Constructing cardiovascular fitness knowledge in physical education

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Abstract:

In physical education, it has become necessary for children to learn kinesiological knowledge for understanding the benefits of physical activity and developing a physically active lifestyle. This study was conducted to determine the extent to which cognitive assignments about healthful living and fitness contributed to knowledge growth on cardiorespiratory fitness and health. Fourth grade students ($N = 616$) from 15 randomly sampled urban elementary schools completed 34 cognitive assignments related to the cardiorespiratory physical activities they were engaged in across 10 lessons. Performance on the assignments were analyzed in relation to their knowledge gain measured using a standardized knowledge test. A multivariate discriminant analysis revealed that the cognitive assignments contributed to knowledge gain but the contribution varied assignment by assignment. A multiple regression analysis indicated that students' assignment performance by lesson contributed positively to their knowledge growth scores. A content analysis based on the constructivist learning framework showed that observing–reasoning assignments contributed the most to knowledge growth. Analytical and analytical–application assignments contributed less than the constructivist theories would predict.

Keywords: Constructivism | cardiorespiratory fitness | written assignments | knowledge growth

Article:

According to the constructivist perspective, learning is defined as enduring change in an individual that enables him/her, individually or collectively, to "perceive the world and reciprocally respond to its affordances physically, psychologically, and socially" (Alexander et al., 2009: 186). The definition implies two particularly important dimensions that can potentially enhance our understanding of learning in physical education. First, learning involves perceiving the world and responding to its challenges. Secondly, learning takes place in a holistic way that requires *cognitive and physical* engagement.

Adopting this definition allows us to view learning in physical education as simultaneous enduring behavioral and conceptual changes. It is common in physical education literature to rely on behavioral change indicators to represent learning achievement. These indicators include skill development (e.g. French et al., 1996) or moderate-to-vigorous physical activity participation (e.g. McKenzie, 2003). It is not until recently that cognitive indicators are considered important indicators of learning achievement in physical education (Sun et al., 2012).

Since the 1960s, kinesiology has evolved into a mature scientific area of study on human physical movement (Hoffman, 2009). According to the American Kinesiology Association (2011), "kinesiology is an academic discipline which involves the study of physical activity and its impact on health, society, and quality of life." The uniqueness of learning in kinesiology lies in its simultaneous emphasis on immediate physical experiences and cognitive understanding of human physical activity across the integrated spectrum of sociological and biological perspectives (Hoffman, 2009). In K-12 education, physical education is the course where children learn kinesiology through physical movement and study knowledge related to various aspects of physical movement.

To fully understand learning in physical education, it is necessary to look beyond the physical indicators and look into changes in children's conceptions (Ennis, 2007). Ennis (2007) argues that successful learning should be exemplified by full "cognitive conceptualizations of knowledge of and through the physical" (p. 139). In other words, all physical and cognitive experiences in physical education should go beyond observable change in movement behaviors and lead to knowledge gain. A primary goal in physical education, therefore, is to help students appreciate cognitive learning experiences through physical movement that contribute to healthful living (Chen and Shen, 2004; Chen et al., 2008).

The purpose of this study was to determine the extent to which cognitive assignments designed with constructivist principles helped urban elementary school children learn and construct much-needed knowledge about cardiorespiratory fitness as associated with health benefits. In this curriculum field-testing research, we were particularly interested in answering the following question: To what extent did the cognitive assignments in physical education lessons contribute to building cardiovascular fitness knowledge as a planned learning goal of a constructivist curriculum?

The conceptual framework

Alexander (2006) suggests that learning is taking place when "a person thinks, reasons, believes, and processes information, in part, by expanding or altering the individual's existing knowledge base" (p. 123). This conceptualization of the learning process acknowledges the importance of individual commitment to constructing personal knowledge. From the constructivist viewpoint, students are called upon to build new knowledge on their prior knowledge (Murphy and Mason, 2006; Vosniadou, 2003). To facilitate this process, an effective constructivist curriculum will involve the learners in tasks that afford extensive opportunities to construct meaning that is relevant to personal life (Zhu et al., 2009).

Creating such a constructivist learning environment to foster students' appreciation of knowledge for healthful living is considered essential to helping them master physical education content (Azzarito and Ennis, 2003; Chen and Ennis, 2004). One salient characteristic of the constructivist learning environment in physical education is the endorsement of mind–body integrated learning experiences. This experience has been found to be able to create a learning context conducive to deep-processing of cognitive knowledge without jeopardizing physical intensity level when physical activities become purposeful (Chen et al., 2007). When the learner experiences mind–body integrated tasks, he/she activates a cycle of active perceiving, conceptualizing, filtering, memorizing, inferring, reflecting, and interacting; all these are coupled with repeated predicting, verifying, and concluding meaningful outcomes through physical activities. The cycle forms a constant loop for the learner to structure, organize, and re-structure, re-organize knowledge, skill, and behavior (von Glasersfeld, 1995).

