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THIRD THROUGH FIFTH GRADE STUDENTS' MENTAL MODELS OF BLOOD CIRCULATION RELATED TO EXERCISE

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Abstract. *Students' prior knowledge plays an important role in learning viewed as a conceptual change process. In physical education, positive changes in students' lifestyles may come from changes in their conceptual understanding of the physiological effects of exercise on the body. Among physical education teachers, charged with teaching health content related to physical activity, a better understanding of students' mental models of blood circulation and how it pertains to exercise may be useful in order to promote an effective instruction-induced conceptual change. The purpose of this study was to examine third to fifth grade students' mental models of blood circulation related to exercise. The students (N=107) were interviewed during their regular physical education class on their understanding of blood circulation during exercise. The interviews were analyzed using descriptive and axial coding and the emerging categories and topics were examined. The results revealed an initial mental model (when you exercise, your blood goes everywhere in your body) and three synthetic mental models described through the 'blood journey' metaphor. These results are discussed in relation to: (a) the gradual nature of students' mental models, (b) the developmental and non-developmental progression of students' mental models, and (c) learning failures during the process of conceptual change.*

Key words: *conceptual change, physical education, blood circulation, primary school.*

INTRODUCTION

Various researchers in cognitive psychology contend that students learn new knowledge based on their prior knowledge (Kendeou & Van Den Broeck, 2007; McGee, Almquist, Keller & Jacobsen, 2008). Cognitive psychologists such as Alexander (2006)

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defined learning as a change "in the way a person thinks, reasons, believes, and processes information, in part, by expanding or altering the individual's existing knowledge base" (Alexander, 2006, 123). Based on students' explanations of phenomena in the domains of astronomy, mechanics, and thermal physics, Vosniadou and her colleagues designed a constructivist theoretical hypothesis, the Conceptual Change Theory (CCT), to describe how infants learn new concepts based on their prior knowledge (Vosniadou, 1994, 2007a; Vosniadou & Brewer, 1992, 1994).

According to Vosniadou's CCT, during the learning process, students generate mental models from their knowledge base. A mental model refers to "a special kind of mental representation, an analog representation, which individuals generate during cognitive functioning, and which has the special characteristic that it preserves the structure of the thing it is supposed to represent" (1994, 48). Mental models are scaffolds to support future learning. These mental models constrain the knowledge acquisition process and provide important information to identify the underlying conceptual structures from which they are generated. Initial mental models are based on individual everyday life experience and are not influenced by culturally accepted information. Synthetic models combine aspects of initial mental models with aspects of culturally accepted domain knowledge. Scientific models are models based on the scientific explanations of a concept or a particular knowledge domain.

Within Vosniadou's theory, conceptual change is not conceptualized as a sudden or radical shift between one mental model to another, but rather as a continuous process that occurs through enrichment or revision. At the enrichment stage, knowledge growth occurs gradually, as children add new knowledge to their prior knowledge structures. However, sometimes new knowledge contradicts students' prior knowledge base. In these situations, knowledge growth can occur through a weak restructuring or necessitate a radical restructuring. In the weak restructuring process, learners must do more than just add new knowledge to prior knowledge. Learning requires a conceptual reorganization of the students' knowledge base by repositioning concepts, building new links or relationships between concepts, adjusting prior understanding to explain new phenomena or reshaping the knowledge base (Alexander, 2006). In this case, misconceptions are more likely to occur as individuals attempt to assimilate new knowledge into their conceptual structure that contains theories contradictory to this new knowledge. Vosniadou (1999) defined misconceptions as naïve conceptions that contain systematic error patterns. Finally, in the radical restructuring process, learners must dramatically change their knowledge structures to be able to reach higher and more complex levels of understanding. Alexander (2006) explains that this process requires a profound reconstruction of the students' knowledge base.

Based on research focusing on student's prior knowledge in physics, Vosniadou (2002) argued that children's naïve knowledge of physics is neither a collection of unstructured knowledge elements, nor stable misconceptions that should be replaced by scientific knowledge but instead is: "a complex conceptual system that organizes children's perceptual experiences and information they receive from the culture into coherent explanatory frameworks that make it possible for them to function in the physical world" (Vosniadou, 2002, 61). Students' mental models represent the explanations they use to describe a particular phenomenon within a domain based on their prior experiences that should be appreciated as an integral part of a student's learning process. CCT has been used to examine and describe student's mental models in specific knowledge domains like astronomy (Vosniadou, Skopeliti & Ikospentaki, 2004), physics (Mazens & Lautrey, 2003), chemistry (Chiu, Chou & Liu, 2002), biology (Williams & Tolmie, 2000), medicine and health (Pavel, Kaufman & Arocha, 2000), history (Leinhart & Ravi, 2008), reading (Diakidoy, Kendeou & Ioannides, 2003), mathematics (Vosniadou & Verschaffel, 2004), and recently physical education (Bonello, 2008; Pasco & Ennis, 2015).

