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Learning through movement: A comparison of learning fraction skills on a digital playful learning environment with a sedentary computer-task

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ABSTRACT

Effects of physical exercise during educational tasks on learning are not obvious. This study examines the effects of movement on learning fraction skills at a physically active Playful Learning Environment (PLE). Employing a mixed-method approach, we investigated whether differences in motivational and verbal helping behaviour processes (underlying learning mechanisms) impacted learning gains. Results from 32 4th and 5th graders (n = 16 with the PLE, n = 16 in an equal sedentary computer task) approached significance, indicating that the PLE group showed higher learning gains compared to the SE group. Motivation was initially significantly higher for the PLE group. However, results indicated decreasing differences between the PLE and the sedentary group. There were no clear differences in the quality of verbal helping behaviour between the groups. Furthermore, subsequent utterances of verbal helping behaviour of two dyads selected in a case-study showed that their helping behaviour was sub-optimal for learning.

1. Introduction

The development of new powerful learning environments for engaging children in arithmetic activities in elementary education is a challenge for many educators. An example of a relatively new tool to teach children fraction skills is a digital Playful Learning Environment (PLE). This learning environment offers an active learning method, which aims to physically engage children in learning tasks, e.g. arithmetic, language or geography. With a PLE, children can create and play games on an outdoor playground while solving fraction problems. It aims to function as an interactive, playful learning environment through physical activity.

A PLE contains characteristics that aim to enhance powerful learning. Powerful learning can be seen as "learning that takes place effectively and efficiently, leading to permanent increases in relevant and usable knowledge and skills that stimulate and support further learning" (Veenstra, Van Geert, & Van der Meulen, 2011, p. 51). In powerful learning environments, learners are encouraged to construct their own knowledge and learn in realistic situations and together with others (De Jong & Pieters, 2006; Veenstra et al., 2011). Powerful learning environments stimulate active learning and constructive learning which are promoted by collaborative playful learning, and are aligned with individual differences, to reach high engagement (De Corte, Verschaffel, Entwistle, & Van Merriënboer, 2003; Hirsh-Pasek, Golinkoff, Berk, & Singer, 2009).

A PLE is based on the hypothesis that physical activity within the curriculum positively affects children's cognition, concentration and academic achievement (Donnelly & Lambourne, 2011; Donnelly et al., 2009). However, this type of physical activity can be defined in various ways. A distinction can be made between physical activity *during* and *after* the educational task (Trudeau & Shephard, 2008). This article is focused solely on physical activity *during* the educational task.

Research of Kangas (2010) and Kangas, Randolph, Ruokamo, and Hyvönen (2010) already indicates that the use of the PLE and various combinations of creative and playful learning methods is worthy of further research and implementation in educational practices. Their study shows, based on pre- and post test scores and qualitative results, that a PLE promotes academic achievement and creativity. However, it was not investigated whether the improvement was due to the specific PLE characteristics, since there was no control group involved in the study. Further, with only pre- and post-tests, valuable information about the learning processes diminishes (Flynn & Siegler, 2007; Steenbeek, Jansen, & Van Geert, 2012).

Effects of physical activity during the educational task are not obvious (Clinton, 2013). Some studies report that movement, whether it is during or outside the curriculum, has a positive effect on concentration, classroom behaviour, memory, self-esteem and reducing anxiety (Chomitz et al., 2009; Donnelly & Lambourne, 2011; Donnelly et al., 2009; Trudeau & Shephard, 2008). There are also studies with less convincing effects, which show that academic achievement neither increases, nor decreases through physical education (Ahamed et al., 2007; Carlson et al., 2008; Rasberry et al., 2010). Several studies report

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that physically active and fit children (whether this was due to physical activity within the curriculum or fitness in general) tend to have better academic achievement (Chomitz et al., 2009; Trost, 2007). However, a review of Taras (2005) reports that long-term improvement of academic achievement as a result of more vigorous physical activity (e.g. aerobic exercises or balance activities) is not well substantiated.

A possible explanation for the differences in outcomes of effects of physical activity might be that effects of physical activity can be either directly or indirectly linked to learning gains (Clinton, 2013). The direct physiological effect might be that this increases the flow of oxygen rich blood, water and glucose to the brain and the production of the mood-enhancing neurotransmitter dopamine, which in turn increases cognitive functioning (Galley, 2002; Hannaford, 1995, 2005). Brain scans show that children learn best when they are actually moving (e.g. jumping, swinging) and learning at the same time (Hannaford, 1995). The indirect effect might be that physical activity enhances on-task behaviour, compliance, attitudes towards learning, academic motivation, and attention, although these relationships seem to be small (Clinton, 2013). In addition, the quality of the task, teaching and school environment determine the amount of learning gains. However, it might be that children do not always experience a physical activity as engaging or intrinsically motivating. Children's expectancy-related beliefs (Eccles, Wigfield, & Schiefele, 1998) and subjective task values influence their motivation, including engagement, the amount of effort exerted, persistence and performance (Xiang, McBride, & Bruene, 2004). Therefore, a PLE should consist of characteristics that stimulate enjoyment, high expectancies of success, and an active role in children's learning. This will help children learn to value physically active tasks and foster authentic or intrinsic motivation. As a consequence, children will be more likely to engage in physically active tasks, which will have a positive effect on their learning (Ryan & Deci, 2000). High levels of engagement can affect the learner's attention, inquisitiveness and reflection (Price & Rogers, 2004). Optimal learning requires the process to be fun, which can increase children's engagement or authentic motivation (Hirsh-Pasek et al., 2009). As a consequence, deep learning can occur (Csikszentmihalyi, 1990; Ryan & Deci, 2000).

