Elementary school students' naïve conceptions and misconceptions about energy in physical education context

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Abstract:

The purpose of this study was to explore and reveal naïve conceptions and misconceptions about energy embedded in elementary school students' prior knowledge. Students' performance on standardized knowledge test was used to classify students into low, median and high levels of knowledge about the cardiovascular system. Semi-structured in-depth interviews were conducted with students in each group to extract their understanding of energy in relation to food choices, physical activities, and exercises. Analysis of the interview data generated six categories of naïve conceptions and two categories of misconceptions. Different conceptual change theories, including Chi's ontological change theory, Ohlsson's resubsumption theory, and enculturation theory were used to analyze and understand these naïve conceptions and misconceptions and why they could be robust to change. The analyses confirm the need to adopt a multi-theoretical approach to the understanding of students' naïve conceptions and misconceptions (Chinn & Samarapungavan, 2009. Conceptual change-multiple routes, multiple mechanisms: A commentary on Ohlsson. *Educational Psychologist*, *44*(1), 1–10). The findings encourage physical and health educators adopt different strategies to address the potential learning obstacles brought by students' naïve conceptions and misconceptions.

Keywords: Conceptual change theories | energy | misconception | naïve conception | prior knowledge

Article:

Introduction

Children with a better mastery of physical health knowledge are more likely to engage in healthy behaviors (Hamilton & Coulby, 2007; Pirouznia, 2001). For adolescents, mastery of physical health knowledge in relation to exercise is positively associated with participation in moderate physical activity and negatively associated with sedentary lifestyle (Nelson, Lytle, & Pasch, 2009). Nevertheless, facilitating knowledge learning is never an easy process for physical education teachers. Evidence indicates that naïve conceptions and misconceptions embedded in students' knowledge frameworks often prevent them from assimilating scientific concepts into their knowledge repertoire (Nussbaum, 1979; Pasco & Ennis, 2015 ; Vosniadou, 1994). Understanding learners' naïve conceptions and misconceptions is a necessary precursor for successful instruction. The primary purpose of this study, therefore, was to identify elementary school learners' naïve conceptions and misconceptions about energy related to physical activity lifestyle decisions, such as food intake, physical activities, and exercises. Based on three different conceptual change theories, the second purpose of the study was to understand why these naïve conceptions and misconceptions could be robust or difficult to change. The third purpose of the study was to utilize the evidence to makes pedagogical suggestions to enhance students learning in physical education.

Conceptual framework

Naïve conception and misconception in prior knowledge

Prior knowledge refers to the knowledge students bring to particular learning tasks or learning processes (Weinstein & Meyer, 1991). Studies show that students' understanding of abstract scientific concepts contains many naïve conceptions and/or misconceptions that they use to alter the scientific conceptions. Research has shown that these alternative conceptions are especially resistant to change and often form barriers to learning the scientific concepts (Nussbaum, 1979; Vosniadou, 1994, 2014; Vosniadou & Skopeliti, 2014).

Naïve conceptions and misconceptions embedded in prior knowledge have been recognized as a major obstacle to learning scientifically sound knowledge (Yip, 1998). Naïve conceptions refer to the systems of knowledge acquired from previous first-hand experiences. These conceptions are also reflected in students' information processing abilities associated with these experiences. Compared to the knowledge generally accepted by scientists, naïve conceptions are often simplistic and formed prior to systematic learning (Clement, 1982; Fisher, 1985). Conversely, misconceptions refer to the ideas students have that are different from those accepted by scientists. Different from naïve conceptions, misconceptions are formed *after* instruction or self-initiated learning and often based on false information and incorrect assumptions (Odom & Barrow, 1995). Misconceptions are constructed through more complex and abstract processes than those of naïve conceptions and are highly resistant to change (Capraro, Kulm, & Capraro, 2005). In this study, both naïve conceptions and misconceptions are considered as alternative conceptions to scientific or expert explanations but with distinctive characteristics.

