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Towards the improvement of the cognitive, motoric and academic skills of students with special educational needs using Kinect learning games

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ABSTRACT

There is an ongoing interest in developing motion Kinect-based learning games that are in accordance with intervention protocols for helping children with special educational needs. These games, which offer natural user interaction modalities, seem to be very beneficial for this population because of the combination of physical activities with cognitive-training tasks. There is still an open research issue about how to integrate such games into schools and how to organize systematic evaluation studies for showing their added value. This paper presents the positive findings of a pilot research study in inclusive classroom settings that were carried out at two primary schools with 20 children who have special educational needs and who used the Kinems suite that contains movement-based educational games for such children. Analysis of data gathered via pre- and post-test questionnaires, interviews and an in-depth study of kinetic and learning analytics showed that these games have a positive impact on children's academic performance and improvement of their cognitive, motor and academic skills.

1. Motivation

Children with special educational needs (SEN) such as dyslexia, dyspraxia, dyscalculia and ADHD encounter difficulties in cognitive skills related to academic goals, particularly in relation to reading, writing and mathematics, and executive functions such as maintenance of information in working memory, concentration and visual perception, as well as gross/fine motor planning and execution [1–3]. These difficulties make it harder for them to improve skills and behavior than it is for most children and young people of the same age. Thus, children with SEN should follow specially designed educational programs (most of the time individual ones) in schools and childcare centers based on each child's unique strengths, weaknesses and needs [4,5].

In the literature, several publications report the positive impact of the use of computer game-based activities in order to accelerate learning processes and promote several cognitive abilities of children with SEN [6–10]. The recent trend is the use of games that are based on natural user interaction with the aid of sensors such as the Microsoft Kinect [11–15]. Using the Kinect sensor, children are engaged naturally, using hand and body gestures, in a playful learning experience where both body and brain stimulation are present and active [16,17].

Longitudinal studies have shown that the increased physical activity (coordinated hand movements, rolling, jumping, etc.) is related to improved academic performance [18–21], better scores on academic tests [22], improved concentration and stronger short-term and long-term memory [23,24], higher concentration [25–27] and reduction of conduct problems [28–30]. As an effect, various Kinect "touchless" movement-based games have appeared with the goal of having a positive impact on children with SEN especially with regards to motor skills [14,15] as well as executive functions like self-awareness, attention, concentration and social behavior [31–33]. Scientists such as Professor Hsu [34] points out that "with the assistance of body movements and

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gestures, meaning making seems to be grappled more easily by students who originally have learning difficulties''.

In parallel, various research studies have shown that both general purpose, commercial Kinect games such as the Kinect Xbox H*appy Action Theater* or *Kinect Sports*, and specially designed ones, can help children with SEN [35]. These studies have also highlighted that there is a need to develop games for children with SEN that should accord to intervention protocols. Consequently, various such games have recently been developed such as the *PicoAdventure* [36], *Somantics* [37], the *Little Magic Stories* [38], etc. In fact, R&D groups from Spain, Italy, Greece and the Netherlands collaborated for this purpose within the context of the EU-funded M4ALL project (http://www.m4all.eu). They ran case studies at child care centers and children's hospitals that revealed specially designed ''touchless'' movement-based games have extreme educational and therapeutic value for children with SEN. Along the same path, commercial games like the Kinems learning games had been developed to help 4–9 year old children with SEN reach their full potential. It should be noted that very few studies in authentic classroom settings have been performed. Most of the existing studies had occurred in child care centers and children's hospitals since they are more controlled environments.

Thus, the goal of the paper is to present the positive results from a new pilot research study where special educators from two primary schools incorporated the highly personalized Kinems learning games into the learning process with 20 young students. This study shows yet another trend that carefully designed Kinect games could create a stimulating and effective learning environment for the benefit of children with SEN.

The structure of the paper is the following: First, an overview of the existing Kinect-based learning games is given, which have not been presented as yet in previous literature reviews like the paper by Kandroudi and Bratitsis [39]. Then, a brief presentation of the Kinems learning gaming approach is given. The following sections outline the scope of the pilot research study, the evaluation tools used and the major findings.