Cognitive goals have traditionally been part of the physical education (PE) curriculum. Physical education scholars placed an emphasis on the need to examine student learning as both a performance and cognitive-based subject (Dodds, Griffin & Placek, 2001; Rink, 1999). Studies confirmed the role of students' prior knowledge in PE learning and expressed concern that some students' conceptual learning is not progressing in the manner intended by their teachers (Nevett, Rovengo & Babiarz, 2001; Placek et al., 2001a). According to Placek & Griffin (2001b), these studies demonstrated that:

> Our students are not empty balls waiting to be filled with knowledge and skill (air) when they arrive at our gymnasium doors. Instead they come ready for action, each with her or his own conceptions (mental models) of activity in general and, more specifically, the focus of that particular unit, lesson, or skill (Placek & Griffin, 2001, 402).

Bonello's (2008) examined sixth-grade students' mental models of fitness concepts (N = 18). Qualitative data collection included questionnaires, student interviews, teacher interviews, document collection and field observations of physical education lessons. The results revealed: (a) diverse configurations in students' naïve theories of how the human body functioned and adapted during exercise; (b) three mediating factors that appeared to facilitate or limit the students' learning process (school district support; language, cultural artifacts, and tool support; teachers' values and beliefs of fitness and learning); and (c) that conceptual change theory appears to be a viable theoretical and methodological framework for examining student learning in PE.

Pasco & Ennis (2015) examined third-grade students' mental models of energy expenditure during exercise. Students were interviewed during their regular physical education class to investigate how they understood energy expenditure during exercise. The results revealed two mental models, initial and synthetic. In the initial mental model, the students considered energy expenditure as an on/off process. They believed that when one was tired (out of energy), the body was slowing down and eventually coming to a stop. In the synthetic model, energy expenditure during exercise was understood as a dimmer switch process. The students believed that when one was tired, the body was in the process of becoming stronger and healthier. These mental models might impact the children's behavioral responses to the task of running a mile during their physical education class. It was found that the students with the first mental model were more likely to stop running when they felt tired, whereas the students holding the second mental model were more likely to keep running by adjusting their pace.

Physical education teachers are charged with teaching health content. In this context, Ennis (2007) recommended defining learning as conceptual change in PE and physical activity settings. For example, positive changes in students' lifestyles may come from changes in their conceptual understanding. These changes can occur directly by adding new knowledge to student's prior knowledge or necessitate a restructuring of this knowledge. Currently, however, we have little understanding of how mental models are generated in PE and how they guide students' understandings and activity choices. The purpose of this study was to investigate third to fifth grade students' mental models of blood circulation related to exercise. The way students explain blood circulation during exercise may be a key element in their understanding of the benefits of exercise and an active lifestyle. Research questions that informed this research were (a) what are students' mental models of blood circulation and, (b) to what extent is it possible to ascertain the progression of children's mental models of blood circulation. This study is significant because it expands the theoretical application of Vosniadou's (1994) conceptual change framework to PE and specifically to concepts within health-related fitness.

THE METHOD

2.1. The sample of participants

The participants were 107 students. Both boys and girls were included in the study (female students made up 43% of the sample). They were recruited from an elementary school in southeastern USA, in which the students achieved scores of 90.9/100 in mathematics (district: 81.9; state: 82.4) and 77.5/100 in reading (district: 68.4; state: 70.7). The sample included 43 third through fifth graders (M_{age} = 8.66 years, SD = .48), 34 fourth-graders (M_{age} = 9.63 years, SD = .44) and 30 fifth-graders (M_{age} = 10.71 years, SD = .50).

The study was conducted with the approval of the University Institutional Review Board. Permission for participation was received from all participating students and students' parents or guardians through assent (students) and consent (parents or guardians) forms.