Prior knowledge plays a critical role in students' learning of new knowledge (Dochy & Alexander, 1995). According constructivist learning theories, students' prior knowledge and the knowledge they receive through on-going learning activities are co-constitutive sources of learning (Hewson & Hewson, 1983; Kendeou & van den Broek, 2007). As Delay (1996) noted, '(S)tudents learn not because teachers teach but because they have taken prior knowledge and rework it in light of new information and experience' (p. 78). In other words, students learn through incorporating new knowledge into their existing prior knowledge system (assimilation) or through making fundamentally changes to their prior knowledge to accommodate the new knowledge (accommodation) (Delay, 1996). It is the dual process of assimilation and accommodation that enables learning. As a result, naïve conceptions and miscomputations embedded in students' prior knowledge can potentially delay or jeopardize their learning process.

In order to develop strategies that can effectively facilitate students' learning, the educators need to identify students' naïve conceptions and/or misconceptions about essential concepts (Dochy & Alexander, 1995). Research has been widely conducted in many domains, such as physics, ecology, biology, chemistry, and mathematics (see Costu, Ayas, Niaz, Unal, & Calik, 2007; Durmuş & Bayraktar, 2010; Magnusson, Templin, & Boyle, 1997; Neale, Smith, & Johnson, 1990; Ozkan, Tekkaya, & Geban, 2004; Rittle-Johnson, Star, & Durkin, 2009; Tastan, Yalcinkaya, & Boz, 2008; Yenilmez & Tekkaya, 2006). These studies provide invaluable information about appropriate teaching strategies to facilitate students' conceptual change. Nevertheless, little effort has been invested in understanding students' prior knowledge in the domain of physical education, especially the knowledge related to their lifestyle decisions, such as food intake, physical activities and exercises.

Energy as an essential concept in health

As Alexander and her colleagues (1991) suggested, knowledge is dimensional in that it refers to one's understanding of a given domain in either a declarative (factual) or procedural (skillful execution) form (Alexander, Schallert, & Hare, 1991). For physical education, especially the domain of fitness, declarative knowledge refers to the conceptual understanding of the facts about human bodies and human practices; procedural knowledge refers to the understanding of applying the facts in daily life to achieve better health (Schulz & Nakamoto, 2005). In schools, knowledge is often delivered or tested on the declarative dimension in classroom settings. How students apply the knowledge in daily life is less an emphasis for educators and researchers. Specifically, to achieve in-depth understanding of students' naïve conceptions and misconceptions about health knowledge, scholarly attention needs to be focused on essential concepts that have implications on both declarative and procedural dimensions.

In this study, we attempted to explore and reveal elementary school students' naïve conceptions and misconceptions of 'energy' in relation to lifestyle decisions, including food intake, physical activities and exercise. Energy as an essential scientific concept has a wide range of implications in different subject domains, including physics, chemistry, astronomy and health. In physical education, the understandings about energy as a concept are implicative on both declarative and procedural dimensions. On the declarative dimension, energy is related to abstract concepts such as metabolism, endurance, power and strength; on the procedural dimension, energy is related to many concepts like physical activities, food intake, caloric balance, weight gain/loss and food choices (Chen, 2011). Its wide implication on lifestyle decisions provides an analytical platform on which students' naïve conceptions and misconceptions can be examined and analyzed.

Methodology

The study was conducted in a suburban public elementary school located in a Southeastern state of the United States. The school serves 658 students from kindergarten to grade five. The student population consists of 66.9% White, 19.9% African American, 7% Hispanic, and 5.9% Asian. Forty percent of the enrolled students are eligible for free or reduced-priced lunch. We choose to focus on 4th and 5th graders (age 9–10) in this study because children of this age are about to actively construct conceptions and develop the knowledge into a rather sophisticated conceptual structure of understanding (Carey, 1985, 1988, 1995).

