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Implementing embodied learning in the classroom: effects on children's memory and language skills

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ABSTRACT

The relationship among bodily movements, cognitive abilities, and academic achievement in children is receiving considerable attention in the research community. The embodied learning approach is based on the idea of an inseparable link between body and mind in learning, aiming for teaching methods that promote children's active engagement in the classroom. This study implements embodied learning as a part of the classroom curriculum in a real classroom environment using motion-based games. A total of 52 elementary students engaged in embodied learning in-class activities for four months. The data-set included standardized pre-post testing for children's cognitive and academic performance, general learning analytics from games' usage, interviews, and observations from the teachers involved. Findings showed significant effects both on children's cognitive abilities (i.e., short-memory skills) and academic performance (i.e., expressive vocabulary). This article contributes to the educational technology community by providing an example of implementing embodied learning via use of motion-based technologies in a real classroom environment.

KEYWORDS

Embodied learning; embodied cognition (EC); motion-based technologies; movement; classroom

1. Introduction

Existing literature on embodied cognition (EC) and embodied learning shows promising effects of bodily engagement and movement on children's cognitive and academic outcomes. Embodied learning appears as a multimodal and playful process that requires the involvement of the human body in the cognitive process (Foglia & Wilson, 2013; Wilson, 2002). Researchers of embodied learning claim that in this type of learning the body, next to the mind, constitutes a significant factor in the overall learning process, while it facilitates the meaning of learning through bodily experiences and interactions with the environment (Foglia & Wilson, 2013; McClelland, Pitt, & Stein, 2015). Specifically, the idea of embodied learning places the student in the center of the learning process giving opportunities for physical interaction with the learning material (Ayala, Mendívil, Salinas, & Rios, 2013; Chandler & Tricot, 2015) and providing hands-on activities in classroom-based environments. From this perspective, different embodied technologies such as

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motion-based games (e.g., Kinect-based games, Wii, leap motion games, and exergames) are embodied learning technology which could be used in classroom settings for learning purposes. Researchers and practitioners argue that games such as motion-based games require the learner's interaction both with the technology and learning material, promoting the physical engagement of the learner in the learning process (Abrahamson, 2013).

Despite the potential use of such games in various educational settings, there is still limited empirical evidence on their impact and utility in real school settings (Malinverni et al., 2016). Little work has explicitly examined the integration of embodied learning technologies in authentic classroom environments. To this end, in this article, we present findings from an empirical investigation of using Kinect-based educational games, as one example of implementing embodied learning in a classroom context. The study relies on the collection and analysis of multiple forms of data using mixed methods to study the embodied learning activities and games. This article considers the potentials that these games provide for implementing embodied learning in authentic classroom settings, with an emphasis on the following:

(1) Effects on children's cognitive skills, particularly in short-term memory ability (Gsm), based on the classification of cognitive abilities of Cattell–Horn–Carroll integrated model (Cattell, 1971).
(2) Effects on children's academic performance, particularly in language skills (i.e., linguistic development and vocabulary acquisition), based on results of Word Finding Vocabulary Test (Renfrew, 1997).

The value of EC and embodied learning was taken as given in this work based on recent evidence in the literature. Our aim was to examine how such practice can become a reality in an authentic classroom environment with documented gains for students. The contribution of this research includes (1) deeper understanding of children's interaction with motion-based technology in an authentic classroom environment, (2) discussion of the potential impact of embodied technologies for specific learning purposes (in this case, memory and language skills), and (3) implications for future studies of embodied learning practice and technology.

This article covers previous research in the area, reports on the methods and procedures of a case study in elementary classrooms, and presents the results of this investigation. Finally, this article concludes with recommendations and implications for future work to promote and facilitate the implementation of embodied learning in authentic school settings.

