical education teacher education programs (PETE) do not address this issue or view public school students' conceptual learning as a process of model building. Hence there may be a need to reconceptualize existing teaching methodologies and assumptions about how students learn. Model development requires the use of many ongoing purposeful instructional interventions within and across grade levels that target concomitantly knowledge and academic belief changes. Further, there is a need to recognize that students develop their conceptions in diverse ways and at different rates.

The Instrumental Role of Language

The results of this study emphasize the instrumental role language plays in fitness knowledge development in both positive and unintentionally limiting ways. Developing sophisticated conceptions of fitness is facilitated when students are helped from a young age to master the language and tools and to appreciate the value for fitness. These foundational experiences provide students with the declarative knowledge (e.g., facts and terminology), procedural skills (e.g., procedures to measure heart rate), conditional knowledge (e.g., under which circumstances low intensity promotes fitness development), and appreciation for fitness that is essential to develop complex conceptualizations of fitness knowledge. Introducing these concepts later in the educational process, for example, in high school, may be too late because students' conceptions and attitudes towards fitness may be entrenched and thus hard to change. Language can also play a limiting role. For example, "everyday language" or maxims such as "no pain, no gain" can be sources of conflicting fitness messages.

In this study, Pam commented that students were receiving the FITT message constantly "without even realizing it's coming at them." This belief reflects what scholars have noted as the tendency for teachers to assume that students are learning instructional messages through repetition. This belief is reminiscent of information processing perspectives to learning that assume teaching entails acts of cultural transmission rather than constructive acts of interpretation (Alexander, 2006; Crockett, 2004; Vosniadou et al., 2001).

The Limiting Nature of Misrepresentations

Further, the findings from this study showed that students can misrepresent information presented by expert teachers who provide clear and sequential explanations. These sixth grade students were unaware that their beliefs influenced the way they interpreted domain knowledge. Additionally, teachers at times overlooked or were unaware of how students were thinking about fitness because they focused solely on observing students' performance. Likewise, traditional forms of written cognitive assessment or questioning techniques may not permit access to the depth of students' conceptual understandings. Vosniadou and colleagues (1991; 2001) reiterated that teachers should avoid dominating classroom dialog; instead, providing students' with opportunities to externalize their conceptions using a variety of questioning strategies and peer discussions. These teaching strategies may help teachers become aware of naive conceptions, and better position themselves to help students' gain awareness, and examine limitations within their existing conceptions. This process also helps teachers become more aware of the consequences/ effects of their practices, which in turn, can facilitate future lesson design.

Examining more closely the nature and meanings of the language in curricular and instructional resources is also important. Rink (2001) and Vosniadou et al (2004) noted that teachers should not assume the effectiveness of their practices and the tools they utilize. For example, teachers may need to understand the implications of using heart rate monitors, understanding why and how they can play a role in students' development of mental models of intensity. Additionally, there is a need to examine more carefully the nature of the messages in instructional resources (e.g., posters) to check if they are sources of conflicting messages. Rink summarized that teachers should know why an instructional methodology/strategy works, when and why it does not work, and consider what alternative strategy could be used to help particular students with specific content.

Emerging Nature of Fitness Knowledge

Clearly, students' understanding of fitness knowledge is an emerging and gradual process that relies on interdisciplinary connections that enrich and add meaning to conceptions. Both teachers in this study indicated that, because of scheduling conflicts, they were unable to work in collaboration with science education teachers. Students in this study were making active linkages and constructions across disciplinary areas, between their home and school environments, and between their understandings of fitness and their experiences during physical activities. Being able to structure interdisciplinary connections intentionally and carefully within curricula could be important to facilitate fitness knowledge development and promote physical education value as a subject that can contribute to the academic mission of schools (Ennis, 2003; Placek, 2003).

Implications for Curriculum Design in Physical Education

Acknowledging the limited generalizability of this study's findings due to the small participant size within unique settings, I share some insights gained from conducting this research that educators may consider in the design of future physical education curricula that focus on fitness education. I first briefly review the merit of the learning-based curricular approach utilized at Oak and Beech Middle Schools. Next I provide some suggestions to further strengthen this curricular approach; in particular I focus on targeting student learning about concepts such as exercise intensity and the effects of cardiovascular exercise on the human body.

The Need for Learning-Based Curricula

Curricula tend to be more effective in promoting students' fitness knowledge, physical performances, and lifestyle behaviors when they are built upon educational goals that emphasize learning rather than when they are based solely upon recreational or behavior change goals (Ennis, 2007). In this research, the richness of the 18 students' fitness vocabulary and rationales reaffirm the merit of a concept learning curricular approach that is implemented by effective practitioners who value teaching fitness. This approach seemed to facilitate the students' knowledge construction process in this study as their teachers provided them with many opportunities to experience and interact with fitness concepts physically and cognitively. The findings from this study suggest that developing students' fitness knowledge base is a developmental constructive process that forms a bridge between students' experiences at school and at home.

In the fitness curriculum examined for this study, teachers' incorporated instructional objectives and introduced and revisited concepts (e.g., fitness components and the FITT principle) across different grade levels and units. This instructional alignment appeared to provide these students with opportunities to learn the language, purpose, and measurement tools, and to understand intensity's relationship with other elements within the FITT principle. In this school district, this curricular emphasis was initiated at the elementary level and extended through middle school. To facilitate the school district's curricular goals, Pam and Sue incorporated instructional tasks providing students opportunities to apply the FITT principle to different activity types that promoted the fitness components across their sports unit. Additionally, they emphasized a flexible approach to fitness development emphasizing that FITT recommendations could be adapted to meet individuals' age, health, and fitness levels. Their use of diverse instructional strategies and tools (e.g., portfolios, heart rate monitors, posters) facilitated students' internalization of the FITT principle and the effects of exercise on the human body, in turn, influencing the knowledge and beliefs their students developed.

Strengthening the Design and Implementation of Learning-Based Curricula

Teachers' ability to identify mental models is critical to their understanding of students' fitness concept development and change; hence they are an important consideration in curriculum design. Based on the findings from this research, I propose strategies educators may consider to strengthen the design of future curricula that focus on enhancing student learning about intensity and exercise induced physiological changes. I first emphasize the importance of developing curricula that target students' academic belief change concomitantly with knowledge change. Next, I emphasize the merit of incorporating students' views within the curriculum process. According to Mason (2002) this reconceptualization of the curricular decision making process is essential if educators are to help students enrich and restructure their conceptions. Furthermore, it is more likely that teachers can promote learners' positive behavior and attitudes towards health related fitness.

Promoting academic belief change. Traditionally conceptually based fitness curricula have focused on knowledge and performance change through enrichment (Ennis, 2007). Tasks were designed to help students learn new information (e.g., FITT principle) and/or to apply and modify their understandings to new situations and problems (e.g., FITT principle can be applied differentially depending on the type of physical activity). Generally, cognitive learning objectives were stipulated in terms of the declarative, procedural, and conditional knowledge experts assumed students needed to master for successful performance and a comprehensive understanding of fitness concepts. Curricular experiences can be enhanced when instructional experiences foster concomitant modification (enrichment and restructuring) to learners' academic beliefs associated with their knowledge about concepts such as exercise intensity. Hence, an important consideration in future curricular design could be physical educators' expansion of the cognitive learning objectives category to include academic beliefs.

Findings from this research confirm the central role that students' academic beliefs play in the learning process. There has been limited attention in physical education research to the types of academic beliefs (ontological and epistemic: authority, structure, stability, value, and justification) students may hold and their influence on students' developing fitness knowledge. Curricular researchers in other academic domains (Mason, 2002; Limon, 2002; Vosniadou, 1991) have reiterated the importance of designing curricular experiences that incorporate academic beliefs as part of the cognitive objectives within the curricular scope, sequence, and lesson design. For example, a teacher can address students' epistemic belief related to the structure (complex vs. simple) of knowledge when teaching the effects of exercise on the human body. Chapter 4 illustrates that advancement toward a scientifically correct conceptualization of physiological functioning requires an increase in students' epistemic sophistication about the complexity of knowledge. This transition enables students to appreciate the integrated rather than isolated function of the diverse body systems (circulatory, digestive, muscular etc.,) during exercise. In doing so, targeting belief objectives may promote students' thinking dispositions about knowledge associated with intensity or exercise induced physiological changes. Further, curriculum designers have rarely considered students' academic beliefs in designing curriculum or lessons. In this research, Pam and Sue were experienced master teachers who emphasized the changing nature of fitness knowledge in their lessons. For example, they explained the revised *time* recommendations within the FITT principle. Neither teacher, however, explicitly planned to address or to facilitate (teach for) students' epistemic belief shifts related to the stability of knowledge in their lesson objectives goals.