2. Brief overview of Kinect learning games focusing on sen

The particular influence of body action on learning has long been cherished by philosophers like Heidegger [40] and developmental psychologists such as Piaget [41]. An important theoretical shift toward considering learning as being influenced by sensory and motor experiences as well as tightly coupled with sensorimotor experience is happening [42]. The intertwining of body movements, action, and thinking is the key consideration around ''embodied learning,'' the importance of which has been reconsidered by an increasing number of researchers from several research areas such as neuroscience (e.g. [43,44]), philosophy (e.g., [45]) and game-based pedagogy [46,47].

With the invention of the low-cost Microsoft Kinect sensor, which became available for widespread use in December 2010, several ''touchless'' embodied-learning applications have been created. Harvard professor Dr. Chris Dede [48] has stated that ''with its gesture interface, and by offering well-designed virtual contexts, Kinect has the potential to transform classrooms into engaging places for learning''. Although several games had been developed for the mainstream K-4 school subjects such as mathematics, the latest trend is to develop specialized Kinect games based on intervention protocols for helping children with SEN to improve their skills. The outcomes of the EU-funded M4ALL project were a typical example of this trend. Researchers from four countries pinpointed that Kinect games, in order to become effective for this population, should be designed according to some key guidelines [14,15,49]:

- Simplify level geometry, reducing the complexity of graphics and the related actions for navigating into the game.
- Avoid fast pace: game elements should move as slowly as needed to allow the player time to react.
- Simplify level flow, reducing the number of decisions players need to make.
- Avoid game mechanics that require multiple simultaneous actions.
- Balance for effort, compensating for the differences in players' skills.
- Do not always require precise timing: avoid the need to always make precise movements at a specific time.
- Reduce consequences of errors: the punishment for making errors in gameplay should be low.

Also, such Kinect games should have embedded in them the key feature of adaptability/customization. The need to customize the games' settings according to a unique individuals' profiles of strengths and weaknesses has been characterized as very essential [33]. Special educators/therapists need to be able to dynamically configure the game elements in order for the game to always fit an individual's needs. The adaptability could happen in three ways: (i) Adaptability related to *content* (C), thus allowing changes according to the cognitive or academic goals (e.g., difficulty in math operations according to numeric range or operation); (ii) adaptability related to *gestures* (G) that allow changes concerning motor goals, such as predefined body gestures and movements; (iii) adaptability related to *game elements* (E) like the number of lives or the timer, thereby allowing more emphasis to be placed on the acquisition of specific skills such as self-awareness, time management, etc.

Moreover, the inclusion of learning analytics for monitoring and assessment of players' behavior, gaming performance, and learning goals achievement has been characterized both by practitioners (special educators/occupational therapists) and researchers as very essential in learning games [50,51]. Thus, practitioners need both *learning* (L) and *kinetic* (K) analytics in order to have a good overview of a child's progress.

Table 1 contains a comparison of specially designed, movement-based, ''game-like'' educational applications for Kinect using five basic criteria: (i) Their applicability to special education; (ii) the educational goals such as social, cognitive, emotional, motor, sensory and academic goals; (iii) the three types of adaptability; (iv) the reporting mechanism with learning and kinetic analytics; and (v) the existence of findings of their impact as documented in published evaluation studies. Each game in Table 1 was analyzed for their goals, and their features were categorized according to the aforementioned criteria. This detailed analysis can lead to the valuation of the special features that would offer the maximum benefit to Kinect games designed for children with SEN.

The various Kinect games differ regarding their basic goals. Social and communication skills are fostered by *Pico's Adventures*, *Alien Health*, *Jumpido Games*, *Little Magic Stories* and *Kinetic Stories*. Academic and cognitive skills like math, spelling and pattern matching are promoted by *Games4Learning*, *Jumpido Games*, *Kaplan Early Learning* and *Xdigit*. Everyday living skills are fostered by *Alien Health* and *Pictogram Room*. Regarding the adaptability features, several games support customizations. Game duration, speed, size, position and number of moving targets or checkpoints can be adjusted in *Polimi Games* and *Dalyn's Dragon Island*. Also, *Polimi Games*, *Remaze* and *Games4Learning* allow the adjustment of the number of game lives. Difficulty in math operations or spelling exercises can be adjusted in *Games4Learning*. Finally, maze games like *Remaze* and *UniPacaGirl* allow the configuration of the complexity of a maze path, the number of obstacles, etc. It is evident that only a few of the Kinect games targeted to children with SEN combine all three types of adaptation: learning content,

Table 1
Review of existing Kinect-based, game-like educational applications.

