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Does Cardiorespiratory Fitness Knowledge Carry Over in Middle School Students?

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Abstract

Conceptual knowledge development in physical education is critical to helping learners become physically literate. Understanding physical education learners' long-term knowledge development is one of the first steps in designing effective curriculum. Guided by the constructivist learning theory, this study aimed to determining the extent to which the cardiorespiratory fitness knowledge learned in the first year contributed to further knowledge development in the second year. A two-year longitudinal design was adopted to track 716 students' learning documented in their physical education workbook from sixth grade to seventh grade. Canonical correlation and multivariate multiple regression analyses were conducted to determine the relationship of learning during the two years. The results showed that student knowledge development in the first year did facilitate their knowledge development in the second year (R_c= .54; Wilks' λ= .69, $F_{(9, 1728.1)}$ =30.99, p<.01, η^2 = .31). Specifically, students' three types of knowledge development (descriptive, relational, and reasoning) were all significant contributors (descriptive: Wilks' λ = .96, $F_{(3, 710)}$ =9.34, p<.01, η^2 = .04; relational: Wilks' λ = .98, $F_{(3, 710)}$ =4.44, p<.01, η^2 = .02; reasoning: Wilks' λ = .90, $F_{(3, 710)}$ =26.13, p<.01, η^2 = .10) to their further learning with the knowledge development from the reasoning assignments to be the strongest facilitator. Students' overall learning in the first year significantly contributed to their descriptive (R^2= .12), relational (R^2= .26), and reasoning (R^2= .21) knowledge learning in the second year.

Keywords

written assignment; physical education; knowledge learning; cognitive learning

1. Introduction

Cognitive learning in physical education has received increasing attention in recent decades. In 2014, the Society of Health and Physical Educators [SHAPE] (2014) adopted the concept of physical literacy to be the ultimate goal of K-12 physical education. Physically literate individuals are considered as people who possess the knowledge, skill, and confidence to enjoy healthful physical activity for life (SHAPE, 2014). Conceptual knowledge is also specifically emphasized in current National Physical Education Standards (see Standard 2 and 3; SHAPE, 2014). One important aspect in this knowledge learning is to master conceptual knowledge about physical activity, its benefits to health and wellness, and scientifically sound principles to conduct daily physical activity. Ennis (2015) argues that the knowledge empowers learner to know what to do and understand when and how to perform and that the knowledge about physical activity should be an integral component in a physical literacy curriculum.

Several physical education curriculum models have been developed to teach student scientific concepts about physical activity and fitness. Early models include Fitness for Life (Corbin & Lindsay, 2002) and Foundations of Personal Fitness (Rainy & Murray, 2005). These models are mainly based on behaviorist theories to teach fitness concepts using classroom lectures separate from gymnasium-based activities (Dale, Corbin, & Cuddihy, 1998). Research studies showed that concepts taught this way might have little impact on in-depth knowledge development required for behavioral change (Saunders & Shepardson, 1987; Wong & Day, 2009).

Constructivist learning theory focuses on students’ knowledge development and understanding that lead to knowledge structural change for behavior/action/application rather than information memorization (von Glasersfeld, 1995). This theory recently has received considerable attention in physical education and has been incorporated into the process of curriculum development (Ennis, 2015; Sun, Chen, Zhu, & Ennis, 2012). Several studies have examined the effects of a concept-based, constructivist physical education curriculum on learners’ conceptual knowledge learning. The findings revealed that the curriculum greatly promoted learners’ knowledge gain measured using standardized knowledge assessments (Sun et al., 2012; Zhang et al., 2014). However, the processes of knowledge development that lead to the observed knowledge gain are still unclear. In particular, it is not clear about the role of long-term knowledge development when studying concept-based curriculum in physical education in helping learners gain the knowledge. The purpose of this study, therefore, was to determine students’ knowledge development in two years when studying the concept-based physical education curriculum. Specifically, we focused on addressing this research question: to what extent did students’ knowledge learning in the first year contribute to their knowledge development in the second year?