Belief modification occurs at differential rates for students and hence curricular designers may need to sequence content specifically to target these important changes in the learning process. For example, while some students' academic beliefs facilitated knowledge development (e.g., MM3 in Chapter 5) the academic beliefs of others (e.g., MM1 in Chapter 5) may have unconsciously limited their learning about the interrelationships existing among the FITT principle elements. My findings also revealed that students within a generic model group could hold different understandings along the epistemic dimensions. For example, although Vito was aware that fitness knowledge changed, his classmate, Jim, indicated it did not. Teachers' awareness of the constraining nature of some students' beliefs can lead them to better understand their students' rationales and design lessons that specifically address these naïve beliefs.

Informed teachers can assist students to modify their academic beliefs. Steps in this process include teacher familiarity with the various types of academic beliefs, understanding of how beliefs facilitate or constrain learning, and knowledge of specific strategies to address academic belief growth. For example, when teachers perceive a student possesses static epistemic beliefs, teachers can develop curricular experiences targeted to help students first externalize and recognize their static beliefs and then help them understand the changing nature of knowledge (e.g., through creating a variety of FITT principle posters for different types of physical activities and explaining how they could be adapted to different individuals). Purposeful interventions of this nature can promote students' beliefs transitions that, in turn, may facilitate their re-interpretation of fitness information about intensity from a broader perspective.

Incorporating students' perspectives within the curricular and instructional process. Understanding students' naïve conceptions are critical to curriculum design because:

> it is only when we understand how students think, know, and believe [about intensity or the effects of exercise on the body], that we shall be able to slowly lead them to form the increasingly more sophisticated models closer to those that are culturally accepted. (Vosniadou, 1991, p. 230)

Students' beliefs, experiences, and perspectives about the physical education curriculum are seldom addressed in curriculum reform and decision making (Graham, 1995). This may be due, in part, to the predominant influence of information processing approaches to curriculum design, teaching, and learning that assume learners' replicate, rather than construct, information (Alexander, 2006; Crockett, 2004). Curriculum scholars in physical education (e.g., Jewett & Ennis, 1995) and educational psychologists (e.g., Alexander, 2006; Vosniadou et al., 2001) have reiterated the power of students' subjective perspectives and experiences to transform curricular meaning (Roth, 1991; Ennis, 2007).

Based on the findings from this research, middle school physical education fitness curriculum and instruction can be enhanced through the purposeful inclusion of tasks that are sensitive to the diverse ways in which students interpret information. These fitness curricular designs and instructional experiences begin with an understanding of students' initial models (i.e., what they already know and believe about body systems and intensity concepts). They then parallel students' synthetic model development (e.g., ways of thinking and acquiring these concepts) within units planned to assist them to advance toward more scientifically correct conceptual understanding. For example, given that chemical awareness begins to emerge at the middle school level, physical education curricula could parallel science education content by focusing on the role of gaseous exchange between the lungs and capillaries or muscles and capillaries. These could be targeted effectively as instructional objectives for students between 10-14 years of age.

Teachers can also better position themselves to create tasks that match students' developing understandings and scaffold instruction as they begin to understand how students develop their mental models about intensity or body systems, recognize students' unawareness of their naïveté in their ideas, and appreciate that students' existing ideas are coherent and make sense to them. Teachers can increase student learning by purposefully scaffolding instructional tasks and questioning to encourage students model development. When teachers acknowledge that students have naïve conceptions that are coherent to them, they can work gradually to create tasks and experiences that encourage students to question their currently held beliefs.

As teachers focus more on the role of students' beliefs in facilitating or constraining learning, they may be able to adapt their existing assessments more effectively to assist students to question their naïve conceptions. For example, if a teacher notices that students' written definitions for cardiovascular endurance refer solely to the heart or the lungs, the teacher can infer that they perceive these as isolated organs. The teacher can encourage students to explain their rationales to verify that they do not perceive the integrated function between the heart and lungs. The teacher can then purposefully target this perception by developing tasks to help students understand how organs are connected via the circulatory system. For example, following intense activity, such as the mile run, teachers can ask students to take their heart rate while holding their nose, helping them realize the interrelatedness of the cardiovascular and pulmonary systems. Alternatively an instructional task can involve the setting up of a "circulatory system course" through which students travel as they adopt the role of a red blood cell, picking up oxygen from the lungs and delivering it to the heart and muscles.

Students in this study actively made connections between information gleaned across different subject areas, body perceptions, and exercise intensity level (e.g. feeling an elevated heart rate and monitoring heart rate with monitors). Additionally, students used their imaginations and analogies with other phenomenon they experienced in their daily lives (e.g., grandmother, car, battery, train, Pac Man) to interpret and explain intensity and its effect on the human body. It is important to recognize that students' achieve conceptual coherence in ways that are not directly observable (e.g., blood flow; intensity) and may involve an interdisciplinary basis (Chi et al., 1991; Modell et al., 2005). Since students make connections among concepts in diverse ways, teachers can help students by making concept relationships explicit and designing learning experiences that assist students to understand the relational structure inherent in the FITT principle (Ennis, 2007).

Traditionally, physical education teachers have assessed student learning through observations of students' physical performances and short answer written responses to factual questions. Teachers in this study used a matching task to check students' factual knowledge about the FITT principle. These tasks are not designed to assess students' beliefs about knowledge. In future programs physical education teachers might select assessments that encourage students' to express their detailed factual, procedural, conditional knowledge. Using performance and cognitively oriented tasks, (e.g., group discussions, written products) teachers can gain access to the rationales students use as the basis for their knowledge about FITT or intensity. These more extensive checking for understanding methods can enable teachers to identify students' naive theories, identify concepts that cause students difficulty, and design remedial instructional interventions. For example, when a teacher notes that students have identified incorrectly the heart as the site of cellular respiration, they can use students' existing idea to help them transition towards a more scientifically correct location for this process. Externalization of students' beliefs and knowledge conceptions can assist teachers to determine the need to revisit certain concepts or establish when students are ready to move on to more complex information.

Recommendations

This study was an exploratory study into the role academic beliefs play in knowledge development in physical education, specifically in relation to fitness concepts. Recommendations for future research should focus on the connections between epistemic and ontological beliefs, instructional supports and scaffolds, development of students' naïve theories, the role of language in conceptual change, and the value of longitudinal research.

Examinations of Epistemic, Ontological, and Motivational Beliefs

Epistemic and ontological beliefs. A number of ontological and epistemic beliefs intertwined with students' knowledge were inferred through the findings. I noted that students' in the same class may be at different places on both types of academic beliefs and even on the dimensions within them. In future studies, there is a need for physical education scholars to understand academic belief constructs more deeply especially epistemic beliefs, because dimensions (structure, source, stability) are interconnected and provide dynamic linkages to ontological assumptions and knowledge. Although scholars have validated epistemic belief instruments to measure students' beliefs about scientific topics such as physics (e.g., Stathopoulou & Vosniadou, 2007), as yet, such instruments are unavailable in physical education. Recently physical education researchers have begun to acknowledge the role of epistemic beliefs in conceptual change although the available literature focuses on epistemic beliefs about physical education as a domain and motivational beliefs, such as conceptions of ability (Lodewyk, 2007). This dissertation research is the first to connect epistemic beliefs to student conceptual learning of specific topics or concepts in physical education.

Buehl and Alexander (2001) and Stathopoulou and Vosniadou (2007) noted that the inherent complexity in investigating academic beliefs is compounded by the fact that they are multidimentional and multilayered in nature. Further, students may have different epistemic beliefs in different subject areas. Academic beliefs comprise domain specific and domain general beliefs that learners hold, develop, and use with specific learning content in specific contexts. Given that fitness knowledge has roots in many disciplines (e.g., physical science, human biology, chemistry), the examination and development of instruments designed to measure the impact of diverse epistemic roots on learning specific fitness and physical education topics may become important in future research.