	Special education	Goals	Reporting system Learning/Kinetic analytics	Adaptability (Content/Gestures/ Game Elements)	Existence of findings from evaluation studies
Dalyn's Dragon Island	×	Social, Cognitive, Emotional, Motor	L	G, E	–
Pico's Adventure	×	Motor, Social	L	E	Malinverni et al. [32,36]
Polimi Games	×	Motor, Cognitive	L, K	G, E	Bartoli et al. [35,14,15]
Remaze	×	Motor, Cognitive	L, K	C, G, E	–
UniPacaGirl	×	Motor	L, K	C, G, E	Altanis et al. [52]
Alien Health	–	Social, Academic (Nutrition)	–	–	Jonshon-Glemberm and Heckler [53]
Games4Learning	–	Academic (Math/Language)	–	C, G, E	–
Jumpido Games	–	Social, Academic (Math), Cognitive	–	–	–
Kaju (Nayi Disha)	–	Sensory, Emotional	–	–	–
Kaplan Early Learning Co	–	Academic (Language/Math), Cognitive	–	–	–
Kin-Educate Games	–	Academic (Language/Math/Verbal Skills)	–	–	–
Kinect Prototype Games	–	Social	–	–	–
Kinetic Stories	–	Social, Emotional, Cognitive	–	–	Huhtanen [54]
Little Magic Stories	×	Social, Emotional, Cognitive	L	–	–
Pictogram Room	×	Social, Cognitive	–	E	Herrera et al. [55]
Somantics	×	Sensory	–	E	Walker et al. [37]
The Three Little Pigs	–	Social, Emotional, Cognitive	–	–	Bickerstaff [38]
Xdigit Math	–	Academic (Math)	–	–	–

Table 2
Cognitive, motor and academic skill per game.

	Cognitive skills			Motor skills		Academic skills	
	Gsm	Gv	Gc	Gk	Gps	Math	Gs
Farm Walks		×		×	×		
Space Motif		×		×	×		
UnBoxIt	×	×	×	×			×
Melody Tree	×	×	×	×			×
Mathloons		×		×		×	×

gestures and game elements. This fact gave the Kinems team the motivation to focus on such a combination in all of the games that need to have very clear academic and motor development goals that accord to good intervention practices.

Very few games have reporting capabilities to monitor a child's performance. Game score is recorded by *Polimi Games* and *Remaze*. Game duration is recorded in *Polimi Games*, *Dalyn's Dragon Island* and *Remaze*. Other reporting information include number of movements in *Remaze* and player's path in *UniPacaGirl*. Each of these games include game configuration information in the reports. The main difference between the most of Kinect games for SEN and Kinems games is that all the previous games did not provide comprehensive information about the progress of each student in both learning (learning analytics) and motor level (kinetic analytics). On the other hand, Kinems emphasizes an in-depth reporting system that gives analytical information (both learning and kinetic analytics) about a student's progress. Finally, not all the aforementioned games in Table 1 have been systematically evaluated via pilot studies. Special educators and occupational therapists always ask for testimonials of effective use. Luckily, most of the Kinect games that are addressed to children with SEN have been evaluated in authentic environments, mostly in childcare centers or children's hospitals.

3. The Kinems movement-based education games

Kinems makes a suite of movement-based educational games that helps teachers and therapists to fully engage children with SEN in activities that aim to improve their cognitive, motoric and academic skills. Children play the games in individual interactive sessions using hand gestures and natural body movements under the supervision of a special educator/therapist who mainly acts as a facilitator and observer. Kinems games are highly configurable, so that the special educator/therapist can modify dynamically and in real-time the game settings (e.g. timer, difficulty level etc.) according to each child's performance and individual needs. Kinems' additional unique feature is that data from children's interactions are safely stored on a proprietary cloud-based platform, which enables teachers to monitor each child's progress and produce valuable reports with learning and kinetic analytics for all stakeholders, including the parents.