2. The Conceptual Framework

Learning in physical education is multidimensional, which traditionally includes three basic dimensions: cognitive knowledge, psychomotor skills, and affective characters (Kirk, MacDonald, & O’Sullivan, 2006). Recently, the national standards for K-12 physical education have been further revised and physical literacy was adopted as the ultimate goal of physical education (SHAPE, 2014). Ennis (2015) argued that this revision further acknowledges the central role of cognitive learning in physical education.

Learning, from the cognitive perspective, is about “changing the way a person thinks, reasons, believes, and processes information, in part by expanding or altering the individual’s existing knowledge base” (Alexander, 2006). This conceptualization of learning implies the important role of prior knowledge and knowledge accumulation in the learning process. It recognizes that learners develop their knowledge by actively restructuring their existing knowledge base (Alexander, Schallert, & Reynolds, 2009).

Learning tends to be domain-specific (Alexander, 2006). The knowledge construction process appears to be consistent with the nature and characteristics of the knowledge structure in a domain (Dodds, Griffin, & Placek, 2001). Scholars argue that in physical education one viable way to facilitate students’ cognitive learning is to integrate physical and cognitive tasks together (Blumenfeld et al., 2002; Ennis, 2006; Rink, 2005). In other words, effective cognitive learning in the physical activity domain relies on the learner recognizing knowledge elements pertaining to a physical activity while the physical activity is being experienced. This mind-body integrated learning experience was found to be conducive to students’ cognitive learning without jeopardizing the opportunity to be active in physical education and to maintain appropriate in-class physical activity level (Chen, Martin, Sun, & Ennis, 2007).

According to constructivist learning theory, learning is a meaning-making process which requires learners to actively construct and reconstruct the knowledge which is meaningful to their lives (Hung, Tan, & Koh, 2006). In this sense, learning is constantly extended and deepened through accumulating and altering self-constructed knowledge base. This implies that to be integrated in the knowledge structure, new ideas and concepts should be connected with the learner’s existing knowledge component(s) that is meaningful or valued by the learner (Ennis, 2006). These theoretical notions support the idea that physical tasks serve as necessary bridges and destinations simultaneously in the cognitive learning process in physical education. The mind-body integrated tasks provide opportunities for students to connect scientific concepts and principles with physical experiences in a personally meaningful way.

Creating a learning-conducive environment is crucial to effective knowledge acquisition. Authentic classroom activities, often referred to those resembling real-world experiences, are effective in facilitating student learning (Ormrod, 2014). Recently, Ennis and her colleagues (see Ennis, 2015) have developed and field-tested concept-based constructivist curricula in physical education that integrate authentic cognitive inquiry process into physical activity in elementary and middle schools. In this type of physical education, students assume the role of a “junior scientist” to actively engage in physical activities to study in-depth cognitive knowledge. The physical activity tasks lead them into “a cycle of active perceiving, conceptualizing, filtering, memorizing, inferring, reflecting and interacting; all these are coupled with repeated predicting, verifying, and concluding meaningful outcome through physical activity” (Zhang et al. 2014, p. 3). Initial evidence from these efforts seems to have shown that the curriculum can lead physical education students to a deep understanding in health-related fitness knowledge (Ennis, 2015).

Another salient characteristic of the concept-based curricula is the use of cognitive assignments along with physical activity tasks. These cognitive assignments are in the form of textbooks and worksheets (e.g., Corbin et al., 2002; Rainy et al., 2005) or learner workbooks (Ennis & Lindsay, 2007). In the learning process, learners use them to observe, relate, and reason using the cognitive knowledge that explains the scientific principles and physiological benefits of physical activities. Cognitive learning assignments in the workbooks are designed to closely link with the physical activity tasks learners perform in class. They progressively guide students to process the information following the cognitive learning hierarchy: from describing what happens to their body during physical activity to reasoning why physical activity can bring about positive change in the body. These focused and cognitively scaffolding experiences help learners to connect health-related fitness knowledge closely to physical activity and to achieve a deep understanding about physical activity (Ennis, 2006).