2.2. Data collection

The data were collected using semi-structured interviews. All of the students in the school initially completed a multiple choice knowledge test consisting of nine questions about physiological adaptations during exercise (e.g., "The heart beat you feel on your neck or wrist is called your: pulse or intensity or muscles"; "If you want your heart to beat faster, you should increase your: frequency or intensity or muscle strength"). Students received one point for each correct answer. Based on their score, they were classified into low, middle and high groups based on their initial understanding of physical adaptation to exercise and energy expenditure. Students were randomly and equally selected from each group (high, middle, and low) for one individual interview which was conducted during their regular PE class.

Vosniadou et al. (1992, 1994) identified two types of questions to unravel children's mental models: factual questions and generative questions. A factual question is one that children can answer by repeating information they received. An example of a factual question is, "Where is your heart located?". A correct answer for this question did not necessarily mean that children understood the function of the heart during exercise. They can repeat information received through instruction, but the information will likely not provide insights into students' cognitive processing. Conversely, generative questions "confront children with phenomena about which they do not have any direct experience and about which they have not yet received any explicit instruction" (Vosniadou, 1994, 50). For example, in this study, we used the generative questions "When you're jumping rope, what is your blood doing to help your body keep jumping?" and, when students said that the blood pumps out of the heart, we asked "Where does the blood go after it is pumped out of the heart ?" to access their understanding of blood circulation related to exercise. Vosniadou (1994) stated that such questions have a great potential for providing information about children's mental models. Students retrieve the relevant information from their prior knowledge base when they are asked generative questions.

Because the purpose of the study was to describe children's mental models about blood circulation related to exercise, a context for the interviews was created that involved children's experiences in physical activity. To do that, students were interviewed during their regular PE class in an open room beside the gym and the interviews were introduced through a scenario related to physical activity. The interviewer began by saying:

> You and your best friend are jumping rope to music in Mr. or Ms. (name of the PE teacher) class. You have been jumping for the whole song. When the music stops, your heart was beating faster than it was before you started jumping. If you looked at your best friend, how would you know that she/he had been jumping rope?

We assumed that the context of PE class and the story related to exercise were more likely to promote student explanations of blood circulation during exercise. Interviews lasted 10 minutes and were audio-recorded.

2.3. Data analysis

Each interview was transcribed as a Word file document and used as input for the Max Qualitative Data software unit (MaxQDA) for analysis. Open and axial coding procedures were used to categorize students' responses (Corbin & Strauss, 2008). The foundation of coding is based on the association between an incident or a quotation in the raw data and a code. In the open coding phase, three researchers independently created codes based on students' words obtained during interviews. For example, if a student answered the question "Where does the blood go after it is pumped out of your heart?" by "Hum, like everywhere in your body", we coded "blood/goes/everywhere/body." Then, each researcher printed her/his own coding list with quotations. All of the researchers looked at each list searching for codes reflecting the same understanding of the phenomena. For example, the codes "blood/goes/to/different/parts/body" and "blood/goes/everywhere/body" were merged into "blood/goes/everywhere" reflecting students' understanding of blood circulation in the body.

During the axial coding phase, codes from each question were analyzed to find patterns reflecting mental models. As findings were compared across students' answers, themes were identified to make sense of student conceptualizations (Corbin & Strauss, 2008). The MaxQDA software was utilized to capture codes as categories and properties assigned along dimensions to capture students' mental models. As the findings were compared across students' responses, mental models emerged and were identified to make sense of the students' answers. Peer debriefing was conducted throughout the analysis process to provide a critique of each conceptual structure and to propose and provide a critique of the emerging levels of understanding. Student interview data were coded and recoded within their conceptualizations to identify patterns and commonalities reproduced consistently across student responses. The students' mental models found in this study are shown in the results section. They are limited by the students' prior experiences and formal/scientific understanding.

2.4. Data reliability

Data reliability was established through the use of five strategies described by Shenton (2004): (a) the adoption of well-established research methods; (b) random sampling; (c) background, qualifications, and the experience of interviewers; (d) negative case analysis; and (e) peer review. Conceptual change methodology has been used successfully in a variety of knowledge domains to identify children's mental models (Vosniadou, 2008). The children in each group (low, middle and high conceptual knowledge) were randomly selected. The interviewers were trained in the semi-structured interview process and certified by the Institutional Research Board to conduct research with children. During the data analysis, the researchers searched for negative cases that could disprove categories or provide an alternative explanation. Finally, data analyses were conducted by three researchers independently using the same protocols. Discussions were conducted until full agreement was reached on each mental model. The researchers agreed to focus on key patterns within the interview responses, identifying children's mental models.