Having acknowledged the start-of-art review on Kinect educational games and related research studies, Kinems has been trying to create games that combine motor, academic and cognitive goals with high adaptability according to the children's needs along with a detailed progress-reporting mechanism. The games were developed by creating a unique blend of K-2 teaching methods provided by special educators in various subjects (e.g., math and literacy) with intervention protocols provided by occupational therapists. For example, *Mathloons* is a game for learning and practicing math calculations up to 100 that combines motor skills in the sense of midline crossing with academic goals such as practicing mental math calculations in four operations and cognitive skills (e.g., hand–eye coordination and time management). Similarly, the *Space Motif* game aims at promoting the acquisition of skills used to recognize repetition of patterns of objects, and at the same time it aims at the goal of refined gross motor hand movements along various paths in addition to goals related to cognitive skills such as concentration and attention.

Particularly, the Kinems suite, which currently consists of 11 games, is helpful for K-3 children with SEN who especially encounter problems in academic, cognitive motor and sensory skills According to the Cattell–Horn–Carroll Integrated Model [56], skills can be classified in the following broad ability domains.

Cognitive skills

- Gsm—short-term memory: The ability of encoding, retaining and immediately using information from memory.
- Gv—visual processing: The ability of creation, storage, retrieval and conversion of optical images and sensations. Requires the perception or converting of optical shapes, images or works by maintaining one's spatial orientation in relation to the objects that can be changed or moved in space.
- Gc—crystallized knowledge: The depth and extent of prior knowledge and skills that a person acquires due to cultural influences.

Fig. 1a. Screen shot of Kinems' *Farm Walks*.

Fig. 1b. Screen shot of Kinems' *Space Motif*.

Motor and sensory skills

- Gk—kinesthetic skills: Skills that depend on senses to detect position, weight, muscle movement etc., and that are involved in the process of control and coordination of body movements, such as walking, speech and gestures.
- Gps—psycho-motor speed: The speed and flexibility with which body movements are performed.

Academic skills

- Mathematics—operations and computation: The academic performance in math is associated with the success rate at a game.
- Gs—speed of cognitive processing: The ability to perform simple cognitive exercises quickly and flexibly is related to the completion time in the games.

In the study presented in this paper, five games had been used. Table 2 gives an overview of the skills that each one of the five Kinems games aims to promote. More details about the games can be found at Kinems.com.

The following five Kinems games were studied:

- ***Farm Walks*** (see Fig. 1a): In this game, a child uses the hand delay gesture to pick the farmer in order to drive him along paths of different shapes. The farmer can make stops to pick up carrots. He should also avoid snakes that appear as obstacles. This game was mainly based on occupational protocols for the development of basic gross motor-planning and co-ordination skills (back, front, top, bottom, right, left, etc.). Particularly, the child who plays *Farm Walks* can practice his or her midline-crossing skills in a playful way and/or work his or her specific horizontal or vertical gross motor skills, which are very essential for 3–6-year-old children [57]. Moreover, by activating or deactivating the obstacles and stop signs, the practitioner can make the game more or less challenging for the child [58].
- ***Space Motif*** (see Fig. 1b): In this game, a child needs to recognize and repeat a given pattern of planets and space objects by driving them from the outer-space into a tube at the right order. The game can become challenging for hand movement when players are called to select (with the hand delay gesture) and move objects while avoiding collisions with other planets, space objects and a black hole that appears in their galactic path. The level of complexity of the patterns can be adapted to the intellectual level of the child (e.g., patterns with 2–4 objects categorized by shape and/or color). The design of this game was based on special therapists' educational protocols for repetition of patterns as well as occupational therapists' protocols for developing spatiotemporal and perceptual gross motor skills [59].

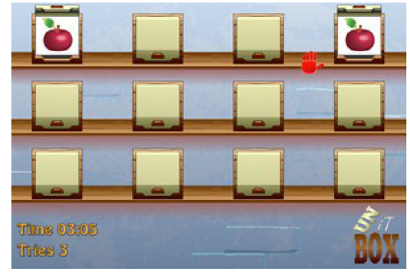


Fig. 1c. Screen shot of Kinems' *UnBoxIt*.