One important tenet of the constructivist theories is that knowledge is actively accessed and constructed by the learner. Rather than passively receiving information, the learner must actively engage in learning materials or experiences by him/herself or with others in the learning community to initiate deep-processing of information (Alexander, 2006). Unlike engaging in a superficial processing whose outcome is mere reinforcing prior knowledge with repetitive behaviors or tasks (Fredricks et al., 2004), deep-processing engages the learner with a high cognitive demand that requires her to connect prior knowledge to new ideas (Salomon, 1984). For learning to take place, students must invest considerable mental effort and must persistently search for solutions to problems resembling those they encounter in real life (Blumenfeld et al., 2006). The success of a constructivist curriculum thus lies in using tasks that provide activation cues that require mental engagement with the intensity that demands learner commitment (Diakidoy et al., 2003). In physical education, the commitment happens on both cognitive and physical dimensions.

A general consensus about how to facilitate students' constructing and structuring abstract concepts supports the notion that simultaneous cognitive and physical involving tasks can improve students' learning achievement significantly (Diakidoy and Kendeou, 2001; Driver et al., 1994; Posner et al., 1982; Smith et al., 1997; Stohr-Hunt, 1998). In physical education, integrating physical and cognitive tasks to facilitate learning has been acknowledged by scholars as a viable means through which students learn (Buchanan et al, 2002; Ennis, 2006; Rink, 2005). The content of physical education consists of a variety of kinesiological knowledge associated with human movement. Rapid disciplinary knowledge development in kinesiology and health science has provided rich and vital cognitive information that children must know to develop and maintain necessary behaviors for healthful living. Instructional strategies such as lectures, task sheets, and group quizzes, etc. have been widely used in teaching this knowledge (e.g. Corbin et al., 2007). It has been reported that more and more physical education teachers have started to adopt written assignments to facilitate students' learning (see Harrison et al., 2006; Manios et al., 1998; Salmon et al., 2007; Zhu et al., 2009). What is not clear is the effect of using the cognition-focused assignments.

Bringing workbooks to physical education

In a learning supportive context, the learner is actively “recognise and construct patterns of symbols to understand concepts and exhibit general abilities, such as reasoning, solving problems and using and understanding language” (Greeno et al., 1996: 18). But incorporating knowledge learning as a central purpose in physical education lessons can be challenging. A previous attempt in physical education is the *Basic Stuff* project (American Alliance for Health, Physical Education, Recreation and Dance, 1981). The outcome is not entirely satisfactory (Placek, 1989) because “physical educators do not agree that a conceptual approach to their subject matter is entirely appropriate” (p. 158) and there is a lack of systematic professional support during the instructional process.

A relevant pedagogy that facilitates the cognitive learning in physical education should guide the teachers to overcome the tension between cognitive and physical approaches and lead the learner through the complex process of connecting cognitive knowledge and physical experiences (Ennis, 2007). As part of a large-scale longitudinal research, the current study was conducted in this pedagogical context. The goal of the larger study was to field-test a physical education curriculum centered on teaching children scientific knowledge about fitness development and healthful living through experiencing physical activities. There were three 10-lesson units corresponding to three important themes in this body of knowledge: cardiorespiratory health, muscular capacity, and flexibility and exercise principles. Topics of lessons were carefully chosen by experienced physical education teachers, science education teachers and university researchers through curriculum alignment to ensure coherent inclusion of important information in each knowledge domain.

One important learning tool designed to facilitate knowledge construction in this curriculum was the use of student workbooks that corresponded with each lesson plan (Ennis and Lindsey, 2007). There were cognitive assignments associated with physical activity tasks in each lesson. Completing these assignments with accompanied social-constructivist learning strategies, such as think-pair-share; the learner was expected to actively construct the knowledge and achieve the intended learning goals.

It has been reported that the students’ knowledge grew significantly through learning in the curriculum across all three grades in comparison with students in control schools (Chen et al., 2006, 2007; Sun et al., 2012). However, whether using the workbooks was effective in facilitating the learning remained unknown. The current study helps clarify this issue. In addition to the specific research question we described earlier, the study also enables us to identify the direct contribution of each lesson in the workbook to knowledge gain. Through accomplishing these goals, we believe the study contributes to our theoretical and practical understanding of using constructivist approach to facilitating knowledge learning in physical education.