Effects on learning gains are dependent on multiple context factors: type of task (e.g. physically active or sedentary) and children and the quality of collaboration or interaction (e.g., Fuchs, Fuchs, Kazdan, & Allen, 1999; Gillies, 2004; Siegler & Alibali, 2005). One of the most consistent findings in the literature is the positive effect of high-quality verbal helping behaviour on learning gains (Gillies & Ashman, 1997; King, 2002; Topping, 2005; Webb & Farivar, 1994; Webb & Mastergeorge, 2003). Collaborative peer learning environments have potential for improving learning and increasing children's motivation, time on task and self-esteem (Webb & Mastergeorge, 2003), if collaboration consists of positive interactions that promote learning (Solomon, 1990). However, to ensure that collaborative learning is used effectively and to understand the effects of collaborative learning, interaction processes should be directly examined within collaborating dyads or groups (Solomon, 1990).

As known to us, no literature is available about the effect of physical activity on the quality of verbal interaction or collaboration. However, literature shows that the effect of the quality of verbal interaction on achievement might be mediated by motivational variables (Solomon, 1990). Since physically active tasks might have a positive effect on children's academic motivation and attitudes (Clinton, 2013), we expect a positive effect on the quality of verbal interaction during physical active tasks as compared to sedentary tasks. Therefore, in order to achieve optimal learning, it is important to develop a PLE that elicits high motivation and high-quality verbal helping behaviour between peers, which can potentially augment children's learning gains (e.g., Oortwijn, Boekaerts, Vedder, & Strijbos, 2008; Webb & Mastergeorge, 2003).

Research has already demonstrated that the computer can serve as a facilitator of social interaction (e.g., Mavrou, Lewis, & Douglas, 2010). Meta-analyses in secondary education have shown that students working with computers in small groups outperform students working with computers individually (Lou, 2004; Lou, Abrami, & d'Appolonia, 2001; Susman, 1998). However, learning benefits are promoted only when students are able to seek and give elaborated help effectively (Webb, Ing, Nemer, & Kersting, 2006).

In this study, we define high-quality verbal helping behaviour as utterances that are *beneficial* for learning, such as giving explanations, asking content related questions, and producing motivational utterances (Baker, D'Mello, Rodrigo, & Graesser, 2010; Oortwijn et al., 2008; Rojas-Drummond & Mercer, 2003). Low-quality verbal helping behaviour is defined as *unbeneficial* for learning, such as off-task utterances (Webb & Mastergeorge, 2003), and demotivating utterances (Baker et al., 2010). Furthermore, studies have shown that thinking aloud has a positive effect on student's performances, though not for the collaborating peer (Kotsopoulos, 2010; Siegler & Alibali, 2005).

To elicit high-quality verbal helping behaviour, it is important to develop tasks that scaffold children's knowledge and to select dyads working together with different levels of skills. Successful scaffolding can take place, which means that the high-ability peer (the scaffolder) scaffolds the lower ability peer (the scaffoldee) (Granott, 2005). Lower ability children can benefit from higher ability children, since the higher ability children can explain how to solve the fraction assignments. Higher ability children can also benefit from lower ability children, since the sharing knowledge with the lower ability peers have particular tutoring effects on the higher ability children (Bransford, Brown, & Cocking, 2000; O'Donnell, Hmelo-Silver, & Erkens, 2006; Vygotsky, 1978).

In this article, we will compare the effect of learning on a PLE to an equally sedentary computer task on children's fraction skills. The PLE condition contains all the elements of the sedentary computer condition plus the element of physical exercise. We expect that physical engagement creates an involvement and activeness in learning that a sedentary task does not.

In addition to focusing on the aspect of physical exercise, the following two important components of learning are taken into account in this study: 1) the frequency and quality of verbal helping behaviour between collaborating peers and 2) the various motivational aspects across time. We focus on the quality of verbal helping behaviour during the intervention, since utterances between a child and a peer mutually influence each other (Steenbeek & Van Geert, 2013). The mutual influences can give rise to high-quality verbal helping behaviour, which are associated with optimal functioning and learning, and over the long-term contribute to the forming of successful learning trajectories, or with ineffective learning, and over the long term contribute to the forming of unsuccessful learning trajectories (Nakamura & Csikszentmihalyi, 2002; Steenbeek & Van Geert, 2013). Therefore, studying patterns of subsequent verbal utterances between peers may generate useful insights into underlying mechanisms of the possible learning gains and gives information on successful or unsuccessful learning (e.g. Lavelli, Pantoja, Hsu, Messinger, & Fogel, 2004; Van Geert & Steenbeek, 2006).

To fully understand the underlying patterns of a learning process, insight is needed in the temporal unfolding of learning processes in *individual* children (Van Geert, 2009). Case study methodology is an appropriate way for studying individual trajectories (Flyvbjerg, 2006; Gerring, 2007; Yin, 2009). An individual case study can provide valuable information about possible underlying patterns of the learning process, even if they are not generalizable in the classical population-oriented sense of the word (Lee & Baskerville, 2003). A case study may contribute to our knowledge of the temporal interaction patterns in the form of which the learning takes place.

The first questions (1–3.1) in this study concern group analyses focusing on learning gains, and motivational and verbal helping behaviour in which we hope to see changes that might lead to the possible difference or correspondence in learning gains between the two groups. To answer the last question (3.2), we developed a case-study, which is a