Students' naïve conceptions and misconceptions often reflect their cognitive levels and information processing abilities. Considering that students may have stratified cognitive levels and abilities to process information, we used an 8-question standardized test to categorize them into groups. The multiple-choice knowledge tests had good validity, as reported in a previous study (Chen, Martin, Ennis, & Sun, 2008). The calculated index of difficulty for the questions ranged from .34 to .55 (average = .48); and the index of discrimination from .67 to .86 (average = .79). All eight questions were related to cardiorespiratory system and fitness, but none of the questions directly addressed the concept of energy. An example question in the 5th grade test is 'To test cardiovascular endurance, take the ___.' Students can choose from the following three choices: (A) weightlifting test; (B) shuttle test; (C) blood pressure test. An example of the test question for 4th grade reads: 'You can control your heartbeat when exercising by adjusting exercise ___.' Students can choose from the following three choices: (A) frequency; (B) intensity; and (C) duration.

Based on their performance on the standardized test, the students were classified into low-, medium-, and high-knowledge groups using ±.5 standard deviation splits (Rencher, 2002). From each class, two students were randomly selected from each knowledge group, and interviewed by the researchers. A total of 62 children (34 boys and 28 girls) were interviewed. According to university IRB regulations, parental permission and student assent were obtained before the interviews.

In order to minimize disruption to the school, the interviews were conducted by six doctoral students during recesses or physical education classes. All the interviewers were enrolled in the physical education teacher education program and had extensive training in qualitative methodology and experiences in interviewing school-aged children. Prior to data collection, the interviewers had a training workshop on interviewing children for educational research. They were provided with a list of questions to probe students' understanding and application of the concept 'energy' in daily life. For instance, if a student answers 'I don't know' to a question, the researchers would probe by rephrasing the question with more age-appropriate vocabulary. The interviews are semi-structured and open-ended. Specifically, based on the students' responses to these questions, the interviewers could deviate from the designated question list and provide follow-up questions to the students spontaneously. The length of interviews ranged from ten to twenty minutes. All interviews were audio-recorded and later transcribed.

Analysis

During the interview transcribing process, we tried to ascertain how students' answers were tied to the various aspects of energy related to human body, physical activities, exercises and food intake as well as interpret the intended meanings of their answers. Due to the students' age, it is possible that some students might not possess enough vocabularies to express their understandings of the abstract concept. Once transcribing and initial open coding were finished, all the interviews were imported into ATLAS.ti, a software for analyzing qualitative data. Then, using the set of conceptual categories generated from open coding, the data were prepared for following axial coding to generate themes. In-depth interpretation of the themes was conducted in terms of the conceptual change and constructivist learning theories. The last step of analysis was to juxtapose students' conceptual understandings of energy across cognitive levels grouped by the results from the standardized knowledge test. Specifically, we wanted to know whether students with higher placement on the standardized test would present more sophisticated and close-to-science understandings of energy.

In the following Findings section, we present the results in the categories summarized through open-coding analysis. These categories include naïve conceptions and misconceptions that students have. In the Discussion section, we focus on in-depth interpretations resulted from axial-coding and theme development. In the Pedagogical Implication section, we provide pedagogical suggestions for educators.

Findings

Naïve conceptions

Naïve conception is characterized as simplistic and experience-based ideas students obtained through daily experiences. Through analyzing naïve conceptions from students' answers, we categorized them into six categories.

Energy as tangible object. The first category of the naïve conceptions is characterized as *understanding energy as tangible objects or materials*. The students described energy as 'a thing' or 'the stuff'—an object-like entity that they can sense directly. For instance, one student stated 'energy is the thing … when you run and jump.' Similar examples, 'energy is um, that thing … when you don't have energy you just like lay down and watch TV, if you have energy you will go play outside or do physical activities,' and '(e)nergy is um, the stuff that helps you stay awake.'

Energy as bodily movement. The second category of students' naïve conceptions is characterized as *describing energy through bodily movements*. For example, one student noted, 'energy is … if I had a lot of energy I'd be running around' and 'Energy is … when you are running you get more energy or like running laps.' Another student shared a similar account by noting 'If you are just running, you have a lot of energy.' In these answers, physical body movement is taken as energy itself.

Energy as physiology change. For the third category of native conceptions, student explained that *energy occurred through physiological changes related to exercises or individual's feeling of the physiological changes*, such as fatigue, shortness of breath and dehydration: 'Energy is like … when you feel tired and need to get a drink.' Other student put, 'energy is like, right now, I'm tired and need to catch my breath' or 'energy is … you are sweating and panting.'