Motivational Beliefs. A limitation of the Framework Theory of Conceptual Change is that Vosniadou (2007) has only recently begun to articulate the role of motivational beliefs on student conceptual change. For example, she reiterated that fostering the development of advanced epistemic beliefs is necessary to promote students' awareness and intentions to revise their existing conceptions. Recently, Stathopoulou and Vosniadou (2007) explained that model revision is influenced by motivational and affective factors. The role played within the knowledge development process by other non-academic beliefs student may hold, such as motivational beliefs (e.g., self-efficacy, locus of control, or conceptions of ability), or interest (Alexander, 2006) is still emerging. Hence, future examinations using FTCC as a theoretical framework should investigate the role of motivational issues on model development in addition to academic beliefs and situational variables.

Examinations of Instructional Supports and Scaffolds

Placek et al. (1998) indicated that little is known about the specific details of student knowledge [and beliefs] about physical education concepts or the instructional strategies and scaffolds that teachers can use most effectively to support learning. FTCC provides an opportunity to address this concern by providing a coherent framework to examine the development of naïve conceptions as mental models. Through this process scholars can examine learners' knowledge, perceptions, and academic beliefs as an integrated conceptual system developed within specific contexts. The interplay of these elements may mediate learners' conceptual knowledge development and structure naive theories or rationales used to interpret, understand, explain, and predict fitness domain concepts. Gaining access to learners' rationales and contextual influences is essential if researchers are to understand students' perspectives about learning fitness concepts and examine variables that both facilitate and limit their development. Further, Mason (2002) has asserted that instruction targeting both knowledge and belief change is more likely to affect behavioral and attitude changes. Thus future physical education research is needed to examine the impact of knowledge and academic beliefs on students' attitudes towards physical activity and fitness.

Alexander (2006) emphasized the importance of examining how learners interact with instructional messages. Findings from this study highlighted the need for researchers and educators to avoid the assumption that instructional strategies are effective. Instead, scholars are encouraged to conduct independent examinations to determine the instructional effects with targeted populations in specific settings.

Examinations of Students' Naïve Theories

Students travel diverse learning pathways and undergo diverse conceptual transitions during the learning process. Vosniadou (1994) emphasized that irrespective of the degree of naïveté in their understandings, students' conceptions are internally coherent from their perspective. Researchers should be sensitive to students' lack of awareness for their tacit academic beliefs, naïveté in their ideas, or distortions in their responses. Naive conceptions may develop due to the inherent complexity and counter-intuitive nature of the concept that are not-directly perceivable. Other reasons include the nature of students' academic beliefs, the inappropriate integration, or the lack of opportunities to learn the concepts. Further, naive conceptions can develop in the instructional setting due to inaccurate and conflicting instructional messages in curricular resources, students' misinterpretations of teachers' explanations, and teachers' explanations, curricular emphases, and practices. These diverse reasons point to a need for researchers and teachers to be cautious when interpreting and labeling students' naive conceptions. It is essential to adopt a non-judgmental stance when conducting interviews with students to externalize their conceptions. Further, the adoption of qualitative probes, future scenarios, and solicitations of student interpretations could permit researchers to gain deeper access to their conceptualizations of academic domain concepts.

Examinations of the Role of Language in Conceptual Change

It is critically important to examine and report students' mental models as they develop in natural settings to gain insight into the role language plays in situational variables that facilitate and limit mental model building. Curricular practices, use of instructional practices, and the nature of the language used verbally or through instructional resources are all factors that play a role in conceptual change. Examining both the products and process of conceptual change is necessary to inform the design of future curricular interventions (Ennis, 2007).

The Value of Longitudinal Developmental Research

I recommend that this descriptive study be replicated using a longitudinal design and be conducted continuously throughout the school year. I was able to collect the data for this research towards the end of the academic year. Future research might follow students' developing conceptual knowledge as they enter sixth grade, during, and later in the school year. This can enable researchers to document more closely the conceptual transitions individual students make throughout a year and gain insight into both the products and process of model building.

Examinations of the Relational Structures of Fitness Concepts

Fitness domain concepts have a relational structure and these relationships need to be examined in isolation and together (Vosniadou, 1994). Both Stewart and Mitchell (2003) and Placek, et al. (2001) reported students' correct and incorrect responses to each FITT elements respectively. However, isolating each element may mask the inter-relation among the elements and the complexities inherent within the FITT principle. Stewart and Mitchell (2003) reported as "confusion" student responses involving a relation between intensity and time. Ennis (2007) noted that meaningful learning entails students' appreciation for the relationships between and across concepts, hence it is also important to examine student learning of the FITT principle as an inter-relational concept.

Researchers in science generally examine one concept in depth, rather than several concepts. Science educators recommend a focus on fewer concepts because each inherently entails a number of interacting concepts that may have an inter-relational and/or interdisciplinary basis. For example, understanding human physiological changes entails a multi-level interaction between physical science, biological, and chemical concepts. Hence, it may be more productive to examine fewer concepts in depth and the relational structures inherent within that one concept rather than examining students' mental models of several concepts in a shallow fashion. Additionally, given that fitness concepts are life science based, when examining students' mental models in physical education, physical education scholars should refer to previous studies conducted in science education, such as those examining students' naive theories in biology (e.g., Inagaki & Hatano, 2006), mental models of respiration and breathing, and the circulatory system (e.g., Chi & de Leeuw, 1991). Access to this literature can facilitate the interpretation of students' rationales about fitness concepts and permit scholars to understand whether there are particular developmental trends associated with learning specific concepts.

Appendix A

QUALITATIVE DATA COLLECTION TOOLS

In this section I include sample data collection tools utilized in this research.

Student instruments are presented in the following order:

1. Questionnaire #1
2. Interview #1 Interview Guide
3. Questionnaire #2
4. Interview #2 Interview Guide

Teacher instruments are presented in the following order:

1. Physical Education Teacher Interview Guide
2. Science Teacher Interview Guide

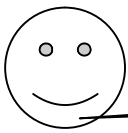
PRE-INTERVIEW TASK #1

STUDENT QUESTIONNAIRE 1 FOR BOTH SCHOOLS

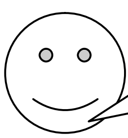
What I know about fitness!

Name : ______________________________ **Circle** Boy OR Girl School : ___________

Directions: Brendan is a new student to your school. His previous school did not have fitness as part of the P.E program. The purpose of this written task is to find out what 6th-graders at XXXX schools can teach Brendan about fitness. Don't worry! This task will *NOT* affect your PE grade. If you do not know how to spell a word, just try your best.

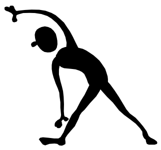
1. 

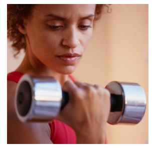
What is the **favorite thing** you do to improve your **physical fitness**? Write (and draw) your answer the space below.

2. 

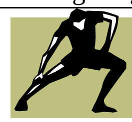
If you were going to explain what **physical fitness** means to a Brendan, what would you say ? Write (and draw) your answer in the

3. Which **element(s)** or **component(s) of fitness** are the active people in the pictures below trying to improve? For each picture, you can write one or more answers.


Side torso stretch


Lifting weights

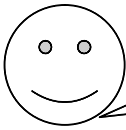

Crunches


Inner-thigh stretch

4. How would you **explain** the term **cardiovascular endurance** to Brendan? Write (and draw) your answer in the space below.

5. **Matching**: Place the letter of the correct explanation from column B (grey) with the **FITT formula** terms in column A. You will ***not*** use all explanations.

Column A: FITT term	**Column B: Explanations**
	a) The kinds of food you choose to eat to become healthy.
___Frequency	b) How hard you work your body when you perform an activity.
___Intensity	c) How long you should rest before you start the next set of repetitions.
___Time	d) How often you should do physical activity each week.
___Type	e) How long you should do physical activity
	f) The kinds of physical activities you do to build your fitness.
	g) How often you should do physical activity each day.

6. 

Read the following sentences. Circle ‘**True’** or ‘**False’**. Explain your decision to Brendan in the space below the sentence.

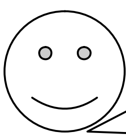
a). Tom thinks he needs to exercise at his **maximum heart rate** to be at the right **intensity** level to develop his cardiovascular endurance. True False

Explanation:

---

b) Stacey just stopped jogging and wants to check the **intensity** level of her exercise. She can do this by measuring how fast her heart is beating. True False

Explanation:

7. 

What are the **benefits** of being physically active and fit? List in words OR draw and label your answer. Use as much of the space below as you need. There is extra space.

STUDENT INTERVIEW GUIDE # I

Thank students for agreeing to participate. Remind students about recording of interview and inform them that they can stop the interview at anytime.