From the curriculum structure perspective, the cognitive assignments in concept-based physical education should be well structured with carefully selected physical activities. They are presented to the learner in an organization tightly sequenced to induce maximum achievement (Gagne, Briggs, & Wager, 1992). Ennis (2006) proposed that one effective organization to enhance learning using cognitive tasks in physical education is the spiral sequencing curricular structure. In this structure, descriptive, relational, and reasoning assignments are presented to the learner with physical activity tasks supporting the cognitive learning. The learner follows learning cues in the physical activity tasks to search, determine, and verify answers scientifically meaningful to them.

3. The Current Study

This study was designed to determine the effect of the cognitive learning process from a longitudinal perspective. Previous research has established the effectiveness of the concept-based constructivist curriculum on students' conceptual knowledge learning in comparison with the traditional physical education curriculum (Ennis, 2007; Sun et al. 2012). The longitudinal influence of the cognitive assignments that are increasingly being adopted in teaching remains unknown. It was a great interest for researchers to explore to what extent the formal instruction students received in a specific domain can be transferred or sustained long enough to enhance subsequent knowledge acquisition. Specifically, we focused on addressing this research question: to what extent did students' knowledge learning in the first year contribute to their knowledge learning in the second year? Guided by the constructivist theory, we hypothesized that students' knowledge learning in the first year would contribute to their knowledge learning in the second year.

In this study, we focused on learners' knowledge development about cardiorespiratory fitness in middle school learners. The content knowledge mainly included basic concepts (e.g., target heart rate, intensity, and rating of perceived exertion) and principles (e.g., FITT principle, principle of progressive overload, and principle of specificity) about physical activity and cardiorespiratory fitness. Cardiorespiratory fitness is one of the most important components of health-related fitness (American College of Sports Medicine, 1995). The knowledge about cardiorespiratory fitness is widely acknowledged as one important area students must understand and commonly incorporated as an important learning area in concept-based fitness education curriculum (Corbin & Lindsay, 2002; Ennis & Lindsey, 2007; Rainey & Murray, 2005). This research is meaningful because it contributes to our understanding of students' knowledge development and long-term cognitive learning in physical education.

4. Methods

4.1 The Research Context

This study was part of a large-scale clinical trial curriculum intervention study that included an experimental and a control group. Students in the experimental group used workbooks as part of the intervention curriculum, while students in the control condition did not use the workbook. Because the variables of interest in this study were workbook assignments and the control group did not complete them, the data only came from students in the experimental group.

4.2. Participants

A total of 716 students (boys=347, 48.5%) were sampled from the 12 experimental schools who completed the entire workbook assignments in two consecutive years (sixth and seventh grade). Of these students, 59.2% reported an Caucasian ethnic background, 8.8% African American, 21.8% Hispanic, 2.8% Asian, 6.3% Mixed Race, .8% American Indian, and .3% Arabic American. Their workbooks from sixth grade to seventh grade were collected, carefully graded with validated rubrics, and analyzed (see Data Collection and Data Analysis for details). This study was approved by the Institutional Review Board of the University. Parental consent and student assent forms were received before data collection.

4.3. The Learning Experience

The experimental curriculum devoted 40 lessons to teach the concepts and principles about cardiorespiratory fitness. The lessons were spirally sequenced (Gagne et al., 1992) and 20 lessons were taught in sixth grade and 20 in seventh grade. The curriculum for sixth grade and seventh grade focused on similar topics (e.g., heart rate, exercise intensity, FITT principle, principle of overload, and SMART goal strategy). But, the content for seventh grade was more advanced than the content for sixth grade. For example, in sixth grade we focused on the introduction of key concepts (e.g., measuring heart rate, introduction to exercise intensity, introduction to FITT principle, and introduction to SMART goal strategy) while in seventh grade we focused on the relationship between different concepts and the application of principles in daily workout (e.g., target heart rate zone and rate of perceived exertion, applying FITT principle to my daily fitness workout, using SMART goal strategies in my daily fitness workout).