THE RESULTS

The students' answers revealed four different mental models of blood circulation related to exercise. These models are presented in Table 1 with their respective frequency scores (i.e., number of students connected to each model). The four mental models are described using the 'blood journey' metaphor. Duit (1991) suggested that metaphors are "potentially valuable tools in conceptual change learning" (Duit, 1991, 653). The 'blood journey' metaphor appeared to be a valuable tool to describe students' mental models identified in this study.

Table 1 Students' mental models of blood circulation related to exercise and their frequency in the sample (N = 107)

Mental models (MM)	Description	Grade level			Total
		3	4	5	
Initial MM	A one-way trip to an unspecified destination	36	25	22	83
Synthetic MM 1	A one-way trip to an unspecified destination using a specified road	2	1	2	5
Synthetic MM 2	A one-way trip to a specified destination for a purpose related to exercise using a specified road	1	6	4	11
Synthetic MM 3	A round trip to a specified destination for a purpose related to exercise using a specified road	4	2	2	8
Total		43	34	30	107

3.1. A one-way trip to an unspecified destination

In this initial mental model (initial MM), students stated that when you exercise, your blood goes everywhere in your body. A total of 83 students expressed this mental model through their answers (36 third graders, 25 fourth graders and 22 fifth graders). We illustrate below with interviewer identified by I, student by S:

I: "What happens inside your body when your heart beats fast?"
S (3rd grade): "It pumps blood faster"

I: "Ok. Where does the blood go after it is pumped out of your heart?"
S: "Through your body"
I: "Through your body"
S: "Through all the parts of your body"

I: "Where does the blood go after it is pumped out of your heart?"
S (4th grade): "Everywhere in my body"

In this initial MM, the blood journey in the body is a one-way trip to an unspecified destination.

3.2. A one-way trip to an unspecified destination using a specified road

Students categorized in the first synthetic mental model (SM1) explained that, when you exercise, the blood goes everywhere in your body through the veins. Five students expressed this mental model (2 third graders, 1 fourth grader and 2 fifth graders). This mental model was identified as the first synthetic mental model because the students are still talking about a general destination for the blood. Compared to the initial MM, they additionally demonstrated they possessed a scientifically inaccurate knowledge that blood goes from heart to the body through the veins. They identify the specific pathway associated with blood circulation during exercise as the quotations below illustrate:

I: "When you are jumping rope what is your blood doing to help keep your body jumping?"
S (5th grade): "Your heart beats faster and pumping blood faster to your body"
I: "Where does the blood go after it is pumped out of your heart?"
S: "The blood goes through your veins to your body"

I: "When you are jumping rope what is your blood doing to help keep your body jumping?"
S (4th grade): "It is pumping"
I: "It is pumping?"
S: "Fast"
I: "Ok. Anything else?"
S: "And…no"
I: "Where does the blood go after it is pumped out of your heart?"
S: "It goes through your veins and all over your body"

In this SM1, the blood journey in the body is a one-way trip to an unspecified destination using a specified road (the veins).

3.3. A one-way trip to a specified destination for a purpose related to exercise using a specified road

In the synthetic mental model 2 (SM2), students explained that when you exercise, blood goes where you need to exercise, using the veins to deliver oxygen. The blood circulation during exercise has a purpose. Eleven students in the sample expressed this mental model (1 third grader, 6 fourth graders and 4 fifth graders). The quotations below show that the students demonstrated awareness of the role oxygen plays in blood circulation, and added a destination (i.e. muscles) as part of the blood circulation process during exercise. They explained a blood pathway from the heart to the muscles:

I: "When your best friend is doing jump roping, what is his blood doing to keep him moving?"
S (4th grade): "Pumping"
I: "Pumping? Okay"
S: "Going through the veins"
I: "Going through the veins. So, where does the blood go after the blood has been pumped out of the heart?"
S: "It travels to the muscles that is needed, that gives to the muscles the oxygen"

Students thus demonstrated awareness for the integrated function of the cardio-respiratory systems. They utilized the terms "heart", "pumping", "oxygen, "breath" and "muscles" to describe blood circulation related to exercise. For example:

I: "What happens inside your body when your heart beats fast?"
S (5th grade): "Every time your heart beats its pumping more blood to your body because when you get active you need more blood to move"
I: "Where does it pump the blood"
S: "Everywhere in your body"
I: "When you are jumping rope what is your blood doing to help keep your body jumping?"
S: "The reason you have to breath is because the heart pumps oxygen in the blood and it sends oxygen to other parts of your body so you can keep doing what you are doing"
I: "How does your body get oxygen?"
S: "You breath"
I: "Where does the blood go after it is pumped out of your heart?"
S: "It goes through your veins to each and every part of your body"

In this SM2, the blood journey in the body is a one-way trip to a specified destination related to exercise (muscles, arms, legs) using a specified road (veins) for a purpose (delivering oxygen).