2. Theoretical underpinnings

EC considers that the body in conjunction with the mind plays a significant role in the cognitive mechanism (Wilson, 2002) and that learning occurs when bodily movements, physical interaction, and sensorimotor abilities are linked with the learning content (Anderson, 2003). Embodied learning practice, as a part of EC theory, constitutes a contemporary pedagogical learning paradigm which emphasizes the use of the body in the educational practice (Anderson, 2003; Kosmas & Zaphiris, 2018; Wilson, 2002). According to embodied approach, both body and mind are able to produce the knowledge significantly by integrating the physical interaction in learning. In that way, as Atkinson (2010) states, "we experience, understand, and act on the world through our bodies."

Embodied education has been defined as the basic concept which includes embodied teaching and embodied learning (Lindgren & Johnson-Glenberg, 2013). The characteristics of embodied learning provide answers to questions related to the ways knowledge is constructed by students while they view everyone's body as a tool for knowledge construction (Kalantzis & Cope, 2004). In particular, the term "body" in embodied practice includes the physical body, the senses, the mind, and the brain, that is the whole of the student's personality. According to Lindgren and Johnson-Glenberg (2013), the primary principles of the implementation of embodied learning are the following: the sensorimotor activity, the relevance of gestures to the theme that is to be reproduced, and the emotional involvement of participant in the whole process.

In the last decades, embodied learning has influenced the educational technology field, especially the human–computer interaction (HCI) and the design of technological environments and objects for learning purposes. Indeed, the embodied approach has informed interaction and user-experience design. Recently, studies in education address the benefits of learning environments designed to incorporate embodied interaction (Dourish, 2001) in children's learning processes (Marshall, Price, & Rogers, 2003). While new technologies are constantly being designed, designers and learning scientists should take into account embodied learning characteristics and principles when designing mediated content (Trninic & Abrahamson, 2013).

2.1. Embodied learning and technology in educational contexts

In the recent years, the development of different emerging technologies that require the human's physical interactions and bodily movements has brought to the light the use of embodied learning in various learning contexts. One example is the use of motion-based games, such as Kinect-based games, to facilitate the delivery of learning in educational environments. Currently, these motion-based games are specifically associated with physical engagement and interaction with learning material and for this reason have received the researchers' attention investigating their impact in many different contexts both in general and special education (e.g., Abrahamson, 2013; Kosmas, Ioannou, & Retalis, 2017; Kourakli et al., 2016). Most commonly, this type of gaming is an emerging form of computer games which has not only physical gains but also social and mental health benefits (Mueller et al., 2011).

Previous research in the area has shown that this kind of interventions and interactions with the technology can improve cognitive functioning and academic performance for children (Kosmas et al., 2017). For example, in a recent study with 21 children in special education the engagement with Kinect-based educational games was beneficial not only for children's cognitive abilities but also for academic performance in math and language (Kourakli et al., 2016). Similarly, empirical findings of a study by Kosmas et al. (2017) showed that the use of Kinect-based educational games facilitated the advancement of 10 children's motoric performance in a special education context. Moreover, the study of Lieberman et al. (2011) discussed the potential health benefits of active-play video games in education.

Furthermore, studies in the field suggest that there is a strong correlation between physical movement and learning. That is, the human sensorimotor system, perceptual processing and muscle control, is capable to find solutions in the physical environment and understand specific learning tasks (McClelland et al., 2015). A great deal of studies has revealed that increased physical engagement during the learning process has the potential to positively affect cognitive ability, memory, and academic achievement (Chao, Huang, Fang, & Chen, 2013; Donnelly & Lambourne, 2011; Gao, Hannan, Xiang, Stodden, & Valdez, 2013). For example, a recent empirical study revealed significant gains in 31 children's short-memory ability after playing Kinect-based games in classroom (Kosmas, Ioannou, & Retalis, 2018). Similarly, in the study of Chao et al. (2013), the Kinect-based learning environment facilitated memory performance of 32 university students, compared to the control group. In the same line, the study of Donnelly and Lambourne (2011) showed that the physical engagement in lessons improved children's overall academic performance based on a standardized test of academic achievement. Also, findings from an empirical investigation in education showed significant progress in learning physics based on the pre- and posttest assessment (Enyedy, Danish, Delacruz, & Kumar, 2012).