Each lesson in this curriculum was designed with a learner-centered 5-E instructional framework: engagement, exploration, explanation, elaboration, and evaluation for students to assume the role of "Junior Scientists" in learning (Bybee et al., 1989). During engagement, teacher involved students into an instant physical activity and used this activity to introduce the scientific vocabularies and concept they were going to learn. Often during this part, students were asked to record their pre-activity heart rate or other measures in their workbook. During exploration, students were organized to do a variety of physical activities to collect post activity responses to compare with the pre activity measures. Through prediction, experiment, observation, and documentation, students collected and studied the data in their workbook during the process. In explanation, students were guided to form small or large groups to "Think, Pair, Share" with their peers to interpret or make meaning of the data. They compared and contrasted the data to understand the impact of physical activity. In elaboration, the teacher further elaborated the concepts and principles the data inform and guided the students to discuss implications of physical activity to life beyond physical education. In evaluation, students summarized the data and the knowledge learned to reach conclusions beneficial to health and life. Usually they were prompted to answer an open-ended real-life question on their workbook using the knowledge just learned.

The workbook, closely tied to learning activities in class, served as a centerpiece of knowledge construction tool to assist learning. The questions/problems were sequenced along with the lesson content for students to learn and reinforce a concept repeatedly in different lessons and across grades. The knowledge students learned in sixth grade are fundamental facts (e.g., measures of exercise intensity and fitness components), concepts (e.g., target heart rate, exercise intensity, frequency, and type), and principles (e.g., FITT principle and principle of progressive overload) about health-related fitness. These facts, concepts, and principles were reinforced in more advanced or complex forms (e.g., the relationships between these concepts and how to apply these principles in daily workout plan) at the seventh grade and eighth grade with new physical activities and cognitive tasks.

The workbook contained 69 cognitive assignments on 43 pages for the sixth grade and 76 assignments on 40 pages for the seventh grade. All these assignments were based on the physical activity tasks the students were experiencing in the lessons. The assignments were in the form of practical problems that prompted students to explore the physical activity tasks in order to understand physiological responses to and benefits from the physical activities. The assignments were designed in three categories, factual/descriptive questions, relational questions, and reasoning questions to lead the learner to an increasingly sophisticated understanding of physical activity and its functions to human body. Based on the spiral sequencing principles (Gagne et al., 1992), the questions were organized as such that the learner would focus on factual information at the beginning of the curriculum and would work on more challenging reasoning assignments later to gain increasingly in-depth knowledge about science of physical activity.

In the sixth grade workbook, there were 37 descriptive assignments, 18 relational assignments, and 14 reasoning assignments; and there were 46, 14, and 16, respectively, in the seventh grade workbook. Descriptive assignments asked students to describe what they did in class and what happened in their body. One example of descriptive tasks was "Record your heart rate following the jump rope routines ______". Relational assignments required student to relate observed physiological changes to physical activities they experienced to understand the relationship between relevant concepts (e.g., heart rate and intensity). One example was “Write two sentences to explain to a new student the relationship between steps and duration in this activity”. Reasoning assignments were designed to initiate and strengthen in-depth knowledge structural change. These assignments required students to understand the relations among concepts, principles, and behavior and how to address the relations in complex daily life. One example was that “Think about the principle of overload, think about how your body systems will change and adapt if you continue to exercise. Write three sentences explaining the physiological change that occurred in your body during the activity today.”

The workbooks were collected by the researchers at the end of the instruction each academic year. The students’ sixth grade workbooks were collected when they completed their sixth grade study, their seventh grade workbooks were collected when they completed their seventh grade study.

4.4. Variables and Measures

Knowledge learning.—Students’ knowledge learning was operationalized as their performance on the learning tasks in the workbook. To measure students’ performance on these tasks, a four-level scoring rubric with 1 indicating a low performance and 4 a high performance were developed for each and every assignment. The content validity of the rubrics was determined using a group Adelphi method where five researchers independently scored the same sets of workbook samples. Discrepancies in the scores were discussed until a consensus of scoring for each task was reached. The researchers then independently scored another sample of workbooks to determine the revised rubrics. This cyclic validation procedure was repeated until 100% agreement among the researchers was reached for all assignments. The final scoring rubrics were written into a matrix for actual scoring.