Methods

The research context

This study was conducted in a very large urban metropolitan school district in the USA. The district was selected from among six around the metro area. All six were identified by the US Department of Education among the 100 largest school districts (National Center for Education Statistics, 2004). The school district for this study was chosen due to its closest data proximity (within one standard deviation) to the means of key selection variables (teacher/student ratio, per-pupil funding, ratio of students in the free and reduced-priced meals programme). Thus, the district was representative of the 100 largest school districts in the USA. At the time of the study, there were 152 elementary schools in the district serving approximately 78,000 students. A random sample of 15 schools was selected to implement the experimental curriculum, while another 15 schools with matching free and reduced-price meals percentage (FARM%) and school academic performance were assigned to the control condition. The physical educators in the control condition received training on the sport education curriculum model, while those in the experimental condition received training on teaching the experimental curriculum. For the purpose of this study, we only used the data from the experimental condition where the workbooks were used as part of the curriculum.

This study was focused on student learning in the cardiorespiratory unit. The reasons for this selection were two-fold. First, this was the first unit in the sequenced curriculum where a number of fundamental concepts about health benefits and exercise principles were taught. Second, helping students develop knowledge about the cardiorespiratory fitness is among the most urgent tasks facing the public and physical education, due to the pressing need to improve children's cardiorespiratory fitness to prevent hypokinetic diseases.

Student participants

Participants of this study were around 10 years old. They were fourth grade boys (n = 320, 51.9%) and girls (n = 296, 48.1%) from the 15 experimental elementary schools who completed all assignments and pre- and post-knowledge tests. One particular reason for selecting the fourth grade students for this study is that children begin to be able to actively construct knowledge and develop the knowledge into rather sophisticated conceptual structure of understanding (Carey, 1985, 1988, 1995). In other words, the data from this age will provide the most relevant information to answer the research question. The sample represented the ethnically diverse student body of the district (Asian = 14, 2.3%; African American = 386, 62.6%; Caucasian = 38, 6.2%; Latino = 82, 13.3%; other = 49, 8.0%; not reported = 47, 7.6%). Parental permission and student assent were received prior to data collection according to university IRB regulations.

The learning experience

All the 10 lessons were taught using a 5-*E*s instructional system (Engagement, Exploration, Explanation, Elaboration, and Evaluation; Bybee et al., 1989) to help children construct the knowledge. *Engagement* invites the students into the knowledge construction process as 'junior scientists' (often as exercise physiologists). Using carefully designed instant activities, the teacher immediately poses the essential problems to the junior scientists where scientific vocabularies and concepts are introduced, explored, and/or confirmed with physical activities. In *Exploration*, students start to gather a variety of information associated with their own responses to physical activities. They predict, observe, and collect their bodily responses to physical activity and record the information in their *Science Journals*(workbook) in learning centers. During the *Explanation*, individual learners start to engage in small or large group activities to ‘think-pair-share’ with peers to come up with scientific explanations for what happens during physical activities. The *Evaluation* challenges the learner by asking them to consult the scientific information in the workbook, or the teacher (expert), or knowledgeable peers to arrive at ‘good’ or ‘bad’ conclusions in terms of the consequence of the physical activities as related to their health. In *Elaboration* the learner is provided with real-life problems to which they are instructed to provide relevant solutions. During this time students have opportunities to discuss their findings with others and situate the science principles and concepts within a meaningful life context. The assignments in the workbook serve as a guide to lead the students through this process from *Engagement* to *Elaboration*.

Variables and measures

Knowledge construction. Knowledge construction process was operationalized as learner performance on the cognitive assignments. There were a total of 34 assignments in the 10 lessons about cardiorespiratory fitness. The nature of these assignments ranged from observing–reasoning assignments to analytical/interpretive problems. For example, a typical observing–reasoning assignment can be, “Circle the pictures that describe what happened to your body while participating in physical education today as a result of our physical activities” with three pictures describing increased heart rate, sweating, and elevated breathing. Observing–reasoning assignments direct students to apply knowledge learned through direct observation in a physical activity to explain a phenomenon. To answer the above question, students are expected to be able to explain why increased heart rate, sweating, and elevated breathing are positive outcomes of physical activity based on their own experiences in the lesson. An example of analytical–application assignment can be (after practicing a shuttle run task such as the Progressive Aerobic Cardiovascular Endurance Run [PACER]):

> Think about how you felt when you ran the PACER Test. Think about whether you ran too fast and became tired too soon. On the line below, describe one strategy you can use next time to run for a very long time in order to pace yourself during the PACER Test.

