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The nature of learning tasks and knowledge acquisition:The role of cognitive engagement in physical education

Yubing Wang, **Ang Chen**, **Ray Schweighardt**
Department of Kinesiology, University of North Carolina at Greensboro, USA

Tan Zhang
Department of Health, Arkansas State University, USA

Stephanie Wells, **Catherine Ennis**
Department of Kinesiology, University of North Carolina at Greensboro, USA

Abstract

Acquiring scientific knowledge about physical activity is necessary for students to become physically literate for life, and cognitive engagement and cognitive levels of tasks are two components that often determine the effectiveness of knowledge acquisition. This study sought to determine the extent to which students' cognitive engagement in descriptive, relational and reasoning learning tasks contributed to their acquisition of knowledge and the extent to which cognitive engagement on lower-level tasks contributed to higher-level tasks (e.g. descriptive to relational to reasoning). The performance of students in descriptive, relational and reasoning tasks and knowledge acquisition was measured in 992 middle school students in active physical education lessons. The results revealed that students' performance in relational (regression coefficient 0.09, $p < 0.01$) and reasoning (regression coefficient = 0.06, $p < 0.01$) tasks directly contributed to their acquisition of knowledge ($R^2 = 0.14$). The performance of students in descriptive tasks indirectly contributed to knowledge acquisition through influencing their performance in relational and reasoning tasks (indirect effect = 0.09, $p < 0.01$).

Keywords

Bloom's Taxonomy; constructivist learning theory; instructional core; written tasks

Introduction

Recently, the Society of Health and Physical Educators in America (SHAPE America) stated that the ultimate goal of physical education, from kindergarten to high school, is to help students become 'physically literate individuals' who possess the knowledge, skills and confidence to engage in and enjoy healthful physical activity for life (SHAPE America,

Corresponding author: Yubing Wang, Department of Kinesiology, School of Health and Human Sciences, University of North Carolina at Greensboro, 1408 Walker Avenue, Greensboro, NC 27412, USA. y_wang27@uncg.edu.

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2014). Although for a long time knowledge acquisition has been widely recognized as an integral part of physical education (Rovegno and Dolly, 2006), it is often overlooked in physical education classes and needs to be emphasized in current curricula (Penney and Chandler, 2000). Ennis (2015) argued that knowledge empowers the learner to know what to do and understand when and how to perform, and further suggested that scientific knowledge about physical activity and fitness should be at the core of the physical education curriculum, and with equal emphasis to that placed on skills and fitness.

A major part of the cognitive knowledge in physical education includes concepts and principles about physical activity and fitness, in addition to information about movement tactics and motor/ sport skill performance (SHAPE America, 2014). It has been suggested that this knowledge can be acquired most effectively through simultaneous cognitive and physical engagement (Ennis, 2007). Sun et al. (2012) investigated the effects of a concept-based physical education curriculum – that is, a curriculum focusing on teaching scientific concepts about physical activity and fitness in physically active learning environments – on elementary school students' acquisition of knowledge about physical activity and fitness using a large-scale, randomized, controlled experimental design. They found that students in the concept-based curriculum condition gained more knowledge, with a large effect size, than students in a traditional multi-activity physical education curriculum (Cohen's d ranged from 0.97 to 2.21). This finding implies that acquiring conceptual knowledge about physical activity and fitness in a physically active learning environment is possible and can be effective.

Cognitive engagement, defined as the mental effort students spend in learning tasks, has been shown to be a significant factor that influences student learning in the classroom (Chapman, 2003; Corno and Mandinach, 1983). To understand the process of students' knowledge acquisition in physical education, Zhu et al. (2009) examined the relationship between students' cognitive engagement and the knowledge they acquired. The researchers used students' ($n = 670$) performance scores received for in-class written cognitive assignments (e.g. 'describe one strategy you can use next time to run for a very long time in order to pace yourself during the PACER Test') to represent students' cognitive engagement. They found that the students' cognitive engagement contributed significantly to their knowledge acquisition in physical education.

Following this line of research, Zhang et al. (2014) further investigated how the cognitive demands of in-class cognitive assignments contributed to students' knowledge construction about cardiovascular fitness, using a mixed method design. Students in fourth-grade ($n = 616$) from 15 schools participated in this study. The researchers found that different cognitive assignments contributed differently to the growth of the students' knowledge. Follow-up qualitative content analysis on responses to the cognitive assignments showed that the assignments requiring low-order cognitive processing (e.g. description and memorization) tended to contribute better to knowledge acquisition scores than the assignments requiring high-order cognitive processing (e.g. reasoning and analyzing) (Zhang et al., 2014).

Based on the findings of these previous studies, it seems evident that cognitive engagement and cognitive demand of learning tasks are two important factors that influence learners' knowledge acquisition in physical education. To understand further students' conceptual knowledge acquisition process in physical education, it was felt necessary to integrate these two factors and investigate how they interact with each other to influence the acquisition of knowledge.

Scholars have argued that students' cognitive process cannot be entirely separated from the cognitive nature of tasks (Ennis, 1992; Newell, 1986). Different types of learning tasks tend to provide different opportunities for students to engage cognitively in disciplinary concepts and ideas (Doyle, 1983; Stein et al., 1996). Learning tasks that ask students to describe a fact or recall information require low-order cognitive information processing, while learning tasks asking students to relate relevant concepts or construct a reasoning argument tend to require high-order cognitive processing. The extent of students' engagement in these different levels of learning tasks tends to contribute differently to their learning achievement (Hiebert and Wearne, 1993; Stigler and Hiebert, 2004). The first purpose of this study therefore was to determine the extent to which students' cognitive engagement in different levels of cognitive tasks contributed to their knowledge acquisition in physical education.