Answers to the questions in all the workbooks were graded by 20 trained scorers who were undergraduate juniors, seniors, or graduate students in kinesiology. The data of this study involved 103.820 assignment questions in total. Each scorer graded about 1.000–6.000 assignments. This grading process lasted for about 6 months. The training featured both intra- and inter-grader agreement/reliability check. The same intra- and inter-grader reliability check was also conducted periodically during the grading process. Whenever the agreement fell below the 80% threshold, the head grader would call a diagnostic meeting to identify the problem and re-train the graders to reach the 80% intra- and inter-agreement threshold. Given the purpose of the study, we were interested in analyzing the data from the students who completed every assignment in the entire workbook in both years. Workbooks with partially answered assignments, missing responses, blank pages, etc. were excluded from the data. A total of 27 (3.6%) workbooks were excluded from the data.

4.5. Data Collection

The data in this study was students’ answers to the questions in the workbook. The PE teachers collected these data during every class as students were learning each lesson of the curriculum, since the workbook includes questions for each lesson of the curriculum. Completing the questions in the workbook was the learning tasks embedded in each lesson of the curriculum. PE teachers were trained to guide students to complete the questions in the workbook when they were trained to teach this curriculum. Every teacher was also given a teaching manual that includes verbatim instructions about teaching each lesson of the curriculum. The fidelity of the curriculum implementation was preserved through on-site observations by the research team in schools. The process that teachers followed to collect the workbook data can be seen in the "Learning Experience" section. Students were encouraged to ask questions when completing the tasks in the workbook and students' questions were addressed immediately by the teachers.

4.6. Aggregated Scores

Aggregated performance scores were calculated using this formula: performance score = sum of total scores earned / the number of the assignments in the category (descriptive, relational, and reasoning assignments). Subsequently, each student received an aggregated performance score for the descriptive assignments, a score for the relational assignments, and a score for the reasoning assignments.

4.7. Data Analysis

The purpose of the analysis was to determine how much students' knowledge learning in the second year could be explained by their knowledge learning in the first year. First, we conducted binary and canonical correlation analyses to determine the magnitude of the relationship between the first and second year's performance scores. Then, we conducted multivariate multiple regression analysis with three predictive (independent) variables (performance scores in the three assignment categories in the first year) and three outcome (dependent) variables (performance score in the three assignment categories in the second year). This analysis allowed us to determine (a) the predicting effects of students' overall knowledge learning in the first year on their overall knowledge learning in the second year, and (b) the predicting effects of students' performance in each assignment category in the first year on their overall knowledge learning in the second year. We then conducted three multiple regression analyses with the performance scores in the three assignment categories (descriptive, relational, and reasoning assignments) in the first year as the predictors and the performance scores on each assignment category in the second years as the outcome variables to determine the contribution from the first year overall performance in all three assignment categories to the second year performance on each assignment category.

5. Results

The descriptive statistics in Table 1 appear to indicate a high-level performance on descriptive and relational assignments, and a moderate level on reasoning assignments in both years. The results seem to indicate a decline in performance scores with the increase of challenge in cognitive assignments moving from descriptive to reasoning. A repeated measure one-way ANOVA did show that students' performance score on descriptive tasks was significantly higher than their scores on relational (p<.01) and reasoning tasks (p<.01) for both grades. Students' performance score on relational tasks was significantly higher than their scores on reasoning tasks (p<.01) for both grades. Correlation coefficients reported in Table 1 showed a low binary correlation between students' performance on each assignment category in the two years.

The canonical correlation analysis yielded three significant canonical functions (R_{c1}=.54, R_{c2}=.12, R_{c3}=.11), with only the first function yielding interpretable squared canonical correlation effect size of 29.16%. The second and the third functions explained only 1.54% and 1.18 %, respectively, of variance between the predictors and dependent variables. Collectively, the full model across all functions was statistically significant (Wilks's Λ = .69, $F_{(9, 1728.10)}$ = 30.99, $p < .001$). The dimension reduction analysis tests the hierarchical arrangement of functions for statistical significance. The analysis results show that the full model (Function 1–3) was significant (Wilks's Λ = .69, $F_{(9, 1728.10)}$ = 30.99, p < .001). The test of only Function 2–3 (Wilks's Λ = .97, $F_{(4, 1422.00)}$ = 4.91, $p < .005$) and Function 3–3 (Wilks's Λ = .99, $F_{(1, 712.00)}$ = 8.51, $p < .005$) was also significant. Since the second and third function only explained minimal percentage of the variance between the predictor and dependent variables, they were omitted for interpretation. Rencher and Christensen (2012) also recommended using the first canonical function to represent the canonical correlation when multiple canonical functions are significant.