Preamble General Questions

1. How old are you?
2. How long have you been going to school at XXXX school district?
3. Where did you go to elementary school?
4. How many times a week did you have physical education in elementary school?
5. How many times a week do you have physical education in middle school?

Explaining to Brendan: The Nature of PE:

1. What do you think is the purpose of PE?
2. How do you learn in physical education?

- Is learning in PE different from learning in other subject areas?
- Why? How?

Explaining to Brendan: Physical Fitness and the Nature of Fitness

1. In relation to student's response to Question 1 (on questionnaire handout), regarding their favorite physical activity.
    - Where do you practice this?
    - Where do you learn about physical fitness? (home, school, media)
        - Is there anywhere else you might learn about physical fitness?
2. Is physical fitness important
    - *to you?*
    - to other 6th graders **?**
    - to adults?
    - Why or why not? (age/lifestyle).

Explaining to Brendan: Knowledge of fitness

1. Has the information you know about fitness *changed* since you've been in elementary school and now moved to middle school?
2. Is learning information about fitness *important* to you? To other sixth graders ? Why?
3. Is fitness information you learn in school *useful* to your life? How? /Why?
4. Do you feel *pretty certain* about what you know about fitness?
5. Do you have to *work hard* at learning about fitness or does it come ***easy*** to you?
    - Is there information about fitness that may be *hard* for Brendan to learn? *easy* to learn ?
    - Do you learn information about fitness on your own?
        - How? Where do you go to learn things?
    - How does your *teacher* help you learn information about fitness during PE?
    - Are there any *other people* at home...at school....who help you learn these things?
6. Do you think information about fitness consists of *simple facts* that you learn and memorize or are they *complicated facts* that are connected with each other?

- Can you give me an example?

7. Is fitness information one hears always correct? Do you think that what you learn about fitness is always *correct*?
    - How could Brendan find out whether fitness information is correct?
8. Do you think that information you learn about fitness stays the same?

Explaining to Brendan: *Being* physically fit

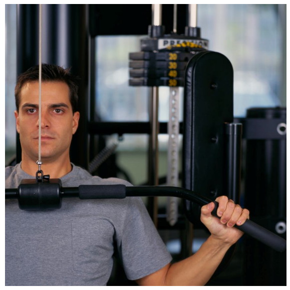
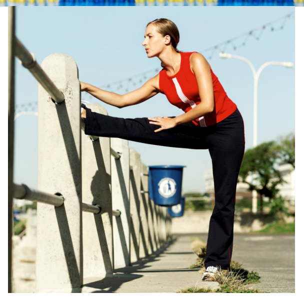
1. Are people who know a lot about fitness also physically fit?
2. <u>In relation to student's response to Question 2 re: e</u>xplaining "physical fitness" to a friend:
    - Is there anything else you would like to add to this? /Can you explain ….
3. Brendan thinks that fitness is something *you are born with*. Some other kids think that you *fitness can change the more you work on it.* What is your opinion?
4. Would you say you are fit?
    - How do you know that?
5. How do you know if someone is fit or not?

Explaining to Brendan : Components of Fitness

3. Sometimes teachers in PE use the words *components of fitness (*or *elements of fitness).*
    - Have you heard these words in class before? Seen them?
    - Did you hear about them anywhere else?
    - How did you learn these long words?
2. *How many* components of fitness are there?
3. <u>In relation to student's response to Question 3</u>
   <u>If student uses components:</u>
    - Can you help me understand what makes you decide which one is which? (They are such long names and I get them all confused). How can you help Brendan learn these long words?
    - How do distinguish between Muscular Strength and Muscular Endurance?

   <u>If student does not identify components:</u>
    - What are you trying to teach Brendan on this answer?
4. <u>Picture Card Classification Task (see pictures at end of document)</u>
   Present student with 4 pictures and ask them to identify the purpose of the activity (e.g., swimming, weight-training, performing curl-ups, group of children running).
    - Can you tell me what the purpose of this activity is?
    - In this picture, which component of fitness is being promoted?
    - Are any other components being developed?

Pictures for Components of Fitness Task. During the first interview, I presented each student with four pictures one at a time. Each picture focused on a primary health related fitness component or combination of components). The purpose was to ask students to identify the purpose of the activity (e.g., swimming, weight-training, performing curl-ups, group of children running) and understand how the attributes they ascribed to the activity type and each component.


Explaining to Brendan : Cardiovascular Endurance.
<u>In relation to student's response to question 4.</u>

1. This is pretty long word! *Where* did you learn about it?
2. How do you remember what it means?
3. (If not mentioned above) Can you give me some examples of cardiovascular endurance activities)

Explaining to Brendan : Fitness Principle/Formula

1. What is the *purpose* of the FITT formula?
2. How can you *apply the FITT* to your own fitness plan?
3. How do you use the FITT formula to develop a fitness plan for a friend?
   i. Cardiovascular endurance
   ii. Flexibility
   iii. Muscular strength
   iv. Muscular endurance?
4. (if not mentioned in relation to questions above) Is there a different in intensity between Muscular strength and muscular endurance?

Explaining to Brendan : Examination of relation between intensity and heart rate.
<u>In relation to student's response to Question 6 a.</u>

1. What is the maximum heart rate?
2. What does reaching the max heart rate mean?
3. I don't know what my maximum heart rate is. Could you teach Brendan how he can find his?
4. In your portfolio I read the word THRR: What is that? What is this range?

<u>In relation to student's response to Question 6b.</u>

1. Can you teach me how you can calculate your heart rate? Show me? Where?
2. What do you do with the number you get?

Explaining to Brendan : Benefits of Physical Activity and Fitness.
<u>In relation to student's response to Question 7.</u>

1. Are there any other benefits you can think of?

2. From all these benefits (you listed/drew), which, do you think is the most important?
3. How do these benefits apply to you personally?

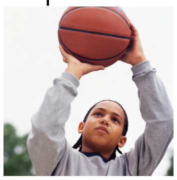
PRE-INTERVIEW TASK #2: STUDENT QUESTIONNAIRE 2 SCHOOL 1

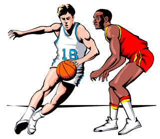
DRIBBLING MY WAY INTO FITNESS

Name:____________________________________Date________________BMS

Brendan is watching a 3-vs-3 basketball game between the white and yellow teams. The game is **very involved** for all the players. List 5 physiological indicators that help Brendan recognize that the players are **working hard**. Write (draw) your answer in the space below.

1. The students below demonstrate some of the ball handling skills you recently practiced with your teammates during PE. In the third column, show how much you think each fitness component is promoted in each activity using the code: *** = a lot, ** = some, *= a little. Explain briefly your choice in the right- hand column.

		*** or ** or *	Explanation
Performing the Spot Shoot  **(standing still)**	Cardiovascular Endurance		
	Muscular Endurance		
	Muscular Strength		
	Flexibility		
Jogging and dribbling up and around a cone, and back for 5 minutes  	Cardiovascular Endurance		
	Muscular Endurance		
	Muscular Strength		
	Flexibility		
Playing an **intense** 3-vs-3 game for 8 minutes 	Cardiovascular Endurance		
	Muscular Endurance		
	Muscular Strength		
	Flexibility		



3. You can use the FITT formula to develop physical fitness to play basketball.
   a) Fill in the missing term for each **F I T T** letter below. One answer is done for you.
   b) Define each term in the left hand column
   c) Answer the questions in the right-hand column as they relate to how you can use FITT to your basketball practice.

F___________:

Define:

How could you apply this to basketball?

I ___________:

Define:

How is this different when you are (a) standing still to do a spot shoot from a side angle **vs**. (b) repeatedly running and dribbling a ball up to and around a cone and back?

T____________:

Define:

How can you apply this to basketball?

Type:

Define:

Overall, which components of fitness can you develop by playing basketball?

Is Basketball an aerobic or anaerobic activity or a combination of both? Explain why.

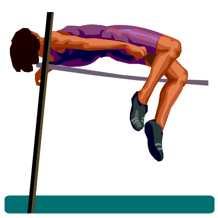
STUDENT QUESTIONNAIRE 2 SCHOOL 2

Jump, Run, and Throw for Fitness!

Name: ____Date______________________OMS

1. Brendan is watching a High School Track and Field meeting. The high school students are **very involved** in their events. List 5 physiological indicators that help Brendan recognize that the athletes are **working hard**. Write (draw) your answer in the space below.

2. The students below demonstrate some of the Track and Field events you recently practiced with your teammates during PE. In the third column, show how much you think each fitness component is promoted in each event using the code: *** = a lot, ** = some, *= a little. Explain briefly your choice in the right- hand column.