Energy as fitness. The fourth category of naïve conceptions is characterized as *using certain attributes of fitness components, such as speed and endurance, to describe energy*. An example of using speed to describe energy is 'energy is what you get to really fast' '[energy is] like if you are slow you don't have a lot of energy but if you are fast you have a bunch of energy.' For the examples of using endurance to describe energy, students claimed: '[energy is] like … how long you can do something,' 'it [energy] … keeps you from stopping,' and 'it [energy] is [that] … you do something for a long time.'

Energy as doing. For the fifth category of naïve conceptions, students interpreted energy *by linking energy with their motivation to participate in physical activities*. One student described that 'I think [energy is] when you want to do something like play baseball, and you want to play, don't want to stop, so you won't stand there.' In another similar case, a student described that 'energy is like something that [you] want to do, [but it is] really, really tiring but you want to do it for the whole thing.' In both cases, student used interest in activities to describe energy. Students also describe energy as external force, regulation or a goal that drives them to perform physical activities. They noted that 'it [energy] is something that gives you the urge to do something,' 'it [energy] is like, I'll just keep on doing it and do my best, even for the ones I'm not good at,' '[Energy is] like how far you can push yourself. It is like getting to your limit or getting passed your goal that stuff.' Similar motivational states/dispositions also include determination and confidence, for example, one student stated that 'energy is like that when you are ready to go, you can do the best you can.'

Energy as feelings. The sixth category of students' naïve conceptions is characterized as *understanding energy through their subjective feelings*. The most often addressed subjective feeling by students is excitement. As students noted:

- Energy is when you feel [exited] you could bounce off walls or you feel like you can do something that you are not used to doing.
- [My body makes energy] by increasing heart rate level, when you get so excited. That's what energy is to me.
- [My body makes energy] by making you have exciting feelings.
- [Energy] is like when you are really hyper.
- Energy is like your body is excited, and it wants to jump around and jump rope and do cartwheels and stuff like that.
- Overall, results echo the definition of naïve conceptions in that they are largely based on students' first-hand experiences. Also, we found that a relatively large portion of students who shared naïve conceptions were from the low and medium performing groups.

Misconceptions

Misconceptions seem to have developed through a complex process in learning. It was based on students' personal experiences, ability of cognitive deliberation, and/or social interaction. Through synthesizing, we identified two major categories of misconceptions that students often relied on to understand the concept of energy.

Metaphor as the vehicle to understanding. For the first type of misconception, we found that students used *metaphors to describe their understanding of energy*. For example, to explain what energy is, students used a battery as a metaphor to explain energy supply for human body. One student put:

> Energy is something that you have. You might stop at certain times [if you don't have it any more]. Like a battery has certain energy. It has energy to turn on anything. Once it is done, it is out of energy.

The student had captured certain characteristics shared by the biological energy of human bodies and the chemical energy of a battery—both storing energy in forms of chemical substances and releasing energy in the processes of converting the substances. Batteries can store energy in the form of chemicals and release energy in forms of electricity by consuming the chemicals. In contrast, human bodies can store energy in the forms of adenosine triphosphate, glycogen and fat, and have three energy systems to release energy. However, physical immobility of human body, such as what the student described as 'stop at certain times,' does not indicate the depletion of adenosine triphosphate, glycogen and/or fat.

In another similar account, in answering the question of 'when you feel tired, what happens inside your body,' another student stated 'because your heart beats so fast, running out of energy. Like … like a motor, if you run out of gas, you got no energy. So, quickly you are out of energy.' Their understanding of energy through this metaphor leads them to believe that the human body gains energy by resting or engaging in low intensity activities. As they described human body movement by using the conceptual mechanism embodied by these metaphors:

- Um, our body makes energy by resting, and if I don't feel like resting [well] I just walk or read a book or something, so I can get energy to do things that I really like to do.
- It [energy] is like when you're sitting, it builds back up again. And when you are playing, it gets low, then it builds back up again.
- Your body makes energy by … if you sit down, it builds up energy while you are doing that. Because the oxygen helps to get your energy in, just being calm helps get your energy in.
- [Your body makes energy] by … when you rest and you wake up you feel like you want to play, because you just rested for a while and you feel like you want to play again.
- Energy is something you build up after a lot of rest. If you rest a lot then you are able to pick up the pace and run, like fast … or do anything that you know you are doing.
- Your body makes energy by like pumping blood, if you have been sitting and watching TV all day, you have tons of energy built up. And, then you go outside you have tons of energy to use because you have not been outside.
- Your body makes energy by going to sleep every night. Because if you stay up like all night, your body will probably be like really tired. When you go down stairs to eat breakfast in the morning, you probably will just go to sleep in the chair.
- Energy is something like what you get like … [after running] if I started walking and a few minutes later. I'd probably get more energy and start running again.

These elaborations suggest that the students realized that the intensity level of their body movement is negatively related to the duration that they can perform the activity, thereby mistakenly believing that the body spends energy by doing high-intensity activities and saves energy by performing low-intensity activities, such as reading, breathing, sitting, walking, and sleeping. This process of spending/saving energy can be done by the body through switching on or off the body system, just as easy as switching on or off an electric or mechanic devise. The battery and/or motor metaphors are convenient for the students to understand the energy system with some degree of ease. They are, however, misconceptions that could potentially make it difficult for them to learn scientific concepts such as overload, endurance and progression, because these concepts violate the fundamental principles of their misconceptions such as the switch mechanisms.

As relatively complex and abstract conceptual constructs, these metaphors-informed misconceptions reflect that the students possess relatively high information processing abilities. The metaphors they adopted may prevent them from assimilating new concepts into their already formed conceptual system. For instance, students may have difficulty to understand that exercise at moderate and high intensity levels would develop endurance and increase the duration of exercise, because it violates the fundamental principles of their metaphor-based misconceptions.

Substances as the vehicle of understanding. The second type of misconception is classified into two categories: one related to food intake and the other related to body images and active levels. In the first category, students identified foods such as vitamins, soda, energy drinks, heavily advertised snacks, vegetarian diet and organic foods as the sources of energy. According to one student, ‘like if you drink soda then it has something in it, and it will give you energy.’ Some students directly pointed out that it is the caffeine in soda and energy drinks that gives them energy. Several students believed that energy or nutrients only come from heavily advertised ‘healthy’ snacks and organic foods. Upon further probes, these students identified parents and commercials as the sources of their information. Many students identified vegetables the primary or even the only source of energy. Similarly these students also identified parents as the source of information.

For the second category, social discourses related to body sizes and active levels were found to shape students’ understanding of energy. During interviews, several students, a group different from the ones who used metaphors of cars and battery to explain energy, explained that energy is produced by large muscles. Also, a different group of students identified that staying lean and not being out of shape are the keys to having energy. Also, we found students believed that not being lazy is the key to have energy. For instance, one student noted that ‘exercising is good for you, because it makes you like … you are not lazy, and you just want to do many things.’ In another similar account, students described energy as ‘not just be lazy, doing nothing.’ Students integrated cultural meanings and social values attached to body images and lifestyles into their understanding of energy.

Naïve conceptions/misconceptions and cognitive achievement. We analyze students’ standardized test scores in relation to their interview answers. Result of the analysis shows that students from the high-performing group on the standardized test have more sophisticated and close-to-science conceptions about energy than students from the medium- and low-performing group. For instance, a higher percentage (58%) of students in the high-performing group identified energy as 'the capacity to do things' or 'something that enables you to move.' The percentages were 18.7% for the low-performing group and 28.5% for the medium-performing group. This finding largely confirmed that the better mastery of knowledge on cardiovascular system is related to fewer naïve conceptions and misconceptions.

We did not find difference between 4th graders and 5th graders' answers. However, many students in medium- and high- performing groups possessed abovementioned misconceptions, while students in the low-performing group were primarily occupied with naïve conceptions. In the meantime, we found that students actively assimilate new knowledge without changing their prior knowledge. As a result, conceptual changes happen on a local scale. For instance, during the interview process, some 4th graders students told the researchers that they had learned the concept of energy from their science class. In explaining what energy is, they were able to accurately define energy as 'the ability to do work,' 'something you used to do work,' or 'the capacity to do things.' Nevertheless, when they were responding to other energy-related questions in the context of physical activities and diet, their answers still contained the previously discussed naïve conceptions and misconceptions.