Table 2 presents the results for the first function, including the standardized canonical function coefficients and structure coefficients (the correlation between each variable with their respective canonical variate). The squared structure coefficients showed that the canonical variate representing performance in sixth grade explained 55% students' performance on descriptive tasks, 62% on relational tasks, and 86% on reasoning tasks in sixth grade. It indicates that all three variables had a substantial contribution to the canonical variate representing students' performance in sixth grade. The canonical variate representing students' performance in seventh grade explained 38% students' performance on descriptive tasks, 90% on relational tasks, and 71% on reasoning tasks in seventh grade. Although this canonical variate reflects more on students' performance on relational and reasoning tasks than descriptive task, it does reflect a non-negligible portion (almost 40%) of performance of descriptive tasks. The negative signs of the canonical coefficient and structure coefficients are interpreted relatively. All coefficients were negative, which means that all variables were positively related to each other.

The multivariate multiple regression analysis showed that students' overall performance in the first year significantly predicted their overall performance in the second year (Wilks' λ =.69, $F_{(9, 1728.1)}$ =30.99, p<.01, η^2 = .31). Specifically, students' overall performance in the second year was significantly predicted by their first-year performance on descriptive assignments (Wilks' λ =.96, $F_{(3, 710)}$ =9.34, p<.01, η^2 = .04), relational assignments (Wilks' λ =.98, $F_{(3, 710)}$ =4.44, p<.01, η^2 = .02), and reasoning assignments (Wilks' λ =.90, $F_{(3, 710)}$ =26.13, p<.01, η^2 = .10). Table 3 showed more detailed information about contributions of first year learning on second-year learning.

The results of multiple regression analysis in Table 3 showed that students' overall performance in the first year explained 12% of their performance on descriptive assignments, 26% on relational assignments, and 21% on reasoning assignments in the second year. Student's first-year performances on descriptive and reasoning assignments were significant predictors of their second-year performances in all three types of assignments, while their first-year performance on relational assignments was significant only in predicting their second-year performance in relational assignments.

6. Discussion

The purpose of this study was to determine the extent that students' cardiorespiratory fitness knowledge learned in the first year facilitated their knowledge learning in the second year. The evidence demonstrates that their overall knowledge learning in the first year facilitated their learning in the second year. However, when considering the effects of learning in the three different knowledge categories in the first year separately, we found that the knowledge learning from the high-level cognitive tasks (e.g. the reasoning assignments) was a stronger facilitator than descriptive and relational assignments for their further knowledge learning.

It is important to notice that in this study students' knowledge learning was represented by their long-term performance on about 70 in-class cognitive assignments. We believe the data were able to better reflect students' learning process and knowledge development than snapshot achievement measurements such as a standardized test. The knowledge carry-over effect demonstrated in this study may be understood from two perspectives: the effects of cognitive assignments on knowledge development and the relationship between prior knowledge and learning performance.

6.1. Cognitive assignments and knowledge development

As learning in other knowledge domains, cognitive assignments facilitate student knowledge acquisition in physical education (Zhu et al., 2009; Zhang et al., 2014). Zhu et al. (2009) and Zhang et al. (2014) studied the effects of elementary students' performance of in-class workbook assignments on their knowledge achievement in a similar concept-based curriculum. Both studies reported that students' performance on in-class cognitive assignments significantly contributed to achievement in standardized tests even though their performance on these assignments was at low-to-moderate level.

According to constructivist learning theory, learning is the process of constructing new ideas and concepts into existing knowledge structure through meaningful learning experiences (Hung et al., 2006). Based on Zhu et al. (2009) and Zhang et al.'s (2014) studies, it is plausible to infer that the cognitive assignments in a physically active learning environment may significantly increase students' existing knowledge base. In the current study, students' performance on cognitive assignments was at moderate level. It is reasonable to speculate that the cognitive assignments in the first year allowed the students to significantly expand their knowledge base on cardiorespiratory fitness to form a relevant prior knowledge base for the learning in the second year.