The goal of analytical assignments is to help students analyze what they did correctly or incorrectly in a physical activity task, and reason and develop strategies to improve in the future. In each lesson, learners worked on the assignments before and after physical activities.

A scoring rubric was created for each assignment by a group of researchers (n = 5) who were trained in kinesiology for their undergraduate and master’s degree. A validating procedure for each rubric included the following: (a) the lead researcher created the rubric draft; (b) each researcher independently cross-examined the rubrics with the assignment and revised the draft as necessary; and (c) a meeting was convened among the researchers to reveal and discuss discrepancies of their evaluation. Consolidated rubrics were created based on the outcome of the discussion on each assignment; (d) after the meeting, the researchers used the consolidated rubrics to individually and independently score a sample of completed workbooks; and (e) the researchers met again to compare the scores and identify scoring discrepancies. At the meeting, reasons for the discrepancies were explored and discussed; solutions and consensus were reached; (f) the researchers scored another sample of workbooks. The process was repeated until a 100% agreement was achieved in the scores. At that time, the scoring rubrics were determined as able to generate scores with content validity. The researchers then used the scoring rubrics to score the entire collection of student assignments. Appendix A displays an example of a workbook assignment; Appendix B displays the scoring rubrics for the assignment.

Knowledge growth. A validated standardized knowledge test with nine multiple choice questions on cardiovascular fitness was used to assess learning achievement. The validity evidence was established in a previous study using an expert panel (content validity), known-group method (construct validity), and calculation of difficulty and discrimination indexes (Chen et al., 2006). 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). The knowledge test was administered to the learners before and after they experienced the cardiorespiratory unit. Knowledge growth scores were calculated using the regression residual adjustment procedure.

Data collection

Trained data collectors administered the standardized knowledge test prior to and after the unit was taught. The tests were conducted in classrooms or in the gymnasium where all students were instructed to work independently. The data collector read aloud all questions and choices to the students and answered their questions.

The workbooks were part of the materials that the teachers and students used in each lesson. With the progression of the unit, the workbook was being completed. The teachers were instructed not to score or grade the assignments. Instead, teachers were provided feedback on students' performance on standardized tests after the curriculum was taught. All the workbooks were collected from the schools after the unit was over. All answers to the assignments were scored by the researchers. The scoring rubrics were used to guide the scoring process and to generate scores. The scores from this assignment-by-assignment scoring process were entered into the data base for statistical analysis in the research laboratory.

Data reduction

Knowledge growth. Each correct answer in the pre- and post-knowledge test was assigned a 1; an incorrect 0. A correct-percent score for each test was calculated by dividing the sum of correct answers by the number of questions. The mean score for students is 4.52 (SD = .54) for the pre-test and is 6.04 (SD = 1.11) for the post-test. Residual adjusted gain scores were calculated and used to represent knowledge growth (Zimmerman and Williams, 1984).

Knowledge construction. As noted above, knowledge construction was inferred from students' performance on workbooks. All the assignments in the workbook were scored. All scores for all assignments in a lesson were aggregated and the aggregated score then was divided by the number of assignments in a lesson to form an average composite performance score for the lesson which could be used in comparison across all 10 lessons. Thus, the composite score for a lesson represented the learner performance in constructing the cognitive knowledge in that lesson. It was assumed that all lessons were equally important in terms of the content. No statistical weights were applied to the scoring process.

Data analysis

To determine the contribution of cognitive assignments to overall knowledge growth about cardiorespiratory fitness, a multivariate discriminant analysis was conducted to classify the assignments that characterized the learners with high, intermediate, and low knowledge growth. In this procedure, the known-group membership verification process was used to divide the learners into high, intermediate, and low-achieving groups based on +/- .5 standard deviation splits (Rencher, 2002) in terms of the mean score of the learning achievement test. To identify lessons that contributed to the knowledge growth, a multiple regression analysis was employed with knowledge growth (residual adjusted gain scores) as the dependent variable and the lesson assignment composite scores as the independent variables. Finally, when effects of assignments were identified, a qualitative content analysis on the assignments was conducted to understand contributing characteristics of the assignments. Only a small sample of the qualitatively analyzed assignments is reported in the results to illustrate the findings.

Results

The mean workbook performance score was 52% (SD = 20%). The result indicates that the students engaged moderately in the workbook activities in each of the 10 lessons, and achieved moderately in constructing the cardiovascular fitness knowledge. Table 1 reports the mean knowledge gain scores by low, intermediate, and high knowledge gain groups.

Table 1. Means and standard deviation by students' achievement level.