Discussions

Through investigating students' prior knowledge about energy in relation to physical activities and food intake, we identify naïve conceptions and misconceptions embedded in students' conceptual system. As Ohlsson (2009) argued, some knowledge can be learned 'as additions to one's prior knowledge in the course of normal, everyday experiences, without need for revision of the prior knowledge' (Ohlsson, 2009, p. 25). However, the evidence revealed in this study appears to suggest that the development of a correct concept of energy requires students to acquire novel knowledge and/or abandon prior knowledge. Educational researchers have conceptualized how naïve conceptions and misconceptions imbedded in prior knowledge make learning of scientific knowledge difficult. In relation to the findings, we use four major theories to interpret and make meanings of students' naïve conceptions and misconceptions about energy, and elaborate on why these alternative conceptions could be robust to change.

First, we adopt ontological change theory to explain the students' naïve conceptions we found. Ontological change theory was developed 'to describe/explain the assimilation paradox' (Chi, 1992, 1997, 2005, 2008; Chi & Roscoe, 2002; Chi, Slotta, & de Leeuw, 1994). The theory assumes that the learner possesses a small set of very high-level categories, including *object, event, process, and mental state,* to specify the types of entities the person believes exist. When the learner faces unfamiliar phenomenon, they assign it to an existing ontological category that seems most appropriate for the phenomenon based on some easily accessible features. In this study, students had accumulated many beliefs about energy through first-hand experiences, and assigned the concept to available ontological categories, including tangible objects, bodily movement, physiological changes, fitness concepts, motivation to move and subjective feelings, such as excitement. As a fundamental source of alternative conceptions that are robust to change, the effort of fitting into the existent ontological categories may lead to a mismatch that generates damaging effect on inferences of students' conceptual system, preventing them from establishing correct understanding of the concept (Chi, 2008).

Second, for the *Metaphor* misconception found in this study, we use Resubsumption theory (Ohlsson, 2009) to explain the metaphors of car motors and batteries that were widely adopted by students in explaining energy, particularly low intensity activities and resting to preserve energy. Resubsumption theory describes learning processes through a two-step procedure: first, bisociation, and second, competitive evaluation based on cognitive utility. For the first step, the resubsumption theory conceptualizes a learning process called bisociation. Bisociation suggests that learners learn through the realization that a theory they developed for one domain can be applied to other domains (Ohlsson, 2009). Taking the *Metaphor* misconception found in this study as an example, the students went through a bisociation event by discovering that their understandings of energy for cars and batteries can be applied to human body movement. Through this realization, the students developed a resident theory about human body movement, which is low intensity movement, resting or being sedentary helps them to save energy for future activity participation, while participation of physical activities, and high intensity activities in particular, contributes to energy expenditure and eventually energy depletion.

The resident theory they developed through bisociation is a misconception that may encounter challenges from other competing theories. For instance, educators and parents may inform the students to be physically active for better fitness. Sometimes, the resident theory developed through bisociation may reconcile with the competing theories, if the learner develops an overarching background theory within which the resident and competing theories are compatible with each other. For instance, if a student understands the human body's adaptation to exercise, he would think the following two seemingly contradictory theories are compatible to each other: (1) participating in moderate- and high-intensity cardiovascular activities is the embodiment of on-going energy expenditure, and (2) participating in the activities in long term contributes to energy saving by increasing the efficiency of the musculoskeletal and cardiorespiratory systems.