From a constructivist perspective, Ennis (2008) argued that coherent learning tasks should be developed and structured to allow scaffolding processes to take place. The scaffolding processes provide a path that leads the learner from the known to the unknown and from low-order, descriptive cognitive processes to high-order decision-making processes. Eventually, these processes result in the construction of new knowledge through connecting the known with newly-acquired knowledge and feeding factual information into high-order cognitive processes. In recent years high-level cognitive learning tasks have been studied and advocated in the classroom setting (Barak and Shakhman, 2008; Barnett and Francis, 2012; Kisa and Stein, 2015). The value of low-level cognitive tasks in learning has, it appears, rarely been studied or emphasized. Booker (2007) reminded educators that low-level knowledge (e.g. factual information or concepts to be memorized) is fundamentally important. In the absence of low-level knowledge as a foundational building block, higher-order thinking and understanding may be difficult to develop and sustain. Thus the second purpose of this study was to determine the extent to which students' cognitive engagement in low-level cognitive tasks contributed to their engagement in high-level cognitive tasks.

Task taxonomy: low-level knowledge as the foundation

Bloom's Taxonomy of cognition provides a framework for teachers to develop and organize tasks according to the levels of cognition, in order to maximize learning achievement (Bloom, 1956). The Taxonomy specifies cognition levels based on task complexity, from low cognitive level tasks (knowledge, comprehension) to intermediate level tasks (application, analysis) to high level tasks (synthesis, evaluation) (Bloom, 1956). Later, scholars revised and renamed the six levels as 'remember', 'understand', 'apply', 'analyze', 'create', and 'evaluate', to enhance the clarity of the complex cognitive processes (Anderson and Krathwohl, 2001). In physical education, a knowledge/remember level task could be, for example, memorizing the definition of aerobic exercise. Thus (excluding 'remember'):

- A comprehension/understand task could involve explaining aerobic exercises in one's own words;
- An application/apply task could require applying exercise principles to solve a problem;
- An analysis/analyze task focuses on analyzing a problem and reasoning for the relevance of the solution;
- A synthesis/create task may demand integrating various concepts or principles in order to apply them in a new setting such as engaging in physical activity at home; and
- An evaluation/evaluate task emphasizes making value judgements for adopting a right course of action.

The first four levels of learning tasks are often integrated into lesson plans in physical education, while the last two levels are rarely emphasized (Ennis, 2015).

An unintended consequence of the wide use of the Taxonomy in education, however, is that the value of low-level cognitive tasks is overlooked, and this has drawn attention and criticisms from scholars (Booker, 2007; Furst, 1981; Paul, 1993; Seddon, 1978; Sockett, 1971). As Booker stated, 'the Taxonomy, in its call for higher order thinking, has become a tool for subverting the transmission of knowledge, even though Bloom considered that to be the basis for all higher thinking' (Booker, 2007: 353). In other words, low-level cognition tasks that serve as building blocks for the development of high-level thinking should not be overlooked in the curriculum and instruction processes. The relationship between low cognition tasks and high cognition tasks therefore needs to be clarified further.

Instructional core: enhancing cognition-engagement interaction

The instructional core is conceptualized as a basic instruction-promoting framework which emphasizes the interconnectedness of the teacher, the content, and students (City et al., 2009). Unlike other concepts about instruction (e.g. academic learning time or student success rate) that are based on the process–product paradigm separating teacher and student behaviors (teaching vs. learning), the instructional core emphasizes the complexity and dynamic nature of instruction and learning as an intertwined entity. The instructional core treats the classroom as an ecological environment in which the teacher, the content and students are all interdependent on each other (Ward, 2013).

As proposed by City et al. (2009), the instructional core is 'composed of the teacher and the student in the presence of content' (City et al., 2009: 22). In this model, 'the teacher' refers to the teacher's knowledge and skill, 'the student' means the role of the student in the learning process that is usually represented by engagement with the content, and 'the content' refers to the level of learning tasks (City et al., 2009). The level of the learning task reflects what the student is asked to do, rather than the level reflected in the content itself (City et al., 2009). For example, when a teacher asks middle school students to memorize the definition of 'anaerobic exercise', the actual task that students are asked to do is a memorization task, even though 'anaerobic exercise' is often treated as an advanced scientific concept that is beyond what middle school students usually learn in physical education. City and colleagues argued that:

> There are only three ways to improve student learning at scale. The first is to increase the level of knowledge and skill that the teacher brings to the instructional process. The second is to increase the level and complexity of the content that students are able to learn. And the third is to change the role of the student in the instructional process. That's it. If you are not doing one of these three things, you are not improving instruction and learning. (City et al., 2009: 24)

The three elements (teacher, student, content) in the instructional core framework interact with each other to influence learning outcomes (City et al., 2009). As one element changes, the other two should be changed to allow the system to adapt to the change. For example, if a teacher is asked to teach high-order content without increasing their knowledge and skill to support that teaching, student engagement may be jeopardized. Similarly, if a teacher teaches high-level tasks and uses relevant teaching knowledge and skills but does not change the strategy to engage students, improvement in student learning will be difficult to achieve.

Researchers (Ko et al., 2006; Ward and Doutis, 1999) have documented the phenomenon of high cognition content with low cognition teaching in physical education. In their study on the effects of professional development on teachers' teaching skills, Ko et al. (2006) reported that even though the teachers had demonstrated adequate understanding about pedagogical strategies of the high cognition content of the sport education model (e.g. sportspersonship, sport skills and concepts of tactics), they taught the curriculum superficially in practice. Ward (2013) pointed out that even though the teachers had sufficient knowledge and support for teaching high cognition content, the students' low level of active involvement in the content tended to jeopardize achieving a positive learning outcome. All of these studies signify the interdependent relationship between the teacher, the content and students that is necessary to ensure desirable learning outcomes in physical education.