	N	Mean	SD
Low	240	.12	.17
Intermediate	164	.36	.03
High	212	.49	.01
Total	616	.31	.19

The multivariate discriminant analysis produced two distinguishing functions that were able to classify low, intermediate, and high achievers. Table 2 reports the summarized statistics of the canonical discriminant functions. The results indicate that the functions can be deemed effective in discriminating the knowledge growth based on performance on in-class assignments.

Table 2. Summarized statistics of canonical discriminant functions.

Function	Eigenvalue	Variance	Correlation	Wilk's λ	df	*p*
1	.31	.67	.50	.64	70	.001
2	.16	.33	.38	.86	34	.011

The analysis of the function centroids revealed that the learning achievement grouping centroids, the most typical positions for the groups, were located within the functions' dimensions with comfortable distances to separate the groups. Table 3 provides the function coordinates for each learning achievement group and Figure 1 shows a visual description of the respective group centroid location based on the coordinates. The functions were further tested for their classification accuracy by comparing predicted learning achievement group membership with their actual membership. The functions correctly predicted 59%, 58%, and 68% learners in the low, intermediate, and high-achieving group, respectively. The overall correct prediction rate is 62%, which can be considered adequate.

Table 3. Group centroid statistics.

Achievement group	Function 1	Function 2
Low	–.79	–.37
Intermediate	–.13	.56
High	.71	–.21

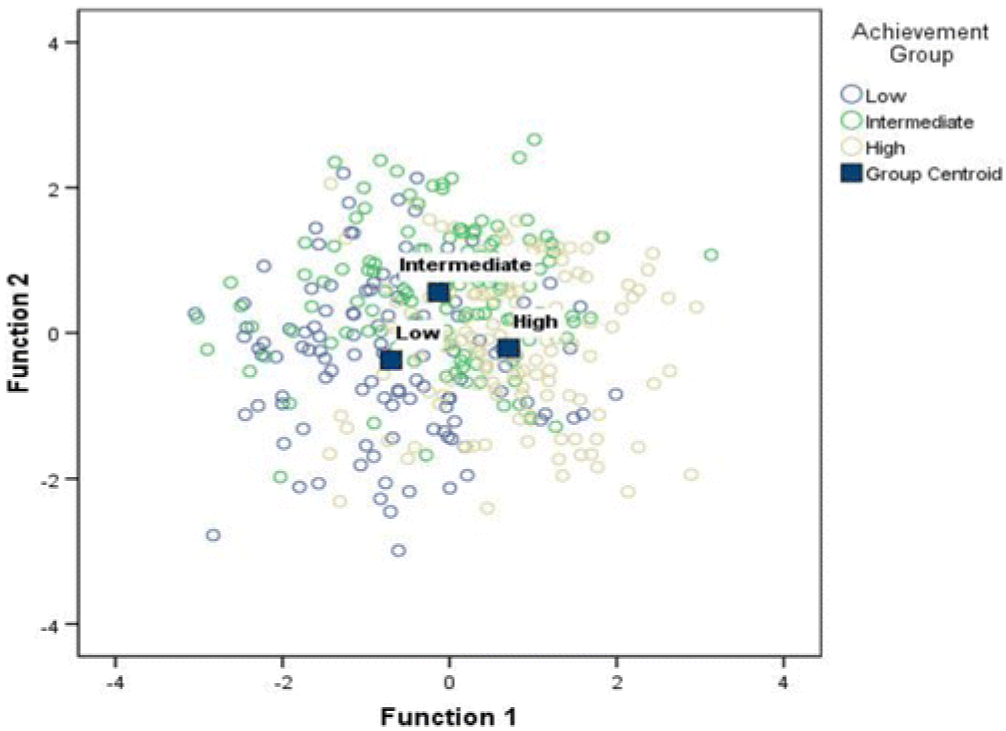

Figure 1. Achievement group centroid distribution.

The discriminant analysis also provided classification function coefficients for the individual assignments that helps determine their roles in assisting learner knowledge growth. Table 4reports the standardized coefficients that indicate, in part, the importance of each assignment in determining knowledge growth. Because higher-achieving groups were coded with values (i.e. 2 for Intermediate and 3 for High) greater than the low-achieving group (coded as 1), the positive coefficients are associated with increase in knowledge whereas the negative coefficients are with decrease. According to Rencher (2002), coefficients with an absolute value greater than the threshold of .30 are considered meaningful contributors to correct classification of membership. The coefficients in Table 4show that performance on individual assignments did contribute to learner membership in the learning achievement groups on knowledge growth.