		******* or ****** or *****	Explanation
Putting the shot 	Cardiovascular Endurance		
	Muscular Endurance		
	Muscular Strength		
	Flexibility		
High Jump 	Cardiovascular Endurance		
	Muscular Endurance		
	Muscular Strength		
	Flexibility		
1600m run 	Cardiovascular Endurance		
	Muscular Endurance		
	Muscular Strength		
	Flexibility		

3. You can use the FITT formula to develop physical fitness to participate in track and field events.
   a) Fill in the missing term for each **F I T T** letter below.
   b) Define each term in the left hand column
   c) Answer the questions in the right-hand column as they relate to how you can use FITT to track and field events. Unless specified, identify one or more events of your choice to explain your answer.

F_________________: Define:	How could you apply this to Track and Field? Provide an example by identify one or more event(s) of your choice.
I _________________: Define:	How is this different when you are (a) putting the shot **vs**. (b) running?
T_________________: Define:	How can you apply this to track and field events ?
T_________________: Define:	Overall, which components of fitness can you develop by practicing in track and field events? Are track and field events examples of aerobic or anaerobic activity or a combination of both? Explain why.

STUDENT INTERVIEW GUIDE # 2

After Unit-Student Interview

Projected Time: 35 minutes.

Introduction:

Thank students for agreeing to participate. Remind students about recording of interview and inform them that they can stop the interview at anytime.

EXPLAINING TO BRENDAN: The FITT formula – why "formula"?

1. Why do you think people use the word *formula*/ principle? Is this formula/principle similar to ones you have in math or science?

EXPLAINING TO BRENDAN: Intensity: Symptoms and causes

1. In the questionnaire, you identified some physiological characteristics of exercise intensity (e.g., sweating, increased heart rate etc).What causes these physiological changes? (general)
2. I learned from watching your physical education class that exercise intensity can be at different levels (low, moderate, and vigorous). Can you tell me more about them.
3. Some people say that low level activities can help you develop physical fitness- do you agree?
4. How do you learn in PE to monitor your exercise intensity level? Probe for type:
   a. Mile run or cardio machine
   b. Doing curl ups
   c. Hamstring stretch
   d. Lifting weights

EXPLAINING TO BRENDAN: Intensity: Cardiovascular endurance and Target Heart Rate Zone

1. What do you think is happening to your ***heart and lungs*** while you are being physically active? (specific) (body's ability to use oxygen, efficiency of heart to deliver oxygen to muscles – over time, stressing body system develops cardio endurance)
   i. **Use students' responses on questionnaire 2.**
   e.g. XXX wrote: You are running a lot (during a game), you need a lot of oxygen. You need to breath hard
   Probes: Why do you need breath hard? Where does the oxygen come from?
   How does your body use oxygen?
5. How do you think your body (muscles, heart, and lungs) work together when you are moving during PE?
6. Is there a difference in the way they work together when you are doing a short activity for a short time vs. doing it for a long time?
   - Oak Middle : I saw you run the 1600m and put the shot. Can you explain to Brendan how you worked hard on both events?
   - Beech Middle: I saw you do a spot shoot vs., play 3-v-3 game very actively for 6 minutes. Can you explain to Brendan how you worked hard on both events?

7. In your test review in your portfolios, I noticed that you read about maximum heart rate (MHR) and THRR. Can you tell me more about them?
   THRR? Probe for ceiling and threshold?

8. Are MHR and THRR the same for everybody? Age, gender, fitness level?
9. From watching your class, I learned that higher the intensity of your exercise, the higher my heart rate will be, and the better my work out is. Is that correct?
10. What happens if I am above/within/below the range?
11. THRR is one indirect method for determining exercise intensity- it a guideline which is quick and easy to use. But it is just one method you can use. How do you think scientists measure exercise intensity directly?

EXPLAINING TO BRENDAN: MUSCLES & INTENSITY M-STR VS M-END

12. How do think your muscles get stronger?
13. Why do you think muscles get tired?
14. Some other sixth graders told me muscular strength has to do with the amount of force your muscles can exert. Where does this force comes from?

    -What do you think happens inside your muscle fibers when you exercise? (To exert this force, your muscles use up energy, muscle fibers contract, become fatigued, break down…need recovery period).
15. During the first interview, you talked to me about lifting weights to develop M-End and M-Str. Your muscles need energy to work and lift weights. Where does the energy come from?
    a. **Where relevant use students' responses on questionnaire 2.**

       E.g., XXX: M-End in BB: Your muscles are trying to get enough energy to shoot.

       Probe: From where do they get this energy ?

       What happens if you run out of energy?
16. How do you think your body muscles use energy when you are lifting a

    a) heavy weight for one set of 5 repetitions?

    b) Lighter weight for a three sets of 15 repetitions?

    Probe – for relation between intensity level and duration of exercise.

EXPLAINING TO BRENDAN : INTENSITY & FLEXIBILTY

17. What do you think is happening inside your muscles when you are stretching?
18. How do you know how to modify the intensity level of your stretch?

19. Additional clarification questions for specific students.

Student Interview #2
Drawing Task 1

Name: ______________________ School ____________________

Draw and label the following pictures.

What I imagine happens inside my body when I am running the mile.

Student Interview #2
Drawing Task 2

Name: ______________________ School ____________________

Draw and label the following pictures.

What I imagine happens to muscle so that they get stronger.

PHYSICAL EDUCATION TEACHER INTERVIEW

After Unit-Teacher Interview

Projected Time: 1 hour

Introduction.

- Thank you for the opportunity to work with you and your students. I have learned so much during these last weeks.

Notes:

- Remind teachers about recording interview and inform them that they can stop the interview at anytime.

Teacher Background

1. How many years have you been teaching physical education?
    - probe for specific school, grade level, additional subjects such as health
2. What was the emphasis of your masters program?
3. What opportunities does your local school district make available to you for your professional development?

FCPS Curriculum

1. The XXXX PE Curriculum has a strong fitness emphasis. Has it always been tradition of this school district to emphasize fitness?
2. Were you already teaching in this school district at the time that FCPS instituted this fitness focus?
3. Did you agree with the strong emphasis on fitness? Why or why not?
   If not, what would you emphasize instead?
4. How do you distribute the fitness content in your program in/across individual lessons and units?
5. Do you feel you have enough instructional time per class?
6. Do your students pick up on this fitness emphasis?

XXXX School District Resources

1. What teaching **strategies** have you found most effective to help your students **learn** fitness content?
    - Probe for resources provided by school district and additional sources or teacher-made teaching materials.
2. What **resources** do you use **to help students** increase their understanding of fitness content?
3. Probe for Heart Rate Monitors (HRM) and Pedometers (PED):

Heart rate monitors/pedometers

1. HRM and PED seem really popular in equipment catalogs and also the focus on instructional presentations during teacher work shops. Are they something you've found useful in your teaching?
2. Which fitness concepts do you try to target through the use of this technology?
3. When you use them, what is the main thing you want your students to take away from using them?
4. Do you use the HRM and Pedometers to relate to the Components and FITT? How? E.g., I've noticed you asked your students to do a pulse check – manual pulse -

Task Cards.

1. What are the purpose/benefits of the task cards your students use in the weights room? (yellow cards)
2. What do students do with their data once they have logged it down?
3. Once you get the task cards back, what do you do with the task cards? (with what students have written)

Use of Portfolios

1. When were the physical education portfolio ***introduced***? Why?
2. What do you see is the role of the portfolio in your PE program? (read and write)
3. Have you seen any ***changes in students learning*** of fitness now that they have the portfolio compared to when they did not have one?
4. I noticed during the lesson review for CRES that students were using the reference material at the back of the book. Did you directly show them how to use the reference info?

Reading and Writing in PE

1. How do you perceive your students connect what they are performing through movement with the tasks they do in their portfolios or their task cards?
2. How *often* would you say they use do written tasks?
3. **Do you think all the students value the incorporation of writing in PE** (e.g., on the portfolio/task cards).
   What makes you say that? Can you give me an example?
   Would your students do their portfolio tasks if there was no grade associated with it?
4. And **what about you –** how important do you think incorporating writing in a PE portfolio is?
   How did you feel when you first introduced the portfolio?
5. Have **your feelings about the portfolio changed since you** started using them with your students?
6. Do you notice any differences in students' a) understandings b) attitudes: across grade levels 6/7/8? OR different cognitive or physical skill levels OR between boys and girls?
7. Do you think your students **feel a sense of ownership** over their portfolio/task cards? What makes you say that? Can you give me an example?
8. Do students take their portfolios home to read? When? Why?