Cognitive tasks in physical education

From the constructivist perspective, learning is a meaning-making process in which learners construct and reconstruct knowledge through actively engaging in structured learning activities (Hung et al., 2006). In this sense the meaningful interactions between the learner and the content play a critical role for learning to occur. In physical education, effective knowledge acquisition relies on students' simultaneous cognitive and physical engagement in learning tasks that require physical exertion at moderate to vigorous physiological intensity (Ennis, 2007).

Cognitive engagement is defined as the mental effort that students exert in learning tasks (Chapman, 2003). To promote students' cognitive engagement, constructivist teachers emphasize using various learning tools and task structures to scaffold student thinking and learning (Ormrod, 2014). One important learning tool used in constructivist physical education is that of providing students with written tasks that are designed to correspond with physical activity tasks, to gradually maximize both cognitive and physical engagement (Ennis, 2013; Ennis and Lindsay, 2008). In each lesson, different cognitive levels of the written tasks are included and carefully structured, to help students actively construct the meaning of physical movement and form their own knowledge structure about physical activity (Sun et al., 2012).

The current study

This study was based on a large-scale curriculum intervention research project which was conducted in a southeastern state of the United States. Twenty-four middle schools were randomly selected from seven school districts. A randomized assignment procedure placed 12 schools in the experimental condition and 12 in the control condition.

The teachers in the experimental condition received four six-hour professional development sessions, throughout the semester, on delivering a concept-based constructivist physical education curriculum. Several strategies were adopted in these sessions to ensure that the teachers could implement the curriculum successfully. These strategies included lectures, group discussions, role-play, lesson demonstrations, and practicum-teaching selected lessons. The teachers in the control condition received, as a placebo, the same amount of training with the same hours and in the same format, on teaching the state-sanctioned multi-activity curriculum. Fidelity of curriculum implementation was preserved through equal time on-site observations by the research team in both experimental and control schools. For the purposes of this study, we used the data from the experimental schools because the control schools did not use the workbooks; the objectives of this study did not call for a comparison of learning performances between the two conditions.

The goal of the intervention curriculum was to help middle school students acquire scientific knowledge about physical activity and health benefits in physical education. Using a concept-based constructivist curricular approach, the curriculum focuses on simultaneously engaging students physically and cognitively in order for them to experience the effects of physical activity on the body and learn the scientific relationship between the effects and health benefits. A salient characteristic of this approach is the use of student workbooks to guide students in every lesson. It was hypothesized that using the student workbooks would facilitate sixth, seventh and eighth grade students' acquisition of knowledge and skills for physical fitness development and healthful living.

The design of the written tasks in the workbooks was based on three cognition levels: descriptive tasks, relational tasks, and reasoning tasks. There were 37 descriptive tasks, 18 relational tasks and 14 reasoning tasks in the workbook for each grade.

Descriptive tasks required students to enter factual information, such as what they did in class or what happened to their body following a physical activity. Examples of descriptive tasks were 'Record the number of steps taken in the Five Pass game'; and 'My personal RPE (Rate of Perceived Effort) level at the end of Round 2 of the Flag Pull game is'.

Relational tasks required students to relate their physiological responses to the specific characteristics of physical activity and to demonstrate an understanding of the relationships between different concepts (e.g. intensity and heart rate). Examples of relational tasks were 'For each of the physical activity benefits listed in the table below, decide if it is an example of short- or long-term benefits and suggest an activity that could be a great way to achieve that benefit'; and 'During Round 1 of Flag Pull, list two ways you progressively overloaded your body'.

Reasoning tasks were designed to strengthen in-depth understanding and promote structural knowledge change. These tasks required students to understand in depth the connection and relationship between various concepts and principles and how to apply the knowledge in daily life. One example of reasoning tasks was 'Think about how often you should participate in cardiorespiratory endurance activities each week and write three or more sentences to explain to your family why everyone needs to be physically active frequently in each week'.

Based on the above theoretical articulations and review of the literature, especially the relationship between descriptive tasks (building blocks) and relational/reasoning tasks (higher-order knowledge) (Booker, 2007), we hypothesized that descriptive tasks would serve as building blocks for higher-order (rational and/or reasoning) knowledge development. As such, students' performances in descriptive tasks in the workbook would contribute to their performances in relational and reasoning tasks. Similarly, students' performances in relational tasks would contribute to their performances in reasoning tasks. Subsequently, it was hypothesized that their performances in completing the tasks at each cognition level would all contribute to their knowledge acquisition. These hypothesized directional relations are depicted in the a priori model in Figure 1. Through testing this model, we sought to answer the following research questions:

a. To what extent did students' performance in descriptive and relational tasks contribute to their performance in reasoning tasks?

b. To what extent did students' performance in descriptive tasks contribute to their performance in relational tasks? In other words, did low-level cognition tasks serve as building blocks for developing high-level cognitive thinking skills?

c. To what extent did students' performance in the three types of tasks contribute to their knowledge achievement?

Answering these questions will not only further our understanding about students' knowledge construction processes in a physically active learning environment, but also provide evidence-informed guidance to physical education curriculum development.