Learners, however in many cases, do not possess such as an overarching background theory. As a result, they often go through competitive evaluation by comparing the two theories' cognitive utilities based on past experiences associated with executing the relevant theories (Ohlsson, 2009). Often, competitive evaluation eliminates the cognitive conflict between the two theories by having one theory completely overriding another. For instance, the students may repeatedly have found that resting and participating in low intensity activities can immediately alleviate fatigue and physical discomforts associated with intensive activities, allowing them to continue their activities. On the other hand, the promised benefits suggested by the competing theory, which is participating physical activity gives them better fitness and ability to exercise for longer durations, is not as evident for two reasons. First, a much longer duration is needed for the students to witness their own fitness improvement to verify the theory. And second, a considerable amount of effort is necessary to achieve noticeable improvement on fitness. Eventually, the resident theory that students developed through bisociation prevails through the competitive evaluation process.

Third, for the *Substance* misconception, we adopt social construction theory to interpret the misconceptions. As Mason (2007) pointed out, the construction of misconceptions is often to transform an absence of knowledge to content socially accepted or personally meaningful (Mason, 2007, p. 2). In certain cases, the personally meaningful content is obtained through an enculturation process during which learners become a part of a community through practices of belonging, participating and communicating (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Kaartinen & Kumpulainen, 2002). For the *Substance* misconceptions found in this study, the students might have participated in a community of consumption practices or endorsed a system of value under external persuasion from media, family members and peers. As a result, they are socialized into the ways of identifying with certain social norms and practicing certain informed behavioral practices. Thus, 'knowledge is not an entity in the head of an individual, which can be acquired, enriched, or changed, but rather an activity that cannot be considered separately from the context in which it takes place' (Mason, 2007, p. 2). Similarly, Kelly and Green (1998) argued, as members being exposed, approaching, negotiating and obtaining group memberships, they construct a situated view of what counts as knowledge as well as acceptable practices within the group. To students, what counts as science-based practices and scientific concepts is indeed the result of their sociocultural negotiation through interaction.

Pedagogical implications

An important pedagogical implication of this study is that, it is critical for physical education teachers to strategically and accurately assess students' prior knowledge. Although standardized test is often chosen as an effective tool to assess students' understanding of domains of knowledge, it is not the best tool to reveal naïve conceptions and misconceptions embedded in students' prior knowledge. In addition, students' naïve conceptions and misconceptions could possibly go through different construction processes. Educators need to adopt different pedagogical strategies to overcome multiple sources of difficulty resulted from the naïve conceptions and misconceptions that impede students' learning (Chinn & Samarapungavan, 2009). To targeting naïve conception and each category of misconceptions revealed in this study, we propose following recommendations.

Ontological change. Based on ontological change theory, the difficulty of learning new concepts is due to (1) students do not possess the correct ontological category relevant to the science concept, and/or (2) students make a mismatch between the ontological category that the science concept truly belongs and the category the learner wrongly assigns. Under this circumstance, learning is unlikely to happen unless (1) students gain knowledge on the correct ontological category at the first place; and/or (2) instructional environment facilitates students to make a cross-category reassignment. With a thorough diagnosis of students' cognitive levels and prior knowledge, teachers may emphasize on helping students develop new ontological categories, especially abstract ones, that they cannot acquire in the course of everyday experiences, or design activities to facilitate students' ontological shift (Chi, 2008). In terms of pedagogical content development, we suggest to introduce energy related content to students before 4th grade to prevent conception mismatch from happening. The findings of this study reveal that students have started to investigate abstract concepts such as energy as early as 4th and 5th grades. Thus, it is critical for students to develop correct ontological categories before this age.

Resubsumption. Resubsumption theory suggests that, for students to choose a competing theory over the resident theory, they must have acquired the competing theory from other domains previously, or developed an overarching background theory that can accommodate both the resident and competing theories. Practically, teachers may ask students to engage in problem-solving tasks through which they can successfully apply a competing theory and validate its cognitive utility. Taking teaching cardiovascular fitness as an example, teachers can use concepts of ‘progressive overload’ and ‘adaptation’ to construct an overarching learning context for fitness promotion. At the same time, they incorporate concepts such as ‘caloric balance’ and ‘energy intake/expenditure’ in the later stage of the learning process, since these concepts are conceptually compatible with students’ resident theory about cars and batteries which was developed through *bisociation*.