Additionally, several studies have also shown the positive impact of embodied learning activities for language development and language comprehension. For instance, the study of Cassar and Jang (2010) showed that their game-based approach enhanced the improvement of literacy skills in elementary children with reading disabilities. Other related studies indicated that the use of embodied learning activities in the classroom facilitated the verbal information of students (Chang, Chien, Chiang, Lin, & Lai, 2013), influenced their understanding and recall of information (Donnelly & Lambourne, 2011), and improved their second-language comprehension (Lee, Huang, Wu, Huang, & Chen, 2012). Other studies in the embodied education field have shown that kinesthetic approaches and embodied activities can improve academic achievement in mathematics and science (Abrahamson, 2013; Chen & Fang, 2014; Kellman & Massey, 2013).

In the context of psychological impacts, these motion-based games may provide opportunities for social interaction that may influence self-efficacy, happiness, and motivation (Staiano & Calvert, 2011). The results of studies on social aspects on such games have shown that social interaction with other players/classmates is important motivation to participate in the learning procedure (Lieberman, 2006). The playful nature of these games attracts easily the children's attention increasing their self-efficacy (Staiano & Calvert, 2011) and their overall emotional state expressed as positive emotions during play (Kosmas et al., 2018).

Overall, motion/Kinect-based games, under the umbrella of embodied learning practice, can provide engaging activities for students in classrooms, enriching the conventional way of teaching and learning. However, there is a lack of sufficient research on the implementation of embodied learning as a part of a classroom curriculum in authentic classroom environments (Kosmas & Zaphiris, 2018).

3. Method

This study adopts mixed-methods approach in order to utilize the strengths of both quantitative and qualitative research data and findings (Creswell, Plano Clark, Gutmann, & Hanson, 2003). Specifically, the methodological approach is based on pre-post standardized testing, general learning analytics (e.g., completion time, speed, and number of errors), direct classroom observations, and semi-structured interviews with the participating teachers. In this way, a rich evidence of the children's experiences was gathered during the intervention period.

3.1. Sample

The study was conducted in four different elementary classrooms in two primary schools. A total of 52 second and third graders ($N = 52$) aged 7–10 participated in 13 intervention sessions of 45 min during a four-month period. Five teachers were involved in the research procedure. All sessions were conducted in a real classroom with the teacher of the class who was trained to implement the Kinect-based educational games with his/her students. Prior to the study, all the ethical approvals from Ministry of Education were obtained. Selection of children was by virtue of them being in the school class that was invited to participate. Both teachers and children participated in the study after providing proper consents.

3.2. Implementation of embodied learning in the classroom

Looking for a reliable technological tool for implementing embodied learning in the classroom, we decided to use the commercial suite of Kinect-based educational games, Kinems (www.kinems.com). We found this professional tool to be adequate and applicable in our setting, thus allowing us to examine aspects of embodied learning in real classrooms. Recent studies (Kosmas et al., 2017, 2018;

Kourakli et al., 2016) have shown that Kinems games can have a positive impact on children's academic, cognitive, and motor performance. This suite of games includes several games which combine motor, academic, and cognitive goals with high adaptability regarding the curriculum. All the available games require the body or hand movement to interact with the content via the Microsoft Kinect camera. For the purpose of this research, we used two particular Kinems games to investigate how the embodied approach facilitates the improvement of memory abilities and language skills of children. These were the "Unboxit" game for short-term memory skills (Gsm) and the "Lexis" game for vocabulary and linguistic development.