Methods

The curriculum and data sources

The intervention curriculum included 20 lessons for teaching the concepts and principles of cardiorespiratory fitness. Each lesson was designed and implemented based on the '5-E' instructional framework: Engagement, Exploration, Explanation, Elaboration, and Evaluation (Bybee et al., 1989). In each lesson, students assumed the role of 'Junior Scientists' to complete tasks in the 5-E processes (Bybee et al., 1989). In Engagement, the teacher involved students in an instant activity or a game which was usually used to elicit one essential question about the science of physical activity and fitness. Often, in this part, the teacher introduced relevant scientific vocabularies and concepts. In Exploration, students often went through a sequence of exercise stations or several games that were designed to help them to understand the scientific concepts and fitness principles. During this part, students followed the assignments in the workbook to frequently predict, experiment, observe and record in their workbooks their physiological, psycho-motor or affective responses to the physical activities. During Explanation, students were paired with a partner to go through the ‘Think, Pair, Share’ process. In this process, students first followed the workbook assignments individually in order to think about the meaning of the responses they recorded and attempt to answer an essential question based on the data they collected. They then shared the meaning with a partner, as instructed in the workbook, to compare and contrast each other’s data in order to address the essential question together. In Elaboration, the teacher illustrated further the relationship between different scientific exercise concepts and fitness principles reflected in students’ data, and then guided the students to discuss how to apply these concepts and principles to their daily lives. The teacher also gave an additional task in some lessons that asked students to apply the concepts and principles in a different exercise setting. In Evaluation, the teacher led students in their summarizing of the core concepts and principles they learned in the class, and completing an open-ended real life question in the workbook using the knowledge gained in the class.

In essence, the workbook was an important knowledge construction tool in this curriculum to assist learning. The tasks in the workbook were sequenced in progressively complex forms, in terms of cognitive demand, from descriptive tasks to relational and reasoning tasks. These tasks were presented to students as questions/problems that were specifically linked to the physical activities being experienced, to facilitate students’ knowledge construction. Appendix A is a sample page from the workbook.

The data analyzed in this study consisted of students’ responses to the written tasks in the workbooks. On completion, research assistants gathered all the workbooks from the experimental schools. Responses came from a total of 992 students in grade six, seven, and eight (n = 411 for boys, n = 581 for girls; mean age = 13.2 years old) who completed the entire workbook. Of these students, 587 (59.2%) registered a Caucasian ethnic background, 87 (8.8%) African American, 216 (21.8%) Hispanic, 28 (2.8%) Asian, 63 (6.3%) Mixed Race, eight (0.8%) American Indian, and three (0.3%) Arabic American. In accordance with the university’s IRB regulations, parental permission and student assent were obtained before data collection.

Variables and measures

Cognitive engagement. Chapman (2003) suggested that cognitive engagement can be operationalized as engagement in learning tasks. Students’ cognitive engagement in this study was operationalized as their performance in the cognitive tasks in the workbook, and students’ cognitive engagement in each level of tasks (descriptive, relational and reasoning) was represented by their performance in completing the tasks at the level.

Students’ performances in each task were measured using a five-level scoring rubric with zero(0) representing the lowest performance and four (4) representing the highest performance. The rubric was validated using the group Adelphi method. First, five researchers independently graded one sample of tasks using the rubric. Scores were compared and any discrepancy in scores was discussed followed by rubric revisions when necessary. This process continued until all researchers reached a consensus about the rubric. These researchers then graded another sample of tasks using the revised rubric and went through the same process as grading the first sample of tasks. This cyclic process continued until the researchers reached 100% agreement on scoring all tasks using the rubric. The final version of the rubric was presented in a matrix format. Appendix B shows sample tasks and the corresponding rubric.

Knowledge acquisition. Students' knowledge gain was determined using standardized, multiple-choice knowledge tests (pre- and post-instruction). The content accuracy of the questions was determined by physiologists and education experts ($n = 7$). These experts were tenured faculty members from departments of kinesiology with the rank of associate professor or above; all of the experts have published extensively in their respective kinesiology fields. The experts were all asked to rate each question on a five-point scale for knowledge accuracy (1 = 'inaccurate', 5 = 'accurate') and language appropriateness for middle school students (1 = 'inappropriate', 5 = 'appropriate'). Questions rated below five by one or more experts were discussed, revised and re-rated. Only questions that were rated as five by all experts were included for field validation testing with a group of students ($n = 330$) not included in the study. Questions that met the standards of difficulty index (0.45–0.65) and discrimination index (> 0.40) criteria (Morrow et al., 2005) were included in the question bank as validated question items. The validated knowledge test was administered before and after the curriculum implementation. Residual gain scores were calculated using the regression residual procedure to gauge individual students' knowledge gain (Tracy and Rankin, 1967).

Data collection

The knowledge test data were collected using Qualtrics, an online survey platform. After the knowledge tests were developed on Qualtrics, the link to the tests was sent to physical education teachers. With assistance from trained data collectors, the teachers administered the tests to students in school computer labs before and after teaching the curriculum. The workbooks were used by students in each lesson and, as noted above, were collected by research assistants for scoring when the instruction was ended.

Data reduction

Trained research assistants scored the workbooks using the validated rubrics. The inter-rater agreement reliability was checked periodically with *rs* ranging from 0.90 to 0.98. An aggregated performance score for each level of cognitive tasks (descriptive, relational and reasoning) was calculated using this formula:

$$\text{Performance socre} = (\text{Total scores earned}) \div (\text{The number of tasks})$$

Subsequently, each student received an aggregated performance score for the descriptive, relational and reasoning tasks, respectively.

For the knowledge tests, each correct answer was coded as 1 and incorrect as 0 (zero). Percent-correct scores were calculated to represent students' pre- and post-test scores, respectively. To calculate students' residual gain scores, students' post-test scores were regressed on their pre-test scores, which resulted in a regression formula. The regression formula was then used to calculate each student's predicted post-test score, based on their pre-test score. Each student's residual gain score was calculatedas theiractualpost-test score minus their predicted post-test score (Tracyand Rankin, 1967).

Data analysis

Descriptive analysis was conducted to determine students' performances in different types of cognitive tasks: binary correlation analysis was conducted to determine the correlation between students' performance in three types of cognitive tasks and their knowledge gain. To answer the research questions, Hayes' PROCESS macro v2.13 for IBM SPSS (Hayes, 2013) was used to test the a priori model shown in Figure 1. Hayes' PROCESS macro can be used not only to calculate the parameters of the regression models involved in Figure 1 but also to calculate and test the total, direct and indirect effects involved in the a priori model (Hayes, 2013). PROCESS used the bootstrap method for inferential test of the indirect effects; the number of bootstrap samples in the current study was 5000, as recommended (Hayes, 2013).