Ohlsson (2009) called this method the *displacement strategy*, through which students’ cognitive attention was shifted to the overarching background or the background of a scientifically sound competing theory (Ohlsson, Moher, & Johnson, 2000). In addition to the displacement strategy, teachers may also point out to students that, using the metaphors for cars and battery to explain human body movements might help us understand concepts such as caloric balance only when the many differences between human body, mechanics and electrochemical devices are acknowledged. For instance, human bodies experience fatigue and physiological changes during exercise much faster than fatigue would take place in mechanical and electrical devices. In other words, teachers can help students to generate dissatisfaction towards the resident theory (Duit & Treagust, 2003), or shift their focus, making substantial adjustments that need to be made on the resident theory for the bisociation processes to be successful (Chinn & Samarapungavan, 2009; Keane, 1996).

Enculturation. Unlike naïve conceptions and misconceptions generated through resubsumption processes, the second type of misconceptions was constructed through enculturation processes. First, these enculturation-generated misconceptions are tightly related to behaviors, such as consumption and diet choices that students engage in their daily life. Second, students often have formed these misconceptions under constant external stimuli, such as long exposure to media commercials and parental advices. Third, these misconceptions are often connected with prevailing social values, such as stereotypes associated with different body images, such as muscle hypertrophy, and behavioral patterns, such as going to gym on a regular basis and outdoor activities. In order to facilitate students’ conceptual changes toward scientific understanding, multiple strategies are needed to overcome these obstacles that prevent students’ learning.

To address the misconceptions constructed through enculturation process, teachers can take the following pedagogical strategies. First, teachers may design activities to raise students’ awareness on widely distributed misconceptions, such as misconceptions by media about certain foods or dietary practices. Second, design activities for students to collect information from scientifically valid sources. For instance, teachers could organize science fairs, workshops or assign students homework that can provide students hands-on experiences on collecting scientifically valid sources and distribute their findings to their peers. These activities can potentially create a learning context in which understandings and practices based on sciences are valued. Third, teachers may provide students opportunities to critically evaluate stereotypes related body images and lifestyle behaviors constructed by cultural discourses. It could be achieved through collective project on finding the healthy body by recognizing the unrealistic nature of the media portrayed ideal body, and learning to identify risk factors related to certain body images, such as excessive visceral fat, and recognizing healthy and risky behaviors in relation to different body images.

Conclusions

Through semi-structured interviews, the study identified students' naïve conceptions and misconceptions about energy in relation to lifestyle decisions, such as food intake, physical activities and exercises. Based on multiple conceptual change theories, the study analyzed the underlying reasons that naïve conceptions and misconceptions could be robust to change. The findings are useful in that they highlighted possible sources of difficulties in learning fitness concepts. Pedagogical suggestions were made to address these difficulties in teaching and to assist teachers to overcome naïve conceptions and misconceptions embedded in students' prior knowledge. Focusing on the concept of energy, the study confirms what Chinn and Samarapungavan (2009) have suggested: 'there are multiple sources of difficulty that impede conceptual change, that there are multiple routes by which conceptual change occurs, and that there are multiple mechanisms needed to explain different routes to conceptual change' (p. 48). Educators need to be conscious about the complex and multifaceted nature of conceptual changes, especially with the presence of students' prior knowledge, and strategically adopt pedagogical practices for students' best learning results.

The study relies on data collected through interviews. Although the interviews provided rich evidence about students' naïve conceptions and misconceptions, they after all were a single source of information difficult to verify. For this reason, the findings from this study is limited in that the analysis was based on students' verbal articulation of their understandings of the concept of energy. It is possible that their articulation of the concept is limited by their vocabulary to express their understandings. The readers are cautioned against generalizing the findings and suggestions without careful verification of the findings in their own context.

Naïve conceptions and misconceptions embedded in students' prior knowledge not only prevent students from assimilating new and scientifically sound knowledge, but also carry the potential of informing students to make unhealthy lifestyle related decisions. In addition, certain misconceptions directly contribute to students' adoption of biases and social stereotypes related body images and lifestyles. In the future, it is imperative to further research on students' prior knowledge in relation to their health literacy and development learning activities to overcome naïve conceptions and misconceptions.

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No potential conflict of interest was reported by the authors.

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