By conception and design, "Unboxit" (see Figure 1, left) aims to improve children's visual-spatial working memory and attention. The child must find the pairs of objects that are hidden in boxes, using his/her hand to select the appropriate objects. "Lexis" (see Figure 1, right) is a missing letter game designed to allow children to practice their skills on spelling of words of different lengths. At an egg-packing plant, the child has to create "egg-words," that is, words that consist of letters written on eggs; the child has to grab the correct missing egg-letter from a set of given egg-letters, place it carefully and appropriately in order to fill it in so that the "egg-word" is packed (www.kinems.com). The Kinems games allow the teacher to change the settings (e.g., duration, level of difficulty, number of words, and categories of words) and save the session to be ready for use into the classroom.

3.3. Procedures

The students attended the sessions in four different classrooms in two primary schools. The teacher of the classroom was trained on the use of these games in classroom for specific learning purposes (i.e., memory skills and language skills). All teachers prepared and organized class-wide intervention sessions, selecting the game (in this case "unboxit" and "lexis") and configuring the settings increasing the difficulty.

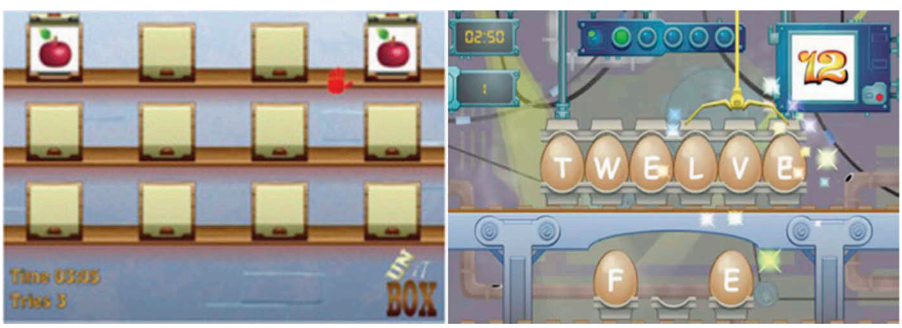

Figure 1. Screenshots of the Kinect-based games, "Unboxit" game (left) and "Lexis" game (right).

Then, children played the games, one by one, while other children did related worksheets and activities based on the lesson plan prepared by the teacher. In all cases, lesson plan, game setting, and procedures were the same. In practice, children were organized into a queue, and each child was waiting for his/her turn to play the game while working on another activity. It is important to note that the teaching material was designed in such a way that it serves the delivery of specific learning subject. The material was linked to the games played by the children each session in the classroom according to the curriculum of the class. Therefore, the game was fully integrated into the lesson in such a way that all children could benefit from it and enrich their knowledge in that particular subject. For example, in the chapter on nutrition, the teacher chose the related category in "unboxit" and "lexis" game to give children the opportunity to consolidate what they learned but also to enrich their knowledge on this specific subject. The study was implemented in a four-month period. During this period, participating children completed 13 game sessions in their own classroom with their teacher, once per week for 45 min (see Figure 2).

3.4. Data collection

3.4.1. Assessment measures

We used the "Psychometric criterion of cognitive adequacy for children" (Gonida & Iossifidou, 2008) as pre- and post-assessment test, to assess the children's short-term memory skills (Gsm), based on the classification of Cattell (1971). The test is an adapted version in Greek from the original "Kaufman Assessment Battery for Children, second edition" (KABC-II; Kaufman & Kaufman, 2004). The test measures the short-term mnemonic capacity of children with 27 exercises through the audiovisual and auditory-motor means.

Regarding the language skills (in this case expressive vocabulary), we used the standardized Greek version of Word Finding Vocabulary Test (Renfrew, 1997) normed on Greek preschool and school-age children (Vogindroukas, Protopapas, & Sideridis, 2009). This test is designed to measure the extent to

Figure 2. Episodes from embodied learning activities in the classroom.

which pictures of objects, arranged in order of difficulty, can be named correctly. The test includes 50 line-drawn pictures.

Both psychometric tests memory and language were given by the teachers, after relevant training and with the presence of specially trained staff. The pre-test was given at the beginning of the school year (particularly 2 weeks prior to the beginning of classroom interventions). The post-test was administered at the end of the 13-week intervention (in particular 1 month after the end of the last intervention). Children who did not complete all pre-post tests were not included in the sample.