Results

The descriptive statistics are reported in Table 1. The results appear to indicate that with the increase of the cognitive levels of learning tasks, from descriptive to reasoning, students' performances tended to decline. Correlation coefficients shown in Table 2 indicate a moderate correlation ($r = 0.51$ to0.58) between scores on tasks at different cognitive levels. The correlation between the students' workbook performances and their knowledge acquisition ranged from low to moderately-low correlation (r ranging from 0.16 to 0.34). These relationships seem to be steady ($p < 0.01$).

Table 3 and Figure 2 show the parameter summary of the regression models depicted in Figure 1. The results suggest that the students' performances in the descriptive tasks significantly contributed to their performances in relational tasks ($R^2 = 0.26$, regression coefficient = 0.63). The performances in both the descriptive (regression coefficient = 0.39) and relational tasks (regression coefficient = 0.44) contributed sizably to their performances in the reasoning tasks ($R^2 = 0.40$). These results indicate that the students' performances in the low-level cognitive tasks contributes considerably to their performances in high-level cognitive tasks.

In addition, the results shown in Table 3 and Table 4 seem to suggest that the students' performances in the relational (regression coefficient = 0.09) and the reasoning tasks (regression coefficient = 0.06) contributed significantly to their knowledge acquisition ($R^2 = 0.14$). The performance in the descriptive tasks did not directly contribute to their knowledge acquisition. The effects of the students' performances in the descriptive tasks on their knowledge acquisition were indirectly mediated by their performances in the relational and reasoning tasks (total indirect effect = 0.09, $p < 0.01$). Table 4 also shows that the total effects of the descriptive, relational and reasoning tasks on the knowledge acquisition were 0.06, 0.11 and 0.10 respectively. This seems to indicate that the students' performances in higher level cognitive tasks (i.e. relational and reasoning tasks) tended to have greater effects on their knowledge achievement than lower level cognitive tasks (e.g. descriptive tasks).

Discussion

The primary purpose of this study was to determine the extent to which students' performances in descriptive, relational and reasoning cognitive tasks contributed to their knowledge acquisition in physical education. The secondary purpose was to determine the extent to which students' performances in low-level cognitive tasks contributed to their performances in high-level tasks in physical education. The findings suggest that the students' cognitive engagement in high-level cognitive tasks (relational and reasoning tasks) directly contributed to their knowledge acquisition in physical education. The students' performances in the low-level, descriptive cognitive tasks contributed indirectly via their performances in the relational tasks and reasoning tasks. It appears that the low-level tasks served as building blocks for performance in the high-level cognitive tasks. Overall, the results helped clarify the logical role of the low-level cognitive tasks in assisting higher-level cognitive understanding and achievement as necessary building blocks (Booker, 2007).

Role of cognitive levels in engagement-achievement relationship

Integrating workbooks into physical education appears to be an effective way to promote students' knowledge acquisition in physical education (Sun et al., 2012; Zhang et al., 2014). Workbooks were found to be an effective tool to help students engage cognitively in physical education and acquire cognitive knowledge related to physical activity and fitness (Zhu et al., 2009). The findings in the current study signify a further step toward helping understand the engagement–achievement relationship, which suggests that cognitive levels of learning tasks moderate the effects of cognitive engagement on knowledge achievement. The data appear to suggest that students' engagement in different cognitive levels of tasks tends to have different effects on their acquisition of knowledge.

An important theoretical proposition of the instructional core framework postulates that student engagement in tasks and the cognition level of tasks interact with each other to influence learning outcomes (City et al., 2009). According to the instructional core framework, increasing students' engagement and increasing the cognitive level of learning tasks are two of three fundamental components required to enhance learning (the third component is increasing teacher knowledge and skills; see City et al., 2009). When all three components are present and working together, instructional effectiveness will be achieved. In the current study, professional development training provided teachers with the necessary knowledge and skills on teaching the concept-based constructivist physical education curriculum. The intervention curriculum provided a set of challenging and developmentally-appropriate physical and cognitive content. The workbook tasks engaged the students with tasks sequenced at descriptive, relational, and reasoning cognitive levels. Our findings clearly support the instructional core proposition with evidence that increasing students' engagement in high-level cognitive tasks directly contributes to knowledge acquisition in physical education. The findings also suggest that the value of low-level cognitive tasks should not be overlooked, because of their significant indirect contribution to knowledge acquisition.

Low-level and high-level cognitive tasks

As shown in Figure 2, students' performances in the descriptive tasks made little direct contribution to their knowledge achievement. However, they did contribute to the students' performances in the relational and reasoning tasks. Students' performances in both the descriptive and relational tasks accounted for a considerable proportion of their scores on the reasoning tasks. These findings seem to suggest that knowing factual information through engaging in low-level cognitive tasks serves as the foundation or resource for the learning in high-level tasks. The evidence seems to be consistent with the perspective of Bloom's Taxonomy, which clarifies the hierarchical nature of knowledge and its interrelated functions. The data appear to lend support to Booker's observation that, ' … the lowest levels of the Taxonomy, particularly "Knowledge", were seen as setting the stage for higher levels of learning. Each level then builds on the previous levels, and is dependent on them' (Booker, 2007: 350). The finding is meaningful for teachers in that it shows the critical value of low-level tasks to performance in high-level tasks. The value of low-level learning tasks should not be overlooked in the process of providing K–12 learners with more high-level learning tasks in order to enhance their high-order thinking skills such as critical thinking and reasoning (Bulgren et al., 2011; Kisa and Stein, 2015). Strategically, teachers should integrate low-level and high-level cognitive tasks together to maximize learning achievement.