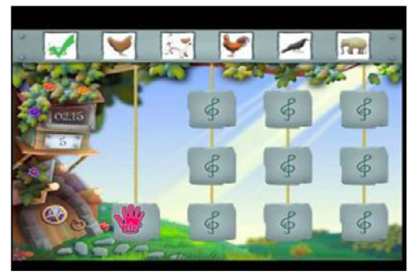


Fig. 1d. Screen shot of Kinems' *Melody Tree*.

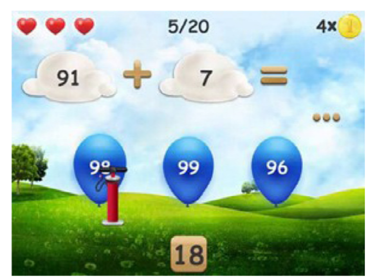


Fig. 1e. Screen shot of Kinems' *Mathloons*.

- ***UnBoxIt*** (see Fig. 1c): This game is based on the concept of the typical flash cards for improving visual memory. The player is called to find the pairs of objects that are hidden in the boxes by opening them with the hand delay gesture one after the other. The children's memory training, linguistic development goals, and hand stability in different points of a virtual grid can be promoted at the same time. Moreover, visual and/or audio distractors could appear in order to challenge players, thus enhancing their visuo-spatial working memory, attention, concentration and processing speed in a unique way [60,59]. As an effect, this game combines both visual memory, early literacy skills, and linguistic development because the practitioner can choose the appropriate library of objects that will be placed in the closed boxes.
- ***Melody Tree*** (see Fig. 1d): This game is like *UnBoxIt* but is focused on sounds, thus aiming at the improvement of auditory memory. The sounds are categorized into different conceptual categories (e.g., animals, weather, instruments, melodies, sound motifs, etc.) that can be easily chosen by the practitioner. Moreover, visual and/or audio distractors could be added into the game so that the children enrich their attentional capacity and processing speed [60].

- ***Mathloons*** (see Fig. 1e): This is a game for practicing mental math calculations up to 100. The child is asked to select a balloon with the correct answer for a given question by using the hand time delay gesture. Appropriate feedback is given for the correct or wrong answers thus resulting in a child's mastery of math operations. The game can be adapted to the appropriate level of difficulty that a child can cope with cognitively, as the game was designed following typical strategies that children with dyscalculia use in order to learn how to solve mental calculations. Such indicative strategies are "the make-a-ten strategy ($7 + 3 = 10$)" or "the doubles strategy for addition ($4 + 4 = 8$)" [61]. At the same time, the placement of the three balloons with the answers are useful for the execution of middle line-crossing exercises [57,59].

As can be easily understood, the Kinems learning games contain all three adaptability features. For example, with regard to the adaptability of the learning content, in the game *Mathloons* the practitioner can change various settings related to cognitive goals, such as practicing addition instead of subtraction or the numeric range (e.g., 1–20 or 20–100). With regard to the adaptability of gestures, the practitioner can change the time delay such that each student should keep his or her hand stable on an item to selected it or determine which is the hand that the student will use for the current session. Also, the practitioner can intervene by adjusting various game elements associated with (i) the profile of a child (e.g., deactivating game lives for children with autism who cannot manage failure), and (ii) the promotion of executive functions such as time management. The main goal of adaptability options is to make the learning process personalized, thus improving its effectiveness.

Finally, Kinems' gaming suite offers an in-depth learning and kinetic analytics mechanism that reports the performance of each student. The success rate, the detailed presentation of the correct and wrong answers, the number of tries, the completion time per game and per session give valuable information about each child's interaction and learning progress. At the same time, detailed reports with graphs showing hand stability and movement provide important information regarding the motor development of each child per session.

4. Research study

4.1. Participants

Twenty children aged 6–11 years (mean $M = 8.91$ and standard deviation std $= 1.72$) from two elementary schools (11 and 9 students from each school respectively) participated to this study. School directors received the parents' written permission for children participating in this study. The majority of the children were boys (i.e. 17 boys [85%]) and there were 3 girls (15%). According to the formal diagnoses or assessments from diagnostic assessment and support centers, these children had SEN and comorbid learning disorders such as dyscalculia, difficulty in regulating emotions, ADHD/ADD and dyspraxia. The two special educators at the schools who had been responsible for applying the Kinems-based intervention sessions, attended a training session about the Kinems platform and the evaluation tools Children did not have experience with Kinect games and got familiar to the natural physical interaction just after playing few games.