6.2. Prior knowledge and knowledge development

Previous studies have consistently shown that prior knowledge is a critical variable in facilitating students' further learning and that the level of existing knowledge determines the extent to which new knowledge is learned (Shapiro, 2004). In their extensive literature review, Dochy, Segers, and Buehl (1999) reported that students' prior knowledge generally explained 30 to 60% of the variance of their classroom learning. In the current study, as indicated by the canonical correlation analysis, students' first-year knowledge learning explained 29% of variance of their second-year knowledge learning. Although the variance seems to be low in comparison with that found in classroom learning (Dochy et al., 1999), we think that physical activity should account for an additional portion of the variance for learning in physical education.

The previous findings on the effects of cognitive assignments on knowledge learning achievement and the relationship between prior knowledge and learning performance offer a plausible way to explain the knowledge carry over effect showed in this study. That is, cognitive assignments in the first year facilitated students' knowledge construction process which led to increased knowledge base. The increased knowledge base, serving as the prior knowledge for the second-year learning, contributed to students' knowledge learning in the second year.

It is encouraging to know that knowledge learned in physical education can be retained by young students in middle schools for at least a year. The ultimate goal of physical education is to help students to achieve physical literacy (SHAPE, 2014). Ennis (2015) argued that literacy is "a lifelong process of gaining meaning with the goal of acquiring a progression of knowledge and skills that culminates in deep understanding" (p. 119). Therefore, to help students to become physically literate, it is important that physical education curriculum is designed to not only help students understand cognitive knowledge but also facilitate their knowledge accumulation and progression. It is reported that learners in the concept-based constructivist physical education curriculum may show great knowledge gain (Sun et al., 2012; Zhang et al., 2014).

6.3. The nature of learning tasks and student learning

Another important finding of this study is that the nature of cognitive learning tasks tends to influence students' further learning. Alexander (2006) argued that learning tasks requiring a deep cognitive processing are more likely to enhance students' cognitive learning achievement. The current study shows that students' knowledge learning from the reasoning assignments tends to have stronger facilitating effects on their further knowledge development than the learning from descriptive and relational assignments. Reasoning assignments in this study asked students to explain why physiological changes took place or how to apply certain concepts and principles to real life. These assignments require higher level of cognitive information processing than descriptive and relational assignments. It is of note that the relationships among descriptive, relational, and reasoning assignments were not as strong as was expected and that merits further exploration. Following the hint of the literature (e.g., Alexander, 2006), the descriptive and relational assignments can be the foundation for developing learners' reasoning aptitude. This should be a worthy research area in physical education to help determine relevant methods to arrange cognitive tasks to facilitate physical literacy.

Previous educational studies (Chi et al., 1989; Chi, de Leeuw, Chiu, & LaVancher, 1994; Nokes, Hausmann, Vanlehn, & Gershman, 2011) have found that explaining why things happen contributes to both learning and knowledge transfer. The current study provides evidence that engaging students in written reasoning tasks also facilitates further learning. Various mechanisms of how explaining affects learning have been proposed. They include that explaining tends to enhance metacognitive monitoring (Nokes et al., 2011), help identify gaps in comprehension (Nokes et al., 2011), help focus on causal mechanisms (Kuhn & Katz, 2009), and lead students to seek patterns which increase their awareness of principles and laws (Chi et al., 1989; Rittle-Johnson, 2006). Recently, researchers in cognitive science propose that students' prior knowledge and experiences tend to determine or constrain the efficacy of explanation (Williams & Lombrozo, 2013).