Cotton suggested that 'in most classes above the primary grades, a combination of higher and lower cognitive questions is superior to exclusive use of one or the other' (Cotton, 2001: 6). Further to the inception of cognitive learning theory, teachers have been encouraged to carefully construct and sequence classroom questions based on Bloom's Taxonomy, to guide students to engage in deep reasoning or deep processing learning beyond merely memorizing factual information (Graesser et al., 2005; Taboada and Guthrie, 2006). The findings echo these theoretical observations by revealing the importance of using carefully designed and structured learning tasks, at different cognitive levels, to lead to scaffolding experiences. These experiences appear to have guided the students' learning from a low-order thinking process to the high-order thinking process.

Ennis (2015) reminded us that physical education curricula for the 21st century should focus on knowledge understanding, transfer and innovation. Although not completely linear, these missions can be considered in a cognitive scaffolding hierarchy (Wilson et al., 2010) where knowledge understanding serves the purpose of knowledge transfer and this, further, leads to knowledge innovation. It is evident in the findings that integrating cognitive learning tasks in physical education can promote students' achievements in learning necessary knowledge about physical fitness and health. The path model implies that the scaffolding processes need to follow the hierarchy of the knowledge. Future studies are needed to further explore effective ways to maximize students' learning through designing and structuring the learning tasks with combined physical and cognitive challenges.

Another interesting finding in this study was that the students' performances in the relational tasks were a stronger contributor to their knowledge acquisition than their performances in the reasoning tasks (regression coefficients equal to 0.09 and 0.06 respectively, as shown in Table 3). Table 4 shows that the total effects of the relational and reasoning tasks on their knowledge acquisition were 0.11 and 0.10 respectively. Similar findings were also reported by Zhang et al. (2014) who examined the effects of elementary students' workbook performances in their knowledge learning in physical education. Zhang et al. (2014) found that students' performances in the low-level observing tasks were a stronger contributor to their knowledge acquisition than their performances in the high-level analysis–application tasks. One possible explanation offered by Zhang et al. (2014) was that the high-level analysis–application tasks might be too complex for elementary students to process cognitively, in terms of their cognitive development level. In our study the participants were middle school students, and so the explanation proposed by Zhang et al. (2014) does not seem to be applicable to our findings because most middle school students are developmentally capable of working on reasoning tasks (Mulhenbruck et al., 1999).

This phenomenon, as observed in the current study, might be explained from the cognitive load perspective (Plass et al., 2010). In concept-based physical education, students were acquiring cognitive knowledge in a physically active environment, where the workbook tasks served them by bridging their physical activity experience with their cognitive knowledge construction. This integrated cognitive–physical process was expected to challenge the students on both aspects, to facilitate learning. Plass et al. (2010) suggested that the intrinsic cognitive load for reasoning tasks is greater than for relational tasks, because the learner needs to simultaneously process more elements of information in working memory when they are working on reasoning tasks than when on relational tasks. In addition, it is likely that the physical engagement also increases students' extraneous cognitive load by demanding physical and cognitive energy. Cognitive load theory (Plass et al., 2010) has rarely been considered in designing learning tasks in physical education. Our findings imply a necessity to study the impact of cognitive loading on student learning in physical education. Further research is also needed to investigate students' in-class physical activity with regard to their performance in cognitive tasks, to determine the extent to which in-class physical activity serves as an added, extraneous cognitive load that affects knowledge acquisition.

Limitations of the study

This study has two principal limitations. First, using students' performances in cognitive tasks to represent their cognitive engagement may not fully reflect their entire cognitive effort. Cognitive strategies that students might use in physical education to complete physical tasks can be another aspect of cognitive engagement, and this was not included in this study. Although the confounding possibility is small due to the guiding effect of the workbook, future studies should examine students' cognitive engagement with a control over different sources of cognitive engagement.

The second main limitation of the study is that teacher variables (e.g. teachers' knowledge) are not integrated into this study because these variables were considered to have been controlled in the controlled experimental research design. Future studies, especially those that afford teachers greater autonomy for content decisions, should incorporate teacher knowledge variables so that the interaction effects of the teacher, student engagement and the level of learning tasks on student learning can be understood coherently.

Conclusion

This study has revealed that increasing the cognitive demand of learning tasks could enhance students' learning achievements in physical education. The findings also appear to suggest that students' performances in relational tasks is a greater contributor to their learning acquisition than their performances in reasoning tasks. As articulated above with regard to the cognitive load perspective, further studies are needed to examine the extent to which physical activity, serving as an extraneous cognitive load in physical education, affects students' performances in high-level cognitive tasks. Another important finding of this study was that even though students' performances in the low-level cognitive learning tasks did not directly contribute to their knowledge gain, it did contribute to their performances in the high-level cognitive tasks and, consequently, contributed indirectly to knowledge acquisition. This finding suggests that it is important for physical educators to integrate learning tasks with different cognitive levels in order to enhance students' acquisition of knowledge.

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Author biographies

Yubing Wang is a Doctoral Student in the Department of Kinesiology at University of North Carolina at Greensboro, North Carolina, USA.

Ang Chen is a Professor in the Department of Kinesiology at University of North Carolina at Greensboro, North Carolina, USA.

Ray Schweighardt is a Doctoral Student in the Department of Kinesiology at University of North Carolina at Greensboro, North Carolina, USA.

Tan Zhang is an Assistant Professor in the Department of Health, Physical Education and Sport Science at Arkansas State University, Jonesboro, USA.

Stephanie Wells is a Doctoral Student in the Department of Kinesiology at University of North Carolina at Greensboro, North Carolina, USA.