Results of the regression analysis revealed that not every lesson contributed to knowledge growth. Table 5 reports assignment lesson composite means and standard deviations and regression analysis results. It appears that assignments of Lesson 2, 3, 4, 6, and 9 contributed more positively than the others to the overall knowledge growth significantly. The five lesson assignments accounted for 9.2% variance ($R^2 = .092$, $F = 3.80$, $p < .01$) in learning achievement. The amount of contribution to cognitive learning seems to be small. However, it should be considered significant in that it came from learning tasks that were physical in nature.

Table 4. Standardized classification function coefficients.

		Achievement group		
Lesson	**Assignment**	**Low**	**Intermediate**	**High**
1	1	.506	.327	.789
2	1	.157	.369	.291
	2	.734	.401	.647
3	1	6.054	6.268	5.686
	2	–1.100	–.370	.480
	3	.781	1.566	1.691
	4	.204	–.048	–.474
	5	–.006	–.171	–.204
4	1	3.398	3.027	2.729
	2	1.425	1.022	1.800
	3	–1.575	–.843	–1.567
	4	–.586	.136	.421
	5	.763	.402	–.098
	6	–1.756	–.725	–.357
	7	1.539	1.341	.710
5	1	.346	.638	.431
	2	–1.215	–1.465	–.395
	3	.010	–.117	–.800
	4	.845	.434	–.149
6	1	.176	.195	.243
7	1	.949	.504	.662
	2	–.633	–.240	.119
	3	–.110	–.144	.157
8	1	1.809	.732	–.198
	2	–.389	–.637	1.121
	3	–.907	.123	.071
	4	–.268	.036	–.006
9	1	–.197	–.296	–.075
	2	.146	.072	–.147
10	1	–1.489	1.496	.219
	2	–.052	–.287	.407
	3	.167	.607	.107
	4	.310	.185	.428
	5	–.146	.377	.510
	6	.636	.623	.685

Table 5. Lesson composite descriptives and regression results.

	M	**SD**	***B***	**S. Error**	***β***	***t***	***p***
Constant			.164	.031		5.357	.000
Lesson 1	.52	.39	.082	.043	.165	1.922	.055
Lesson 2	.48	.23	.150	.058	.180	2.583	.010
Lesson 3	.65	.26	.251	.065	.342	3.849	.000

Lesson 4	.74	.34	.124	.049	.213	2.510	.012
Lesson 5	.36	.30	.009	.062	.014	.151	.880
Lesson 6	.50	.37	.143	.048	.268	2.964	.003
Lesson 7	.36	.25	.117	.064	.151	1.835	.067
Lesson 8	.61	.40	–.003	.025	–.006	–.115	.908
Lesson 9	.47	.32	.142	.053	.231	2.654	.008
Lesson 10	.61	.31	.076	.059	.119	1.287	.199

To better understand the nature of the contributing assignments we conducted a qualitative content analysis on these assignments in reference to the results of the discriminant analysis by comparing the assignments that distinguished learning achievement better than those that did not. The questions and student responses were read and categorized in terms of the nature of the assignment (i.e. observing–reasoning or analytical–application). Then, the categorized responses were grouped by the discriminant function coefficient within each of the three achievement groups. We found that those distinguishing learning achievement well are observing–reasoning assignments. For example, Lesson 3 Assignment 2 has a discriminant function of −1.10, −.37, and .48 for low, intermediate, and high-achieving groups. It asks the learner, "*Enter your partner's heart rate after completing the PACER.* ____________*bpm*." To complete the assignment, the learner first needs to know how to take pulse and when to take it, and to understand the relation between pulse taken (for 6 seconds or 10 seconds) and the time period (1 minute) used to calculate the heart rate (times 10 or 6, depending on the time unit used in taking the pulse). The reasoning process seems to be simple. But it requires the learner to mentally organize these steps correctly in order to understand the concept of heart rate.

Contributions from most analytical–application assignments did not seem as strong as those from the observing–reasoning assignments. Assignment 1 of Lesson 2, for instance, is an analysis–application problem, "*You have to run two blocks to catch the bus. Write three sentences to explain to a friend the physiological changes that occurred to your body when you exercise vigorously*" for the learner to answer after a running activity. It can be seen in Table 4 that the contribution of this assignment was not as highly distinguishable as the previous example. This assignment expects the learner to possess knowledge about a context outside of gymnasia and to extend what is experienced in physical education to that context in which the concept of cardiorespiratory capacity is at work.