Learning

a)Pre-concepts: Concepts students bring at the beginning of the school year.

1. What do you think your sixth grade students come to you already knowing about fitness when they begin the school year?
   - Strengths and weaknesses
   - Sources: Where are they getting their "prior knowledge" from?
     - ES - Taught in ES curriculum or just picking it up from other sources/parents/?

b) Developing Concepts:

2. What concepts have been easy for kids to learn in sixth grade? Difficult or demonstrate confusion?

3. How do you see your students' understandings of fitness change as they move through 6-8?
4. How do you think what kids are learning in other subjects area affects how they learn fitness content? Which subjects and how?
5. How ….outside of school influences …..affect how they learn fitness content when they are in MS ?

Components of Fitness

1. First page in the portfolio there are 5 components of fitness- but in the book only 4- removed Body Composition- why? What is your take on the elimination of this for students at this age?
2. What do you your students bring to you at the beginning of the school year about the components?
3. How do you talk to your students about the effect of exercise on their bodies? (Hotter, sweat – how do you talk about them?)
4. How much instructional time do you spend on FITT and COMPONENTS per year?
5. How do you help your students connect the components to different physical activities?

a) Cardiovascular Endurance

1. What is the most important thing you want your sixth grade students to know about it?
   How do you explain CE to them ?
   How do you help them learn this (verbal/visual/activities)
2. How do you think Low/middle/High cognitive ability students might think about CE? How do your students talk/write about it in class (activity that raises heart rate)?
3. Do you explain to your students how a) the heart gets stronger and b) heart and lungs work during aerobic physical activity? How do you explain it to them?
4. What do you think students understand about the heart getting stronger?
5. Have you heard students talk about "cardiovascular muscles"?
6. From where do you think students could also be learning information?

b) Muscular Strength and Muscular Endurance

1. What is the most important thing you want your sixth grade students to know about these?
   How do you explain it to them?
   How do you help them learn this (verbal/visual/activities)
2. And distinguish between them?
3. How do you explain how they develop strength and endurance?
4. Do you explain how muscles a) work together and fatigue b) get stronger and bigger as part of the 6^{th} grade PE program?
5. How do you think your students think about what is happening to their muscles as they are getting stronger? - Do they associate stronger = bigger?
   Some students mentioned that muscles use energy to work. Do you talk about this with your students - how?

c) Flexibility

1. What is the most important thing you want your sixth grade students to know about it?
   How do you speak to them about it?
   How do you help them learn this (verbal/visual/activities)
2. How do you explain how they develop flexibility?

Conceptual Complexity
Which aspects of the components of fitness do you think your students find easy /difficult to understand?

F I T T

1. What is most important thing you want students to know about the FITT principle ? How do you talk to them about it?
2. **Frequency:** what do you want students to know about frequency? How do you talk to them about frequency?
3. **Intensity:** what do you want your students to get about I? How to you talk to them about Intensity?
   - probe :Do you find that sixth grade students are able to understand that I may be different depending on the type of activity?
     - How do you speak about the Target Heart Rate Zone?
       And about being above or below the zone (ceiling and threshold)?
4. **T**ype: what do you want your students to know about Type: How did you explain it to them?
5. **Time**: what do you want your students to know about Time? How did you explain it to them?

Conceptual Complexity
Which aspects of the Fitness Components and FITT principle do you think your students find easy /difficult to understand?

SCIENCE EDUCATION TEACHER INTERVIEW

Thank you for the opportunity to review science text books and samples of student work sheets.
Note: Remind teacher about recording interview and inform them that she can stop the interview at anytime.

Teacher Background

1. Training
2. Years teaching
3. Professional involvement

Teaching Body Systems in Science

1. Some students mentioned to me homeostasis – how do you talk to them about this?
2. Can you share with me how you talk about body systems with your students?
3. How do you talk during science about the effects of exercise on the body?
4. Students mentioned to me that they learned in science about increased oxygen uptake during exercise. How do you explain that to them?
5. How do you talk to your students about muscles getting stronger?
6. How do you talk to your students about the heart getting stronger?
7. Can you explain to me how you used a hand sanitizer to explain why they sweat during exercise?
8. Some students mentioned “cellular respiration”: Could you share with me how to talked about oxygen and glucose?
9. Some students mentioned “cardiovascular muscles” get stronger when running the mile. What do you think they are referring to?
10. Have you noticed any alternative ideas students have about their bodies and how it works?
11. Students mentioned to me a “brain pop” video. What is that? How do you use it? Can I see some of these video clips?
12. Some students mentioned that an untrue source of information was that “blood is blue” Do you talk about this with your students? How?
13. Some students said to me “six-pack” and “ripping” when they talked about muscles getting stronger. Can you tell me what these mean as I am unfamiliar with them- is this American idiom?
14. One student mentioned to me muscles can use carbon dioxide as a source of back up energy. Do you know where this information comes from?

APPENDIX B

IRB PROTOCOL FORMS.**UNIVERSITY OF MARYLAND, COLLEGE PARK**

Institutional Review Board: Initial Application for Research Involving Human Subjects

Name of Principal Investigator (PI) or Project Faculty Advisor Dr. Catherine D. Ennis, Professor **Tel. No** 301-405-2478

Department or Unit Administering the Project Department of Kinesiology (School of Public Health)

E-Mail Address of cde@umd.edu

Where should the IRB send the approval letter? Attention: Marina Bonello: 2132 Curriculum Lab, Dept. of Kinesiology, School of Public Health, University of Maryland,

Marina Bonello **Tel.** 703-980-4291

mbonello@umd.edu

Check here if this is a student master's thesis or a **dissertation research project** ☒

Project Duration (mo/yr – 03/2008 **--** 08/2008

Project Sixth-Grade Students' Mental Models of Physical Education Concepts: A Framework Theory Perspective

Sponsored Project Data	**Fundi**	**ORAA Proposal**	

(PLEASE NOTE: Failure to include data above may result in delay of processing sponsored research award at ORAA.)

Vulnerable Populations: The proposed research will involve the following (Check all that apply):
pregnant women ☐ , human fetuses ☐ , neonates ☐ , minors/children ☒ , prisoners ☐ , **students** ☒ , individuals with mental disabilities ☐ , individuals with physical disabilities ☐

Exempt or Nonexempt (Optional): You may recommend your research for exemption or nonexemption by completing the appropriate box below. For exempt recommendation, list the numbers for the exempt category(s) that apply. Refer to pages 5-6 of this document.

Exempt----List Exemption Category ***Or*** ☒**Non-Exempt**

If exempt, briefly describe the reason(s) for exemption. Your notation is a suggestion to the IRB Manager and IRB Co-Chairs.

Date **Signature of Principal Investigator or Faculty Advisor** *(PLEASE NOTE: Person signing above accepts responsibility for the research even when data collection is performed by*

Dr. Catherine D. Ennis

Date **Signature of Student Investigator**

Marina Bonello

Date **REQUIRED** Departmental Signature
Name ____,
Title________________________________
(Please also print name of person signing above)

(PLEASE NOTE: The Departmental signature block should not be signed by the investigator or the student investigator's advisor.)

SIXTH GRADE STUDENTS' MENTAL MODELS OF PHYSICAL EDUCATION CONCEPTS: A FRAMEWORK THEORY PERSPECTIVE

Marina Bonello, PhD Candidate & Dr. Catherine D. Ennis, Professor,

Department of Kinesiology

The purpose of this dissertation research is to examine the knowledge and beliefs students hold about learning physical education concepts/knowledge. This study is based upon the prevailing approach to examining students' mental models, namely Framework Theory of Conceptual Change. Mental models are knowledge structures that children use to think and reason about a domain. Although this theoretical framework has been applied by scholars in other subject areas, (e.g., science, mathematics, history, and social studies) it has not been applied in physical education to examine student cognitive learning.