Catherine Ennis is a Professor in the Department of Kinesiology at University of North Carolina at Greensboro, North Carolina, USA.

Appendix A

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.

Sample workbook tasks

Appendix B

Grading rubric for lesson 5

Lesson	Question	Score	Description
5	1	0	The answers provided did not make sense (not fitness components).
		1	Correctly identified 1−3 fitness components.
		2	Correctly identified 4−6 fitness components.
		3	Correctly identified 7−9 fitness components.
		4	Correctly identified 10−11 fitness components.

Lesson	Question	Score	Description
		9	Blank
5	2	0	The answers provided did not make sense (not sports/physical activities) or were invalid.
		1	Correctly identified 1−3 sports/physical activities.
		2	Correctly identified 4−6 sports/physical activities.
		3	Correctly identified 7−9 sports/physical activities.
		4	Correctly identified 10−11 sports/physical activities.
		9	Blank
5	3	0	Provides a response such as ‘I don’t know’.
		1	Provides an incorrect/illogical response and/or a response that contains spurious information.
		2	Provides vague information but demonstrates comprehension of the question.
		3	Provides an accurate but simplistic response.
		4	Provides an accurate and sophisticated scientific response.
		9	Blank

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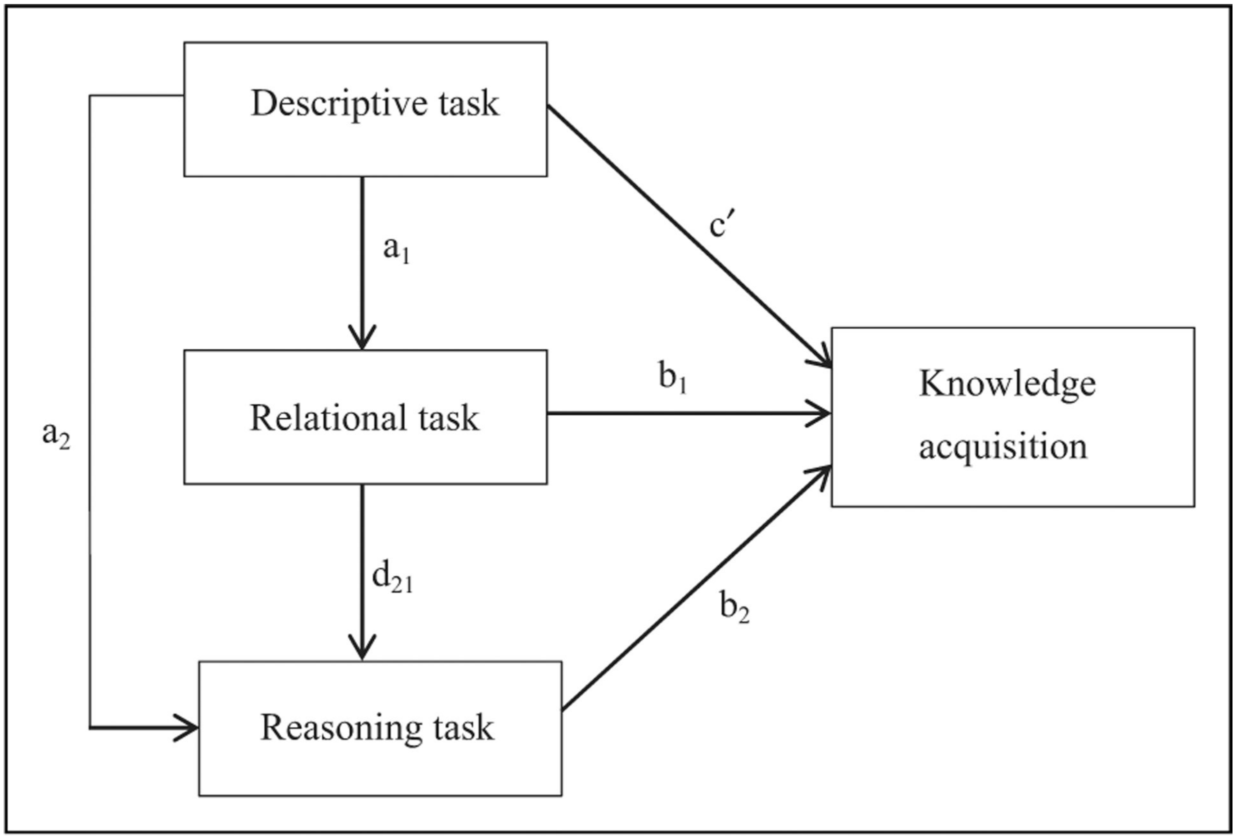

Figure 1.
The hypothesized model (a_1, a_2, b_1, b_2, d_{21}, and c' refer to regression coefficients).