3.4. A round trip to a specified destination for a purpose related to exercise using a specified road

In the synthetic mental model 3 (SM3), the students explained that when you exercise, blood goes from the heart to where you need to exercise (muscles), using the veins to deliver oxygen and then goes back to the heart. Compared to SM2, they expressed the knowledge that blood goes back into the heart demonstrating awareness for a "loop" in the blood pathway (initial awareness for systemic circulation). Eight students expressed this mental model (4 third graders, 2 fourth graders and 2 fifth graders). Two examples from this level are given below:

I: "When you are jumping rope, what is your blood doing to help your body keep jumping?"
S (3rd grade): "It's…. the blood going out body and going into our muscles which helps us to doing many things we need to do"

I: "Where does the blood go after the blood has been pumped out of the heart?".
S: "It pumps out and goes to your muscles through veins. Once it reaches your muscles, it gives you oxygen and goes back to your heart, it will start all over again"

I: "What happens inside your body when your heart beats fast?
S (5th grade): "The blood goes through veins to the place in your body where it is needed to exercise."
I: "When you are jumping rope, what is your blood doing to help your body keep jumping?"
S: "It gives you oxygen to keep you moving instead of slowing down and stuff."
I: "Where does the blood go after the blood has been pumped out of the heart?".
S: "It goes back around and back to your heart".

In this SM3, the blood journey in the body is a round trip (the blood goes into and then back into heart) with a purpose related to exercise (delivering oxygen to help the muscles keep on going) using a specified road (the veins).

Discussion

The goal of this study was to examine third to fifth grade (N=107) students' mental models of blood circulation related to exercise. The results revealed four mental models but also a scientifically inaccurate knowledge observed at each synthetic mental model that the blood goes from the heart to the body through the veins. These results are discussed related to: (a) the gradual nature of students' mental models, (b) the developmental and non-developmental progression of students' mental models, and (c) learning failures during the process of conceptual change.

Our results indicated that the students' mental models of blood circulation related to exercise is gradual. These findings support previous results on the students' understanding of scientific concepts in the CCT. Vosniadou et al. (1992) studied students' explanations of the shape of the earth. The results showed five alternative shapes from the scientific sphere model held by first to fifth grade students (N=60): the rectangular earth, the disc earth, the dual earth, the hollow sphere, and the flattened sphere. Vosniadou et al. (1992) demonstrated that the process of learning does not involve a sudden and dramatic shift from one theory to another but a continuous process that happens gradually from students' naïve theory to the scientific model. The results showed the gradual impact of new information about the shape of the earth on children's naïve theories. Conceptual change appears when students try to make their understanding more consistent with the scientific model. In our study, knowledge development occurs when students add new information (i.e. the blood goes where you need to exercise) to their prior knowledge (i.e. the blood goes everywhere). This type of conceptual change has been called "enrichment" in CCT. As Vosniadou, Vamvakoussi & Skopeliti (2008) has pointed out, "Enrichment type mechanisms can be very successful in many cases of knowledge acquisition" (Vosniadou, Vamvakoussi & Skopeliti, 2008, 15). Our results show that third to fifth grade students' knowledge development about blood circulation related to exercise is gradual and that mental models are scaffolds to support future learning. These results have been confirmed in Vosniadou's and her colleagues' empirical studies (Vosniadou, 1994, 1996; Vosniadou, Ionnides, Dimitrakopouou & Papademetrios, 2001).

Previous longitudinal studies in CCT found a developmental progression of the mental models held by children (Mazens & Lautry, 2003; Vosniadou et al., 1992). In Vosniadou et al. study (1992), most first grade students expressed a dual earth model or a mixed model while third graders expressed a range of models including sphere, hollow sphere, and flattened sphere. Most of the fifth graders expressed either the sphere model or the hollow sphere one. Mazens & Lautry (2003) found five mental models of the concept of sound with a group of children from six to 10 years old (N= 89). The distribution of these models across school grades suggested a developmental trend. Our results confirm a developmental progression from third to fifth grade for the initial MM (the blood goes everywhere in your body). As children moved from the third to the fifth grade, fewer students expressed this initial MM: 36 in third grade, 25 in fourth grade and 22 in fifth grade. However, our results are not congruent with the developmental trend hypothesis for the synthetic mental models. There are more fourth graders (6) in SM2 than fifth graders (4) and there are more third graders (4) in SM3 than fourth graders (2) and fifth graders (2). These results indicate that students' knowledge growth is not always related to grade level through a developmental trend. According to CCT (Vosniadou et al., 2008; Vosniadou, 2007b), children learn new knowledge based on their previous knowledge and experiences. A third grader can know more about blood circulation related to exercise than a fifth grader based on his previous knowledge and experiences.