Although the assignments contributed differently as shown in the discriminant analysis and assignment-by-assignment content analysis, their overall impact should be considered in the lesson context. Following the regression analysis results, we found that lessons with coherent cognitive challenge tended to be associated with knowledge growth. Particularly, Lesson 2, 3, 4, 6, and 9 used a theme approach that provided holistic cognitive challenge. For example, the overarching objective for Lesson 3 was to learn how to use the PACER test to assess the cardiorespiratory capacity. The first assignment states:

> Think about how you felt when you ran the PACER test. Think about whether you ran too fast and became tired too soon. Think about what strategies you can use next time to run for a very long time. Write a paragraph explaining to a friend how to get the highest score on the PACER test.

In Lesson 9, the learners were asked to predict which of the following: jumping rope, word game with jump rope, shooting baskets, badminton overhand volley, and steeplechase, would raise their heart rate into the target heart rate zone. They then did the activities in the same amount of time, recorded their heart rate at each, rested for the heart rate return to normal. When finished, they were asked to examine the data and identify the activities that helped raise the heart rate into the target heart rate zone. Although the discriminant function coefficients show little and uneven contributions of the two assignments, the regression results suggest that the lesson as a whole contributed to the knowledge growth significantly ($B = .14$, $\beta = .23$, $p = .008$).

Discussion

The results indicate that deliberately planned cognitive assignments in physical education did contribute to the students' cardiorespiratory capacity knowledge construction. In summary, the findings suggest that learning knowledge in physical education relies on meaningful, rigorous, and developmentally appropriate cognitive assignments. Yet, not all cognitive assignments will lead to learning achievement equally. The information in Table 4 clearly shows that some contributed more than others and some might not contribute at all. However, the results from the content analysis and regression analysis suggest that the contribution from each assignment should not be viewed in isolation. In each lesson, various assignments were likely to form a holistic and, possibly, coherent learning experience that ultimately contributed to learning achievement. It appears, nevertheless, that not all lessons included in the cardiorespiratory unit contributed equally to student knowledge gain.

The results should be interpreted in an empirical context larger than what was conceptualized for this study. In an earlier study, Zhu et al. (2009) reported that participating in cognitive tasks is the necessary and sufficient condition for knowledge development. In Zhu et al. study, learners who had opportunities working on cognitive assignments with workbooks learned better than those who did not. Doing assignments *correctly* played a less significant role than just doing the assignments in determining the level of learning achievement. Zhu et al. concluded, "non-engagement may be the worst enemy of learning" (p. 228).

The current analysis was based on the data from the learners who completed all the assignments. The analysis of their knowledge growth showed that the knowledge growth was associated with the quality of performance on the cognitive assignments, but only to a degree. It seems that the data reiterate Zhu et al.'s above argument. According to Cueto et al. (2006), we should be cautious about expecting learners to respond correctly to all assignments. In learning mathematics, it was found that sixth grade students were able to solve only about 44% of mathematics assignments correctly (Cueto et al., 2006). The evidence from the current study shows a positive, predictive association between rigorous cognitive assignments and achievement of learning cognitive knowledge.

From a constructivist perspective, children learn differently because they bring in different prior knowledge that is relevant, or in most cases irrelevant, to the learning of the content (Vosniadou, 2007). The data clearly show that after experiencing the same learning tasks, the learners in the study responded to the assignments in different ways. Workbook assignments are a unique content delivery system. Regular and systematic use of this system is rare in physical education.

The discriminant and content analysis results may imply that assignments with various levels of cognitive challenge are likely to contribute differently to learning achievement. In general, assignments which lead to deep cognitive processing are likely to enhance cognitive learning achievement (Alexander, 2006).

In terms of cognitive development, Mulhenbruck et al., (1999) found that assignments serve different purposes at different grade levels, and thus should be developmentally appropriate to the learning goal. In elementary school, assignments are functional in that they reinforce the knowledge covered in class. In middle schools or secondary schools, assignments prepare students to potential problems they may face. In the current study, analysis–application assignments involve extending knowledge learned in one context (e.g. classroom) to another, which demands higher-order information processing (Wu and Tsai, 2005). This processing often creates a "conceptual complexity and case-to-case irregularity" which often led young learners to failures because of their "conceptual oversimplification and inability to apply knowledge to new cases (failures of transfer)" (Spiro et al., 1992: 58). In contrast, observing–reasoning assignments provide students less irregularity through hands-on experiences or tangible information (e.g. visual images of exercise) that simplifies the contextual complexity. It can be speculated that analysis–application assignments might be excessively challenging for fourth graders in that they might not be able to extend learned knowledge that can be applied to the abstract scenarios presented in the assignments. With little research conducted in this area, future studies are needed to determine the relationship between higher-order cognitive tasks to learning achievement in physical education.