1. **Abstract:** The purpose of the study is to examine sixth grade-students' mental models of physical education concepts and identify variables in the learning environment that may affect their development. I will use a ethnographic, multi-site case (qualitative) study design involving naturally occurring physical education programs at two middle schools in a nearby suburban public school district . Student data collection will include a: (a) questionnaire administered by the teacher to one sixth-grade class at his/her school before and after an instruction unit (b) follow-up multi-method interview (i.e., both verbal and movement responses) conducted by the researcher with a representative sample of 9 students from each class (n=18). During the instructional unit, I will conduct field observations of the unit lessons and review documents, including the curriculum guides, lesson plans, and student assignments. After the instructional unit, I will conduct a formal, open-ended interview with each teacher. Teacher consent, parental permission, and student assent will be sought prior to data collection. To ensure data safety and confidentiality, all participant demographic and response data will be locked in a cabinet at my home. These data will be accessible only to me and my advisor.
2. **Subject selection:**
    a. **School District:** The school district where data will be collected will be selected/recruited because (a) of the curricular emphasis on fitness content taught with an emphasis on cognitive concept development and (b) all physical education teachers are certified to teach physical education and health.
    Teachers: The teachers include two middle school physical education teachers in the Frederick School District (Maryland). I will select/recruit experienced, master teachers who teach cognitive content, use questioning, and instructional resources in their physical education programs. Additionally, the selected teachers will have been recommended by the school district physical education supervisor.
    Students: Each sixth-grade class will be selected/recruited to fit into my schedule so that I can observe each class each day at each middle school. A representative sample of students (see 2b below) will be selected/recruited based on their cognitive concept performance on the written knowledge questionnaire administered to all sixth grade students in each class.
    b. **<u>Will the subjects be selected for any specific characteristics?</u>**
    A representative sample of students will be selected based on their performance

on the knowledge questionnaire and recommendations from their physical education teacher. Because students will be asked to respond to interview questions, I will select students that the teacher recommends are able and willing to expressive their ideas. Three students from the low, middle, and high achievement levels on the knowledge questionnaire will be selected for interviews and as the focus for class observations. Additionally, I will consider class representativeness in terms of gender, ethnicity, and physical skill level in addition to academic ability.

c. <u>State why the selection will be made on the basis or bases given in 2(b).</u>
Conceptual change scholars examining students' mental models have recommended recruiting student sample representing a range of gender and cognitive ability. This permits researchers to examine the range of students' conceptual understandings students with greater accuracy.

d. <u>How many subjects will you recruit?</u>
Teachers: 2
Students: Two intact sixth grade classes (knowledge questionnaires) and 18 (9/class) for multi-method interviews and observations.

3. Procedures: The overall protocol of this multi-site case study is presented in the figure below.

Sources	Data collection techniques	April -June 2008		
		Pre-testing prior to unit	Regular instructional phase	Post-testing after unit
Students	Written questionnaire (each class)	√		√
	Multi-method interview (representative sample)	√		√
Learning context	Document collection		√	
	Field observations		√	
Teachers	Interview			√

<u>Students:</u>

(a) *<u>Pre- and Post-Knowledge Questionnaires</u>:* (20 min. each on two occasions = 40 min. total): The teacher will administer the knowledge questionnaire before and after the physical education instructional unit. The questionnaire will comprise a series of open and closed questions that parallel the students' regular physical education assessment tasks. Students will complete their responses using words and/or drawings. The questionnaire has not been developed at this writing. Once in the schools, I will develop the student knowledge questionnaires in consultation with each teacher to be consistent with the content to be taught in each sixth grade physical education unit. I will submit a copy of the final knowledge questionnaire to the

University of Maryland IRB office prior to administration.
(b) *Multi-method Interviews:* (30 min./ student (n=18) on two occasions = 60 minutes /interviewee): The interview questions will be consistent with the knowledge questionnaire and constructed to collection additional in-depth knowledge data about the target concepts. Additionally, the post interview will reflect the knowledge questionnaire and events observed within instructional unit. I will conduct the one-on-one interviews with 9 students from each class in a quiet location that is familiar and comfortable for the students. Questions will comprise follow up and clarification questions related to the knowledge questionnaire and any additional questions about the target concept that could not be expressed textually or visually on the written questionnaire. All student interviews will be audio-recorded and students will be asked to verbalize and demonstrate their understandings of the target concept. A copy of the interview questions will be submitted to the IRB office prior to administration.
(c) *Field Observations:* During the 5-7 weeks instructional unit. I will observe naturally occurring physical education lessons at each school. I plan to observe all the lessons during this time and document the concepts taught and strategies teachers use to present the concepts to students. Teacher-student and student-student interactions will be observed when they relate to concept teaching.
(b*)Student Documents:* I will collect examples of students' written work such as in-class assignments and homework.

Teachers:

(a) Post –Interview (45-60 min for each teacher): After the instructional unit, I will conduct a one-on-one formal, open-ended verbal interview with each teacher. The topics will relate to teachers' perceptions of how to facilitate student learning using questioning, charts, and instructional tasks that I observed in the lessons. All teacher interviews will be audio recorded in a quiet area familiar to the teacher, such as the school conference room. A copy of the interview questions will be submitted to the IRB office prior to administration.
(b)Field Observations: Observations of teachers' lessons will focus on the teachers' directions, instructional tasks, and comments. Observations will focus on the teachers' use of instructional materials, the order of presentation, and use of questioning in each lesson.
(c) *Teacher Documents:* I will ask teachers for a copy of their lesson and unit plans, and I will take photographs of teachers' instructional charts.

4. **Risks:** There are no known psychological or physical risks to the participants. This research will be conducted within the regular physical education class. Student knowledge questionnaires will be limited to the curriculum content approved by the school districts. The questionnaires will be administered by the physical education teacher as part of the regular physical education lesson. The student interviews will be limited to content approved by the school district and included on the knowledge questionnaires. The interviews will be conducted in a public location in the school, such as the school conference room or teachers' office. I will inform all participants of the purpose and procedures involved and take steps to help participants feel comfortable. I will speak to them using their own terms (e.g., child friendly language) and be open to anything they would like to say (i.e., I will avoid judgmental stances but rather will adopt a stance of naïveté). Student interview questions will relate to students' subjective experiences of the target concept only. Teacher interview questions will relate to their understandings of how students learn the target concept and the teaching methods used to address learning of the target concept. Data collection will occur in settings familiar to the participants: the knowledge questionnaire will be completed during the regular physical education class and the interview will be conducted in a quiet area familiar to the students (e.g., the teachers' physical education office that is connected to and overlooks the gym).

Benefits: There will be no direct benefits to these students and teachers involved in this study because of the confidentiality procedures established. I will not reveal student responses to their teachers and thus teachers will be unable to use the data to increase student understanding. Although the results of this study will not benefit the students in this study, it is my hope that the results can benefit future students and teachers by increasing teachers' understanding of how students learn cognitive concepts in physical education. The final section of the dissertation will include an "Implications for Instructional Practice" which can be adopted by the school district to facilitate the development of meaningful physical education experiences for students in the future.

5. Confidentiality:

To ensure data safety I will store all knowledge questionnaires and interview transcripts in a locked cabinet at home. To protect participant confidentiality, I will replace participants' names with pseudonyms. I will list participants' real names and pseudonym on a master list that I will file and lock securely at home. During the analysis phase, I will use only pseudonyms. After five years, I will destroy the master sheet, knowledge questionnaires, and interview data once I have completed the final reports.

6. Information and Consent Forms: I will conduct this study with the support of the Frederick County School District (Maryland). I will inform all participants of the purposes and procedures in this study. I will obtain parental permission and assent from the students themselves. Additionally, I will obtain consent from the respective physical education teachers. I will provide a copy of the consent/assent/parental permission forms to all participants for their personal records and inform them that they can withdraw from the study at any time.

Attached to this application is a request for a parental permission waiver (46.116(d)) for students taking the knowledge questionnaire as part of their regular physical education class. I will seek parental permission for interviews with the 18 students and teachers who will be the focus of this research

7. Conflict of Interest : There is no conflict of interest

8. HIPAA Compliance: I am not using data that is involves HIPAA clearance

9. Research Outside of the United States: I will collect data in the USA.

10. Research Involving Prisoners: Prisoners are not involved in this study.

<u>Request for Waiver of Parental Permission (46.116(d))</u>

Permission is requested to waive parental/guardian permission for the knowledge questionnaire that will be conducted with all students in two sixth grade classes in Frederick County School District. This knowledge questionnaire will be administered by the physical teacher and will reflect the content taught in the upcoming unit (pretest). The knowledge questionnaire will be repeated at the conclusion of the instructional unit using the same administrative protocols.

Parental permission and student assent will be sought for the interview that will be conducted with 18 students.