Within each synthetic MM, the students expressed the knowledge that blood goes through the body, or where you need to exercise, through the veins, which is not a scientifically accurate (the blood goes from the heart to the muscles through arteries, arterioles, capillaries and, on the way back to the heart, from the capillaries, vessels called venules and veins). Vosniadou (1994) has called this phenomenon a "learning failure". Learning failures can happen for many reasons at any time during the knowledge acquisition process. These learning failures can lead to inconsistency, inert knowledge or misconceptions in the students' mental models. Inconsistencies "are produced when conflicting pieces of information are simply added to existing knowledge structures" (Vosniadou, 1994, 49). According to Chi (1988), inert knowledge is produced when a student memorized and stored inconsistent information in a separate microstructure used only in specific tasks (e.g. school-type tasks). Misconceptions are formed when students attempt to assimilate new scientific information into their existing understanding of phenomena based on their prior knowledge that contains information contradictory to that new scientific information. Our results revealed that students formed an inconsistency about the blood using veins to travel from the heart to the muscles. When students are confronted with the scientific knowledge of blood circulation in the body, the formation of misconceptions is likely to appear because they will be confronted with scientific knowledge that differs from their mental models of blood circulation related to exercise. As Vosniadou (2007c) has pointed out, an instruction-induced conceptual change process requires students to be aware of their inconsistencies and teachers to evaluate students' understanding of phenomena before teaching them any new scientific knowledge. With PE teachers charged with teaching health content related to physical activity, they may need to consider how to take into account students' inconsistencies and evaluate student's prior knowledge about physiological concepts related to exercise in order to promote an instruction-induced conceptual change.

In conclusion, this study's findings support Ennis's theoretical perspective (2007) and Bonello's empirical research conclusion (2008) that conceptual change theory can be a viable framework for examining student learning in PE. It contributes to a better understanding of students' mental models about blood circulation related to exercise and the process of learning new knowledge. Future research should investigate how students' mental models of physiological concepts related to exercise might affect their understanding of physical activity benefits and their engagement in physical education and physical activity.

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MENTALNI MODELI CIRKULACIJE KRVI TOKOM VEŽBANJA UČENIKA TREĆEG DO PETOG RAZREDA

Prethodno znanje učenika igra važnu ulogu u učenju kao procesu adaptiranja postojećih koncepata. Na primeru nastave fizičke kulture, pozitivne promene u načinu života ispitanika mogu biti posledica promene njihovog razumevanja koncepata i fizioloških efekata vežbanja na ljudsko telo. Među nastavnicima fizičkog obrazovanja, koji su zaduženi da deci predaju nasavni sadržaj koji se tiče zdravlja i fizičkih aktivnosti, bolje razumevanje mentalnih modela koji se tiču cirkulacije krvi tokom vežbanja mogu biti korisni u promociji efikasnih konceptualnih promena koje bi usledile kao posledica instrukcije nastavnika. Cilj ovog istraživanja bio je da se ispitaju mentalni modeli učenika od trećeg do petog razreda koji se tiču cirkulacije krvi tokom vežbanja. Učenici (N=107) su intervjuisani tokom njihovih redovnih časova fizičkog obrazovanja o tome kako razumeju cirkulaciju krvi tokom vežbanja. Intervjui su analizirani upotrebom deskriptivnog i aksijalnog kodiranja i utvrđene kategorije, kao i manifestovane teme, su dalje analizirane. Rezultati su otkrili inicijalni mentalni model (kada vežbaš, tvoj krv ide svuda po telu) i tri sintetička mentalna modela koja se opisuju kroz metaforu 'putovanja krvi po telu'. Ovi rezultati su analizirani u odnosu na: (a) postepenu prirodu razvoja mentalnih model učenika, (b) razvojnih i ne-razvojnih progresija mentalnih modela učenika, i (c) grešaka u učenju koje nastaju tokom procesa konceptualnih promena.

Ključne reči: *konceptualna promena, fizičko obrazovanje, cirkulacija krvi, osnovna škola..*