4.3.2. General learning analytics

The learning analytics, automatically recorded in the suite of games, were used to examine in depth the progress of each child in the two games ("Unboxit" and "Lexis"). Analytics monitor the student growth across sessions based on learning skills, making vivid the details of interventions delivered and the moment-by-moment impact on student improvement. In our analysis, we focused on general analytic details such as the time spent on using the game, speed of completing the session, and number of errors in each session. The analysis of learning analytics concentrated on the (1) children's memory performance in the case of "Unboxit" and (2) children's performance and speed in the case of "Lexis."

4.3.3. Qualitative data-set

Additionally, teachers noted their comments upon each intervention session in the form of a reflective diary; these were saved in the Kinems platform. The comments focused on monitoring how the students perceived the game and how was the children's performance in relation to the specific goals. The analysis of teacher's comments concentrated on (1) learning benefits as perceived by the teachers and (2) overall students' appreciation of the method as perceived by the teachers.

Finally, at the end of the intervention, semi-structured interviews were conducted with all participating teachers to assess their overall experience and perceptions of embodied learning in this authentic classroom environment.

4. Results

In this section, we present findings regarding the children's interaction with the Kinect-based educational games focusing on their gains in language/vocabulary acquisition and memory.

4.1. Effects on children's short-term memory skills (Gsm)

To examine differences and gains in children's cognitive skills (i.e. Gsm short-term memory skills), according to the classification of cognitive abilities of Cattell–

Horn–Carroll integrated model (Cattell, 1971), based on children's scores in pre- to post testing, a paired sample *t*-test was conducted. As shown in Table 1, there was a statistically significant difference (p-value < .001), from pre- to post testing, with strong effect size (Cohen's $d = 1.01$).

Given the statistically significant differences in memory skills, the general learning analytics recorded per child in "Unboxit" were further considered to evaluate the improvement of children's memory performance during the educational intervention. It seems that as they progressed in the game, the participating children made less effort to find the right answer (in this case, to match the objects). The "unboxit" game requires that children are concentrated in order to remember all the visual objects and make progress. At the beginning, the children made a lot of wrong trials to remember where each object fit. Moving into play, the wrong attempts/trials were greatly reduced, which proves that the children begun to improve their memory ability and thus found the right answer easily. It is worth mentioning that although in each session the difficulty of the game increased, the children continued to improve their performance in the game. As shown in Figure 3, the majority of children ($N = 42$) performed very well in the memory game, with an average number of only two wrong trials, while the rest of the children had only one trial ($N = 7$) and three trials ($N = 3$) in order to complete the game successfully. The children's memory performance progressively improved, completing the game with fewer wrong trials compared to their first sessions.

The teachers' perceptions were fully consistent with these gains in memory skills. The teachers' interview, in accordance with teachers' observations notes, were coded and analyzed, as described in Saldaña (2009). The teachers discussed cognitive gains of children, specifically gains in short-term memory

Table 1. Effects on memory skills from pre- to post testing ($N = 52$).

	Pretest (mean)	Posttest (mean)	p-value	Cohen's d
Short-memory ability	15.04	19.00	.000[a]	1.01

[a]$p < .01$ indicates significance.

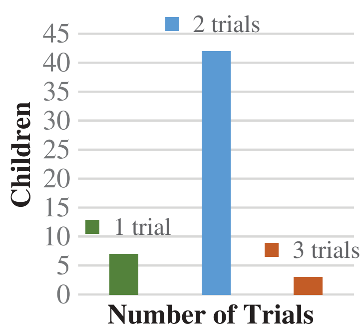

Figure 3. Children's average number of wrong trials in "Unboxit" in 13 sessions ($N = 52$).

skills during the intervention period. The teachers claimed that the "unboxit" game enhanced the memory abilities of the children, particularly their ability to recall words and to practice their memory skills.