(1) The research involves no more than minimal risk to the subjects. The knowledge questionnaire poses minimal risk to the participant because it is part of the students' regular physical education experience as confirmed by the Physical Education Supervisor within Frederick County Public Schools (FCPS). Students within FCPS are accustomed to completing written tasks as part of their regular physical education lesson and the knowledge questionnaire will parallel the format students are already familiar with. Each student holds a physical education portfolio and fitness log in which they log or write in their personal data independently during their physical education class. Additionally, the students' regular physical education teacher will administer this questionnaire as part of the regular physical education instructional process.

(2) The waiver or alteration will not adversely affect the rights and welfare of the subjects.
Any students who do not wish to participate will be exempted. Participation on the knowledge questionnaire will not affect students' physical education grade in any way.

(3) The research could not practicably be carried out without the waiver or alteration.
The need to obtain consent from all the students in each class may instigate un-necessary parental concern about the physical education program at each school. The research office in the school district is already aware of my intention to apply for permission to conduct research in FCPS. This research project is supported by the physical education district supervisor who indicated that this project parallels already existing educational experiences within FCPS and can support future staff development experiences.

(4) Whenever appropriate, the subjects will be provided with additional pertinent information after participation.
I will provide my contact information on all teacher consent/parental permission/student assessment forms so that I can respond to any inquiries about this project. I can return the unmarked original knowledge questionnaire to students who may request them.

2132 Curriculum Lab
Department of Kinesiology
School of Public Health
University of Maryland
College Park, MD 20742

PARENTAL PERMISSION LETTER

_______________ 2008

Dear Parent/Guardian,

I am a graduate student at the University of Maryland, College Park, majoring in physical education curriculum development. Presently, I am conducting a research project to examine how children learn physical education concepts from students' perspective. I believe that an improved understanding of how children think about PE, from the children themselves, can help teachers determine effective ways to promote student learning. I am working in conjunction with your child's physical education teacher, Ms. ____________, and the physical education supervisor at FCPS. Permission to conduct this project has been received from the school principal ________________ and from the University of Maryland Research Review Board. During the next five to seven weeks, I will be joining Ms. ____________ at _____________ Middle School and will observe sixth grade physical education classes.

This letter asks for your permission to allow me to ask your child to participate in this project. As part of the regular physical education program, your child participates on in-class written assignments. Prior to starting the new unit in the fourth grading period, Ms. ______________ will ask students to complete another of these assignments and I would like to conduct a follow-up interview with your child to understand more deeply your child's own ideas of the fitness concepts they are learning. After the unit it over, I would like to interview your child again. All interview questions would be directly related to your child's understanding of the fitness content they experience during PE. Interviews will be audio recorded and occur during the physical education lesson and will not last longer than 25-30 minutes.

The benefits of this research are not designed to help your child personally this year. However, the results may help me and FCPS physical education teachers learn more about how sixth-grade children think and learn fitness concepts in PE. These assessments will NOT affect your child's physical education grade in any way. For the purposes of the study, I will NOT be using individual students' responses or names. Your child's responses will be confidential and anonymous. To protect your child's confidentiality : (1) your child's name will be replaced by a pseudonym and (2) the final report will provide information about sixth-grade children in general not specific students.

Participation in this project does not have any known physical or psychological risks to the children. Participation is voluntary and your child is not obliged to participate. If you initially agree to have your child participate, you may withdraw you child from the project at any time. Please complete the attached slip and have your child return the form to Ms. ___________. I will also discuss the project with and ask your child for assent to be involved in this study. Thank you for your support and consideration. Please contact me if you have questions regarding this project.

Sincerely,

Marina Bonello mbonello@umd.edu (703) 980 4291

The following statements refer to Ms. Bonello's research project at SCHOOL Middle School.

- I have read and understood the goals and procedures for the project.
- I understand that my son's /daughter's participation is voluntary.
- I understand that all data collected at my school will be protected and remain confidential.
- I understand that my child will participate on two short interviews (30 min.) that will be audio-recorded.
- I understand that I can withdraw my child at any time.

Please complete the appropriate section that reflects your choice and return the form to your child's physical education teacher.

I ***DO*** grant permission for my son/daughter to participate in the project at _________ Middle School

NAME: ____

SIGNATURE: ____

DATE : ____

Please check off √ the circle (○) below and return the form to the physical education teacher.

○ I grant permission for my son/daughter to participate on the interview during this project.

Please check off √ the box below (□) and return the form to the physical education teacher.

□ I **DO NOT** grant permission for my son/daughter to participate on the interview during this project.

I ***DO NOT*** grant permission for my son/daughter to participate in the project at _____________Middle School

NAME: ____

SIGNATURE: ____

DATE: ____

2132 Curriculum Lab TEACHER CONSENT LETTER/1

Department of Kinesiology
School of Public Health
University of Maryland
College Park, MD 20742

____________________ 2008

Dear Ms. __________________,

As you know from my previous discussions with you, I am interested in examining how sixth grade students learn concepts in physical education. Although you have verbally agreed to my project plans, in order to fulfill University of Maryland Institutional Review Board Procedures, this letter requests your formal consent to participate. I am hereby writing to ask if you are able to administer a written test to one class of your sixth grade students as you would typically do in your physical education class. Additionally, I would like to request your permission to:

- Observe the lesson you conduct with one class of your sixth graders over the course of your instructional unit during the fourth grading period (April-May, 2008).
- Conduct a follow-up one-on-one interview with a representative sample of nine students from your class.
- Conduct a one-on-one interview with yourself after the completion of your instructional unit.

Written questionnaire: I would like to ask you to administer this test during your class time using your already existing protocols for completing written work in your class.

Lesson observations: I would like to observe your regularly scheduled classes over the next five to seven weeks. I will not interrupt your class and would like to stay with you for part of the day. During the observations, I will write down field notes to note narrative accounts of your lessons, especially how your students respond to your class. After each observation, I will type up in detail each lesson observed. You are welcome to review these lesson write-ups at any time. I may also check with you some aspect of lesson descriptions in order to ensure that I have correctly described your lesson.

Interviews: I would like to conduct short one-on-one interviews with a representative sample of students from your class and yourself. Ideally, these interviews will be conducted in quiet location in your school to facilitate the audio-recording.

Prior to data collection, I would like to obtain your students' parental permission and their assent and your consent. All data accumulated will be confidential and anonymous. Only my advisor, Dr. Catherine Ennis, and I will have access to the data that we will allocate codes and pseudonyms. Participation is voluntary and you may withdraw from the project at any time. Your involvement is greatly appreciated if you agree to participate. Please complete the slip below at your convenience. Feel free to contact me if you have questions regarding this project.

Sincerely,

Marina Bonello mbonello@umd.edu (703) 980 4291

The following statements refer to Ms. Bonello's research project at _____________ Middle School.

- I have read and understood the goals and procedures for the project.
- I understand that my participation is voluntary.
- I agree to conduct the written questionnaire as I typically conduct physical education assessments during the sixth grade instructional time.
- I understand that Ms. Bonello will join me and observe my physical education program.
- I understand that all interviews will be audio-recorded.
- I understand that all data collected at my school (teacher and student data) will be protected and remain confidential.

I agree to participate in the project:

NAME: ____

SIGNATURE: ____

DATE : ____

Please return form to:

Marina Bonello
2132 Curriculum Lab
Department of Kinesiology
School of Public Health
University of Maryland
College Park, MD 20742

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Department of Kinesiology
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College Park, MD 20742
2008

STUDENT ASSENT FORM

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Dear Student,

As explained to you during class, I am a physical education student from the University of Maryland. I will be joining you and your physical education teacher, Ms. ___________, for the next weeks for physical education. I am interested to learn how sixth-grade students learn about things in physical education. I would like to invite your participation on this project. Should you accept to participate, I would like to ask you to participate on a follow-up interview related to one of your PE in-class assignments. I would like to audio-record the interview to ensure that I capture your ideas correctly. Participation does not affect your physical education grade in any way. My goal is to learn from you how you think you and other students your age learn in physical education. Please read the sentences below.

If you **WOULD LIKE** to participate in this study, please check off √ the circles (○) below and return the form to your physical education teacher.

○ I would like to take part on the written physical education task on this project.

○ I don’t mind being interviewed during this project.

○ I understand that even if I initially agree to participate, at a later date, I can always drop out this study at any time.

If you **prefer NOT to take part** in the study, simply check off √ the boxes (□) and return the form to your physical education teacher.

□ I prefer NOT to take part on the written physical education task on this project.

□ I prefer NOT to be interviewed during this project.

Name : ___________________________________ Date : ______________________

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