In the current study, students were involved in learning as "junior scientists". In class, they followed scientific inquiry methods (5Es) to explore physical activities and benefits. They were taught to hypothesize, observe, and gather evidence following the assignments in the workbooks. Based on the data they collected and the evidence they generated, students examined their hypothesis, discussed results/evidence with their partners, and drew conclusions. All these scientific inquiry activities and collected data tend to have the potential to change students' misconceptions and increase their prior knowledge and experience, which served as critical sources for students' reasoning process. Therefore, we can reason that the three types of cognitive assignments do not function in isolation. Instead they function in a connected and holistic way as a coherent learning experience for students. Even though students' performance on reasoning assignments showed greater effects on their further learning than performance on descriptive and relational assignments, we should not overlook the importance and contribution of descriptive and relational assignment in students' reasoning and learning.

7. Conclusion

This longitudinal study has demonstrated that the cardiorespiratory fitness knowledge learned in the first year facilitated students' knowledge development in the second year. The three types of cognitive learning tasks (descriptive, relational, and reasoning) are all significant contributors to this knowledge carry-over effect with the knowledge development from reasoning assignments to be the strongest facilitator. Collectively, the findings of this study also suggest that students must have requisite knowledge to understand more complex materials. It is important for teachers to ensure that students understand the basic concepts before moving to more advanced material. Future studies are needed to verify the speculated mechanism of knowledge carry-over effect by incorporating appropriate prior knowledge variables, especially with the effect of physical activity tasks to be accounted.

Appendix 1: Sample Page of the Workbook

Cardio Fitness Club - Lesson 5 Journal

1. In the table below name the fitness category you improved at each obstacle.
2. Then think of a sport or recreational activity where this **type** of exercise would help you become stronger, more flexible, or perform better. The push up obstacle in line 1 of the table is completed as an example.

Obstacle	Fitness Component	Sport/Activity Benefited
Push-ups	Muscular Strength	Wrestling
Stability Ball Crunches		
Basketball Speed Dribble		
Kettlebell Rows		
Sitting Straddle Stretch		
Soccer Shot		
Abdominal Plank		
Fitness Bar Run		
Medicine Ball Wall Toss		
Balance Discs		
Line Jumps		
Jump Rope		

Think About

3. Think about how your body feels after exercising today. Write three sentences explaining why it is important to perform activities representing different **types** of activities.

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Highlights

- The nature of the learning task influences students' further learning
- Knowledge learning from the high-level cognitive tasks (e.g., the reasoning task) was a stronger facilitator for further knowledge learning
- Cognitive learning tasks can be integrated in physical education to further knowledge learning.

Table 1.

Descriptive statistics and correlation matrix of performance on each type of tasks

		1	**2**	**3**	**4**	**5**	**6**
6th Grade Descriptive	1						
Descriptive	2	.57**					
Relational	3	.48**	.64**				
7th Grade Descriptive	4	.31**	.42**	.28**			
Relational	5	.37**	.42**	.47**	.54**		
Reasoning	6	.32**	.32**	.44**	.44**	.63**	
	Mean/SD	3.29/.40	3.10/.46	2.44/.68	3.37/.47	3.09/.70	2.05/.68

Note.

** p<.01; the full score of each type of tasks is 4.

Table 2.

Canonical Solution for Sixth Grade Performance Predicting Seventh Grade Performance

Variable		Function 1		
		Coefficient	r_s	% r_s^2
6th	Descriptive	−.32	−.74	54.76
	Relational	−.19	−.79	62.41
	Reasoning	−.66	−.93	86.49
	R_c		**.54**	**28.09**
7th	Descriptive	−.10	−.62	38.44
	Relational	−.64	−.95	90.25
	Reasoning	−.39	−.84	70.56

Note. Coefficient= standardized canonical function coefficient; r_s = structure coefficient; r_s^2= structure coefficient squared or variance explained. R_c = canonical correlation coefficient between independent variables and dependent variables.

Table 3.

Multiple Regression Results

IV(6th Grade)	DV (7th Grade)	R^2	β	F value
	Descriptive	.12		32.53**
Descriptive			.22**	
Relational			.043	
Reasoning			.15**	
	Relational	.26		82.02**
Descriptive			.14**	
Relational			.14**	
Reasoning			.31**	
	Reasoning	.21		61.83**
Descriptive			.14**	
Relational			.01	
Reasoning			.36**	

Note. IV=independent variable, DV=dependent variable

** p<.01