In particular, the analysis of observation data concentrated on the (1) children's memory performance, (2) children's academic performance, and (3) overall appreciation of the method. The teachers' comments and reflections, upon each intervention session, showed that children had progressively improved their memory adequacy by playing the game. It is clear from the teachers that after the first two sessions, the children began to improve significantly their performance in the game. In fact, the teachers' comments for the first two sessions mention words such as "*embarrassment*," "*a lot of wrong trials*," "*lack of certainty for the right answer*," and "*difficulty to remember the object*."

Then, according to the teachers' comments, the children began to unconsciously apply some "*techniques*" so as not to forget the objects they had to match. The majority of the teachers' comments in the last three sessions mention "*absolute concentration*," "*focus on the game*," "*structure and organization of objects*," "*think aloud*," and "*use of body and especially of hands*." In other words, based on teachers' observations, children managed to improve their memory performance by finding alternative ways to remember the visual objects and complete the game.

Similarly, the semi-structured interviews complement the teacher's observations and they provide important insights regarding the improvement of students' memory performance during the intervention period.

As one of the teachers (T3) argued, "*This game was really good for second graders! It helps the children with practicing their mnemonic capacity and I really saw that children improved their memory across sessions, even those with very low memory skills*."

Along the same lines, a teacher (T1) explained,

"The highest improvement that I saw during this period was the improvement of children in performing the memory [unboxit] game. It was absolutely great to see that children managed to improve their memory skill and coordinate their thinking with action and movement. In the first 2–3 sessions children made a lot of effort to remember the objects correctly. As the game progressed over time, the children managed to complete the game with fewer wrong trials and this was great!"

4.2. Effects on children's language skills

In order to find out if there any improvement on children's language skills and particularly in expressive vocabulary, we examined the data from pre- to post testing. In this case, we report the results from a paired sample *t*-test (see Table 2) in which there was a statistically significant difference (p-value < .001), from pre- to post testing, with large effect size (Cohen's $d = 0.28$).

Table 2. Effects on expressive vocabulary from pre- to post testing ($N = 52$).

	Pretest (mean)	Posttest (mean)	*p*-value	Cohen's *d*
Expressive vocabulary	17.40	19.92	.000[a]	0.28

[a]$p < .01$ indicates significance.

Then, given the analytics recorded in "Lexis," we performed post hoc correlations between time on task (i.e., duration of playing the games) and child's academic performance in language assessment. In particular, a Pearson product–moment correlation was conducted to determine the relationship between test scores in language testing and time on task in "Lexis" game during the intervention (see Table 3). There was a positive strong correlation between scores on vocabulary test and time on task, which was statistically significant ($r = .675$, $N = 52$, $p < .001$).

Moreover, the teachers' perspective was fully consistent with these learning gains. All the teachers argued that this motion-based interaction with the technology facilitated the children's academic achievements in language and vocabulary acquisition. Indeed, they stated that the engagement in these gaming sessions enabled the children to increase their academic performance in language in the form of increased spelling skills, new vocabulary acquisition, and comprehension.

The teachers' observations in classroom during the game mention "*many new words only after three sessions of Lexis game*," "*the visual help of the word facilitates the acquisition of new words*," "*children find the appropriate word immediately*," and "*children spell the word correctly*."

Equally, the data from semi-structure interviews gave us related important insight regarding the children's experience with Lexis.

As one teacher (T1) explained,

"*In practicing with Lexis game, the children acquire new vocabulary and at the same time improve their language comprehension as they combine words with picture*."

In another teacher's own words (T2),

The Lexis game helped my students to understand the meaning of new words from different categories available in the game. All the children were playing Lexis very concentrated and thus almost all of my pupils completed the session successfully. At the end, I realized that my second graders enriched their vocabulary.

Table 3. Correlation between completion time in "Lexis" and students' test scores.

		Children's scores
Time on task in "Lexis"	Pearson correlation	.675[a]
	Significance (2-tailed)	.000
	N	52

[a]Correlation is significant at the .01 level (two-tailed).