4.2. Evaluation hypotheses

The present study aimed to examine:

- If, and to what extent, the Kinems-based educational intervention is considered effective by contributing to the improvement of the children's cognitive skills (number recall, word recall—Gsm [short term memory], conceptual thinking—Gv [visual processing], expressive vocabulary—Gc [crystallized ability]) (*Hypothesis* 1—*H*1).
- If, and to what extent, the Kinems-based educational intervention is considered effective by contributing to the improvement of the children's motor skills (Gk [kinesthetic skills], Gps [psychomotor speed]) (*Hypothesis* 2—*H*2).
- If, and to what extent, the Kinems-based educational intervention is considered effective by contributing to the improvement of the children's academic skills (performance in mathematical operations and Gs [speed of cognitive processing]) (*Hypothesis* 3—*H*3).
- If, and to what extent, the Kinems-based educational intervention is considered acceptable in a real school environment (*Hypothesis* 4—*H*4).

4.3. Evaluation tools

Firstly, in order to examine if, and to what extent, the Kinems intervention has an influence on the improvement of the participants' cognitive skills (H1), the pre- and post-assessment tests used were the "Psychometric criterion of cognitive adequacy for children and adolescents," [62] which is the adapted version in Greek of the "Kaufman Assessment Battery for Children, second edition" (KABC-II) [63]. This battery contains the following tests:

Recall number: This test consists of 16 questions that measure sequential processing and short-term memory through auditory–linguistic means. A child is asked to repeat a series of numbers in the same order as presented by the examiner. The test assesses the short-term mnemonic capacity, since the child has to repeat all the numbers in the same order, without additions or omissions [62].

Recall word: This test consists of 31 questions that measure sequential processing and short-term memory through the audio–visual and auditory-motor means. The child is asked to repeat a series of words in the same order as presented by the examiner. The test assesses short-term mnemonic capacity, since the child has to repeat all the words in the same order, without additions or omissions [62]. In particular, the "Recall number" and "Recall word" tests focus on the assessment of short-term memory (Gsm) like in the corresponding version of Kaufman and Kaufman [63] (Flanagan et al. [64]).

Conceptual thinking: The test consists of 20 questions of nonverbal assessment that assess "the ability of designing and inferring conclusions (reasoning) through recognition of a pattern which follows a standard". The child has to examine hypotheses in relation to a pattern, which obeys a standard presentation (it is similar to the Raven's test). The child sees 5–6 images that follow a specific pattern. The child is asked to choose a missing one among 4–6 options and complete the appropriate set of images according to the pattern. These questions are of increasing difficulty, and the difficulty associated with the pattern, i.e. its layout, the orientation, the disappearance and reappearance of data etc. This test was utilized to assess the visual processing (Gv), like in corresponding version of Kaufman and Kaufman [63] (Flanagan et al. [64]).

Expressive vocabulary: The test assesses the knowledge of elements that the child acquires through interaction with the social environment (crystallized ability). It includes 40 images that the child has to name. The images are of everyday objects (ball, book, pencil, etc.), animals, professions, elements of culture and sciences. Only the answers that name exactly the image (and not the periphrastic descriptions) will be received as correct. This test assesses crystallized knowledge (Gc), like in corresponding version of Kaufman and Kaufman [63] (Flanagan et al. [64]).

Furthermore, in order to measure the improvements of children's motor skills, especially via the *Farm Walks* and *Space Motif* games – and in particular the kinesthetic abilities (Gk) and the psychomotor speed (Gps) referenced in H2 – an analysis of the kinetic analytics data, which had been automatically captured and stored in a monitoring cloud platform during the game-play interaction, was performed.

Also, the acquisition of special learning goals with regards to mathematical operations – the academic skills referred to in H3 – was assessed via (i) pre- and post-mental math calculations tests that follow the school's curriculum goals and (ii) an in-depth study of learning analytics reports of the children's interaction during the *Mathloons* game focusing on examining the cognitive processing speed (Gs).