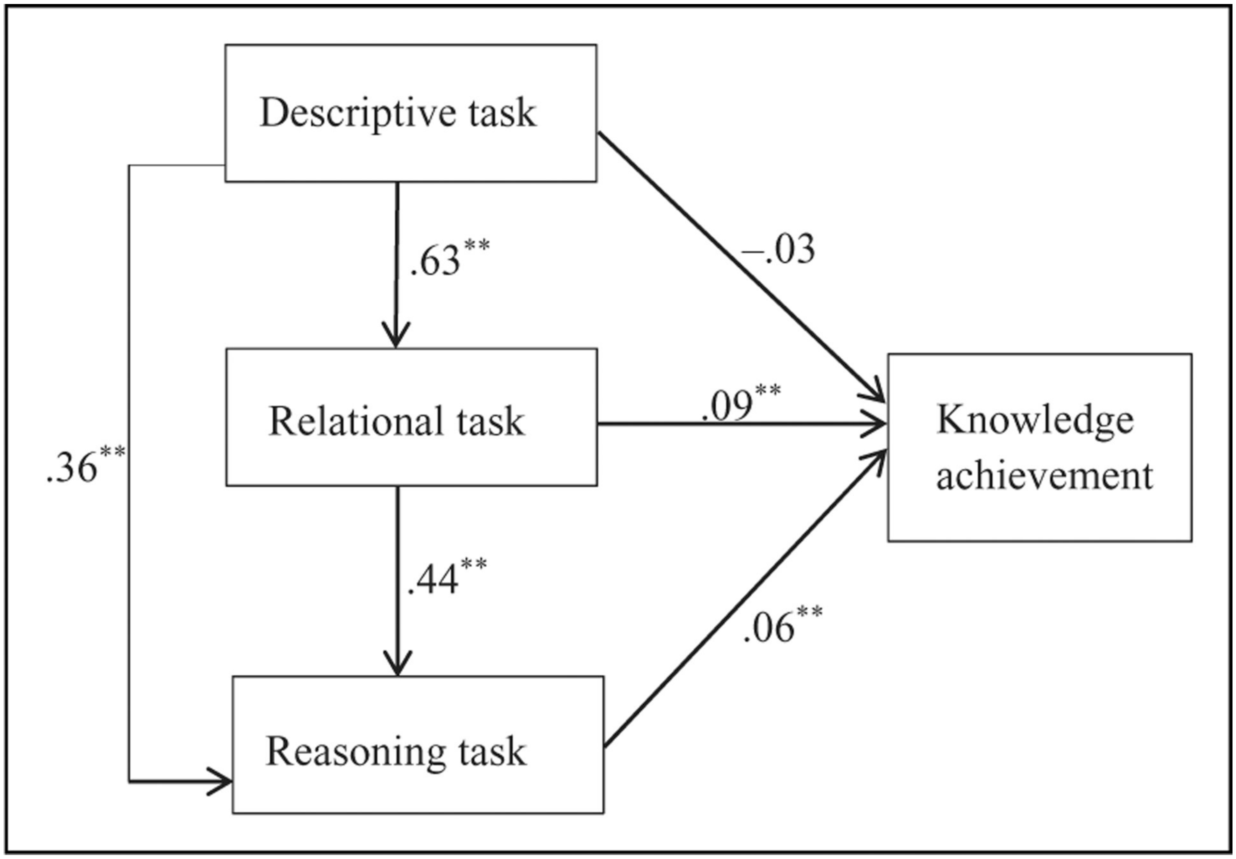

Figure 2.
The model with regression coefficients (**p < 0.01).

Table 1.

Descriptive statistics for all variables (**N**= 992).

Variable	**Mean**	***SD***	***Skew/SE***	***Kurt/SE***
Descriptive tasks	2.79	0.41	−0.71/0.08	2.22/0.16
Relational tasks	2.60	0.51	−0.17/0.08	0.66/0.16
Reasoning tasks	1.79	0.51	0.50/0.08	1.00/0.16
Pre-knowledge	0.37	0.16	0.17/0.08	−0.12/0.16
Post-knowledge	0.61	0.18	−0.59/0.08	−0.33/0.16
Residual gain score	0.00	0.17	−0.55/0.08	−0.27/0.16

Note: *SD* = standard deviation; Skew = skewness; *Kurt* = kurtosis; SE = standard error of skewness.

Table 2.

Correlation coefficients for variables included in the model (**N**= 992).

Variables	Descriptive tasks	Relational tasks	Reasoning tasks
Relational tasks	0.51**		
Reasoning tasks	0.51**	0.58**	
Knowledge achievement	0.16**	0.34**	0.31**

Note:

** $p < 0.01$.

Table 3.

Model summary of the serial multiple mediation analysis.

Independent variable(s)		Deperndent vairiable										
		Relational task				Reasoning task				Knowledge acquisition		
		c*	SE**	p		C	SE	p		C	SE	p
Descriptive task	a_1	0.63	0.03	< 0.01	a_2	0.36	0.04	< 0.01	C’	−0.03	0.01	0.04
Relational task		—	—	—	d_{21}	0.44	0.03	< 0.01	b_1	0.09	0.01	< 0.01
Reasoning task		—	—	—		—	—	—	b_2	0.06	0.01	< 0.01
Constant		0.85	0.10	< 0.01		−0.37	0.09	< 0.01		−0.26	0.04	< 0.01
		$R_2 = 0.26$				$R_2 = 0.40$				$R_2 = 0.l4$		
		$F (1,990) = 339.70$,				$F (2, 989) = 333.29$,				$F (3, 988) = 52.87$,		
		$p < 0.01$				$p < 0.01$				$p < 0.01$		

Note:

*C = Coefficient;

**SE = standard error; a_1, a_2, b_1, b_2, d_{21}, and c’ refer to regression coefficients.

Table 4.

Direct and indirect effects of different levels of task on knowledge achievement.

Independent variable		Indirect effect path	Effect	SE*	p
Descriptive task	Total effect **	–	0.06	0.01	< 0.01
	Direct effect	–	−0.03	0.01	0.04
	Indirect effect 1	Descriptive→Relational→Knowledge achievement	0.06	0.01	< 0.01
	Indirect effect 2	Descriptive→Relational→Reasoning→Knowledge achievement	0.02	0.00	< 0.01
	Indirect effect 3	Descriptive→Reasoning→Knowledge achievement	0.02	0.00	< 0.01
	Total indirect effect	–	0.09	0.01	< 0.01
Relational task	Total effect	–	0.11	0.01	< 0.01
	Direct effect	–	0.08	0.01	< 0.01
	Indirect effect	Relational→Reasoning→Knowledge achievement	0.03	0.01	< 0.01
Reasoning task	Total effect	–	0.10	0.01	< 0.01

Note:

* SE = standard error;

** Total effect =(direct effect) + (indirect effect).