5. Discussion

A few studies in the fields of educational technology have recently focused on exploring the impact of engaging the body in authentic classroom environments. Researchers in the field of EC and embodied learning emphasize on the significant role of the body in the learning process, as it enables cognitive and learning outcomes through embodied interaction with the learning content. The value of EC and embodied learning was taken as given in this work based on recent evidence in the literature. Our aim was to examine how such practice can become a reality in an authentic classroom environment with documented gains for students. Indeed, from our data analysis, it becomes evident that the embodied approach, as a learning method in a real classroom environment, supported and mediated by motion-based games (in this case, Kinect-based educational games), can have positive impacts on children's cognitive skills (i.e., short-term memory ability – Gsm) and academic performance (i.e., linguistic development and vocabulary acquisition).

Notably, this study concentrated not only on statistical analysis of data but even more on ideas and hints coming from the teachers' observations and interviews. By analyzing both quantitative and qualitative data, we found full consistency between them. The meaningful differences and significant effect sizes in measures of our two variables of interest – memory skills and language skills – agree with the teachers' perceptions, notes, and reflections regarding the overall children's experience. Moreover, our results agree and confirm findings from previous studies conducted in different educational settings (Bartoli, Corradi, Garzotto, & Valoriani, 2013; Kosmas et al., 2017, 2018; Kourakli et al., 2016).

Another interesting finding from this study was that we found progressive improvement of cognitive and academic skills across time (13 sessions in four months) and increasing difficulty of the game. The learning analytics reported earlier confirm that the participating children progressively improved their performance and managed to complete the games with 100% success during the intervention period. Nonetheless, by looking across all intervention sessions, it is clear that children were fully engaged in the learning process providing their maximum effort to complete the game successfully, acquiring academic skills.

We believe that these are promising insights which offer a deeper understanding of how we can engage the body in a classroom learning environment making use of motion-based games such as Kinect-based educational games. It is important to note that our investigation was conducted in an authentic classroom setting. Our results point out that this kind of embodied learning activities can be integrated effectively in the class-wide context with the use of technology offering meaningful, multimodal, and playful experiences to the children.

Although the research has reached its aims, there are some limitations to be addressed in future research. First, the study was conducted with a small sample of students in four primary classrooms. Thus, to generalize the results of the study, a larger representative sample should be drawn from the population in future studies. Also, future studies should aim for longer intervention periods in order to examine the longitudinal effects on children. Finally, as noted above, we chose to use a professional commercial suite of games which was linked to our variables of interest. Teachers and researchers can find other examples of implementing embodied learning in their classroom using other technologies and software tools. It is actually our next aim to use other noncommercial technologies in embodied learning environments. Finally, without a control group, it is not possible to detect causal effects in our findings. Yet, our aim in this work was not to document differences between experimental and control groups but to provide a deeper understanding of how the idea of embodied approach could be implemented in a real classroom environment with the use of technology.

Overall, the study contributes to the educational technology research community by providing a deeper understanding of how we use embodied learning technologies in real learning contexts. Indeed, this study suggests that Kinect-based games, as a motion-based technology, can be used as an example for implementing embodied learning activities in the classroom with potential to improve memory and language skills/abilities for children. This study also confirms the value of the enactment of embodied learning in the classroom environment for specific learning gains and purposes. Finally, the findings can inform and further encourage the design of embodied learning experiences using technology.

5.1. Conclusions and future work

The research on motion-based technologies in relation to embodied learning approach in real class-wide environments is limited. There is still lack of work on how we can implement embodied learning activities with the use of technology. More work is needed to get a deeper understanding of body's engagement in the learning process. More investigation is needed to examine what aspects of the motion-based games specifically could lead to academic or cognitive gains. Future studies could investigate the long-term impact of such embodied learning activities. It would be also significant for future studies to work on the development and design of technologies for implementing embodied learning in different educational settings and for specific learning goals.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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