Finally, in order to examine if, and to what extent, the Kinems-based intervention could be smoothly integrated within a school environment (H4), the comments and the responses given by children, teachers and parents were analyzed. Both quantitative and qualitative analysis of data were performed using a mixed-approach evaluation method for triangulating the data and reaching valid findings.

4.4. Research process

The intervention lasted eight weeks (May and June) in 2014 with the approval of the Greek Ministry of Education. The first week was spent training teachers about the Kinems approach and the evaluation toolkits, the collection of data from pre-tests, and children's familiarization with the games. Children understood the motion-based interaction quickly and without difficulty. The last week was spent gathering data via post-tests and interviewing parents and teachers to collect the children's experiences.

The interventions based on the Kinems approach were implemented as part of individual educational program at both schools. Special educators chose the games and their settings according to the intended learning goals per child per intervention session. In fact, they were able to make changes on the fly during a session. If a child's performance was good enough, they either changed the game level accordingly or launched a new game for meeting a new goal. In case a child was not in a good mood or found difficulties, educators changed the game settings so that each time the games could fit the needs of the child.

Table 3 shows an overview of the training sessions per child (i.e., which children played which game and for how long). Analytically, as indicated in the Table 3, some children, such as Child1, Child2, Child3, Child5 and Child6, were involved in the educational intervention only for a few sessions. Despite the intense efforts of their teachers, this mainly happened because of the high level of clumsiness of these children, an impairment of motor-functioning skills that often appears at children with below-the-expected level of intelligence [65]. For all the other children, the organization and design of sessions were based on the profile of each child, which derived from both their diagnosis and their performance in the pre-test evaluation.

Child4 is an indicative example for better understanding the design of sessions. This child faces serious motor-planning disorders, intense deficits in vocabulary expression and weakness in solving mathematical operations. Based on the individual learning goals and the profile of Child4, a personalized educational intervention was designed. Aiming to improve the child's motor skills, the teacher chose the game *Farm Walks* (at the easiest level). *Space Motif* requires "more accurate gross motor movement" than *Farm Walks*, which this child was unable to make. Midline-crossing skill along simpler paths, which the *Farm Walks* game promotes, is an ability that this child needs to improve. In addition, the weak expressive vocabulary of the child (pre-test performance at "Expressive Vocabulary" was 13/40) had to be improved with the aid of the *UnBoxIt* and *Melody Tree* games (in which the child is asked to recognize images of various vocabulary categories, such as toys, food, etc.). After 8 games of *UnBoxIt* and *Melody Tree*, the post-test analysis showed that the performance was noted clearly higher ("Expressive Vocabulary" = 18/40). Finally, because of the child's deficits in solving mathematical operations (pre-test performance at "Mental Math Calculations" was 5/15, which was quite low compared to the mean performance of 11.68), the special educator chose to offer more learning activities via the *Mathloons* games.

Similar sessions were also organized for the other children who participated in the educational intervention. The order of games and the duration of each training session was affected by the individual needs of each child, such their mood, their concentration and their daily program. The performance of these children is presented in detail with the diagrams that follow.

5. Findings

5.1. Cognitive skills improvement

5.1.1. Descriptive statistics

The first hypothesis (H1) concerned the improvement of the participants' cognitive skills. Table 4 shows the mean improvement in children's cognitive performances at the aforementioned pre- and post- assessment battery and the percentage of the mean improvement for measuring cognitive skills such as "Number recall-Gsm-Short term memory," "Word recall-Gsm-Short term memory," "Conceptual thinking-Gv Visual processing," and "Expressive Vocabulary-Gc-Crystallized knowledge" with the use of paired sample t-test (data follow a normal distribution). The above findings show a general tendency of improvement but cannot lead to firm conclusions due to the small number of participants and the short duration of the intervention. However, Cohen d analysis showed a large effect size for "Number Recall" (1.13), "Word Recall" (2.45) and "Conceptual Thinking" (1.21) and a medium effect size for "Expressive Vocabulary" (0,70). Despite the short-duration of the Kinems-based intervention, these findings are highly encouraging.

5.1.2. Case studies' findings

An in-depth-analysis of each child's performance at the various games using the 79 learning analytic reports of *UnBoxIt* and *Melody Tree* was carried out. Particularly, it was investigated if children were improving:

- Their short-term visual memory in the game *UnBoxIt*.
- Their short-term auditory memory in the game *Melody Tree*.