Our content analysis seems to echo the finding that construction of a contingent learning context depends on the match between learners' developmental characteristics and the appropriateness of learning tasks. The data seem to argue that the observing–reasoning assignments tend to provide a level of conceptual complexity that is developmentally appropriate to fourth graders in physical education where deep-processing can be conducted effectively and, yet, excessive higher-order cognitive challenges are controlled.

The essential purpose of using workbook assignments to help learners focus on cognitive knowledge is to bridge the cognitive and physical learning experiences to facilitate learning achievement in physical education. Ennis (2007, 2010) postulates that to help children develop and sustain healthful living behavior, it becomes necessary to teach them not only *how* to be physically active (the behavior) but also *why* they need to be active in certain ways (the knowledge). From the constructivist perspective, cognitive knowledge drives the formation of a behavior. According to von Glasersfeld (1995), voluntary action is the constructed experiential reality that relies on human beings' mental representation (knowledge) of a phenomenon. In other words, if a child/adolescent has not acquired a sound mental representation about the benefits from and scientific principles of exercise, he/she will be unlikely to develop and sustain a voluntary behavior of regular physical activity. The challenge in the field of physical education is where, when, and how cognitive knowledge about exercise and actual physical activity experiences can be bridged. Our data seem to show that assignments that bridged the two in Lesson 2, 3, 4, 6, and 9 helped the learners better construct positive mental representations of the cardiovascular fitness knowledge better than those in the other lessons.

Apparently, one explanation for the differentiated and uneven assignment contribution to achievement may be attributed to the issue of cognitive load (Moreno and Patk, 2010). With the fact that the children in the study might have not been exposed to intensive cognitive tasks in physical education throughout their education experiences until learning in this curriculum, it is likely that some cognitive tasks, along with physical tasks, created a more extraneous information load that others that demanded larger processing capacity. The information would have a stronger impact on learning. Although cognitive load theory has been considered in designing learning tasks in other subject content areas, it has not been fully studied in conjunction with physical activity experiences. This research was not designed to study cognitive load with physical activity, thus the above explanation should be taken with caution.

In addition, we suspect that the inconsistency between the assignments and learning achievement may be attributed to the demand for deep information processing. It has been documented in research that learners in physical education, like in other content areas, tend to conduct superficial (shallow) processing of the content. For instance, Placek et al. (2001)reported that adolescent physical education learners tend to understand fitness as “looking good” or “being thin.” To develop relevant mental representation of fitness knowledge, radically restructuring one’s mental representation is quite necessary (Ennis, 2007, 2010). Although studying the causes for the inconsistency was not the purpose of this study, the results certainly point to a need for additional research that will further analyze the role of cognitive assignments in physical education in relation to both cognitive and physical learning achievement.

This study contributes to the literature with a relatively holistic view of how a physical education curriculum led students to achievement in the cognitive domain by identifying lessons and assignments that impacted knowledge learning achievement. The student learning experiences were well documented in their responses to the workbook assignments. The analysis of the relation between their responses to the assignments and their learning achievement provides insightful evidence to inform future curriculum design. The reader is cautioned, though, that the study is limited to one learning unit of cardiorespiratory health and fitness. The specific results and findings about lessons and assignments may not be generalizable to other content domains in physical education, although they can inform the curriculum reform effort to integrate the cognitive and psychomotor learning experiences.

In summary, this study adds useful evidence to a growing body of research on adopting cognitive assignments to facilitate learning knowledge of physical activity and health (Harrison et al., 2006; Manios et al., 1998; Salmon et al., 2007; Zhu et al, 2009). The findings revealed a complex association between the workbook assignments children that were expected to complete and their achievement in learning the knowledge of cardiorespiratory fitness. Although the study has shown positive results that studying cognitive assignments in physical education lessons did contribute to learning important knowledge, mechanisms of the contributions remain unclear. A significant number of assignments were questionable in terms of their contribution to high-level achievement. The findings call for additional studies to further enhance our understanding of the role of using cognitive assignments in knowledge acquisition and physical activity behavioral change in physical education.

Appendix A: Sample workbook page

IMAGE OMITTED FROM THIS FORMATTED DOCUMENT

Appendix B: Grading rubric for Lesson 2

Question 1

Lesson	Assignment	Score	Description
2	1	3	Only circle "sweating and tired"
		2	Identify one physiological change and explain the relationship between the changes to exercise intensity
		1	Identify one physiological change without explain the change in relationship to exercise intensity
		0	No answer

Question 2

Lesson	Assignment	Score	Description
2	1	3	Identify two physiological changes and explain the relationship between the changes to exercise intensity
		2	Identify one physiological change and explain the relationship between the changes to exercise intensity
		1	Identify one physiological change without explain the change in relationship to exercise intensity
		0	No answer

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