Figs. 2 and 3 present the number of tries at match making that children made in order to succeed in the visual and auditory memory games. Children who managed to decrease the tries over time, thus completing the game more quickly despite the increase in the difficulty level (e.g., a game with objects/sounds that had small differences), are presented in the Figs. 2 and 3. Fluctuations in the performance of few children were also apparent. For example, the performances of Child10 in session 3 and Child7 in session 2 were decreased in visual memory due to carelessness and lack of concentration, as the special educator stated in her notes. Similarly, the performances of all children at the *Melody Tree* game increased. Of course, Child18, who is within the autism spectrum, had poorer performance in auditory memory during session 2, as he faced difficulty in identifying sounds related to public transportation that were troubling him, according to the educator's notes. At the same time, children who indicated a constant improvement through

Table 3
Training sessions per child.

Child	Gender	Age	Diagnosis	*Farm Walks*	*Space Motif*	*UnBoxIt*	*Melody Tree*	*Mathloons*	No sessions/ Total duration
Ch1	Boy	10.5	Mild autistic spectrum disorders & low level intelligence	2	0	0	2	2	2/24 m & 32 s
Ch2	Boy	11.7	Mild autistic spectrum disorders & low level intelligence	1	0	1	0	1	1/13 m & 50 s
Ch3	Boy	8.7	Mild autistic spectrum disorders & low level intelligence	2	2	1	1	1	2/25 m & 54 s
Ch4	Girl	11	Motor impairment	4	1	4	3	6	5/1 h, 5 m & 22 s
Ch5	Girl	8.8	Low level intelligence	2	1	0	1	1	3/37 min & 26 s
Ch6	Boy	6.8	Low level intelligence	2	1	1	1	1	2/26 m & 26 s
Ch7	Girl	6.9	Mild autistic spectrum disorders	5	0	4	3	5	6/1 h, 15 m & 8 s
Ch8	Boy	8.6	Mild autistic spectrum disorders	4	2	2	3	3	5/1 h, 13 m & 12 s
Ch9	Boy	9.7	Borderline intellectual functioning	0	1	2	1	3	2/25 m & 5 s
Ch10	Boy	7.3	Dyspraxia	3	3	3	3	4	7/1 h, 20 m & 54 s
Ch11	Boy	7.11	ADHD	4	2	3	3	4	6/1 h, 12 m & 42 s
Ch12	Boy	8.9	Dyscalculia	3	3	2	2	6	5/1 h, 5 m & 17 s
Ch13	Boy	7.6	Dyspraxia	4	4	1	1	2	4/51 m & 32 s
Ch14	Girl	6.9	Dyscalculia	2	2	2	2	5	5/58 m & 2 s
Ch15	Boy	9.11	Dyscalculia	3	3	3	3	6	5/1 h & 9 m
Ch16	Boy	8.11	Dyspraxia	5	3	1	3	4	7/1 h, 17 m & 21 s
Ch17	Boy	11.8	Borderline intellectual functioning	1	2	2	2	3	3/32 m & 15 s
Ch18	Boy	9.4	Mild autistic spectrum disorders	3	3	3	5	6	6/1 h, 10 m & 9 s
Ch19	Boy	7.1	Dyscalculia	3	2	1	2	4	4/54 m & 43 s
Ch20	Boy	7.3	Dyscalculia	3	2	1	1	4	4/49 m & 36 s

Table 4
Mean performance in pre-test and post-test.

Cognitive skills	Mean performance pre-test	Mean performance post-test	Maximum performance	Percentage of the mean performance	St.D	*p*	Cohen d
Number recall (Gsm—Short term memory)	6.75	8.20	16	9.06%	0.07	0.000^{**}	1.13
Word recall (Gsm—Short term memory)	16.44	19.44	31	9.67%	0.03	0.000^{**}	2.45
Conceptual thinking (Gv—Visual Processing)	8.95	11.50	20	12.75%	0.10	0.000^{**}	1.21
Expressive vocabulary (Gc—Crystallized knowledge)	20.25	21.80	40	4.00%	0.05	0.006^{**}	0.70

** $P < 0.01$ = Indicates significance.

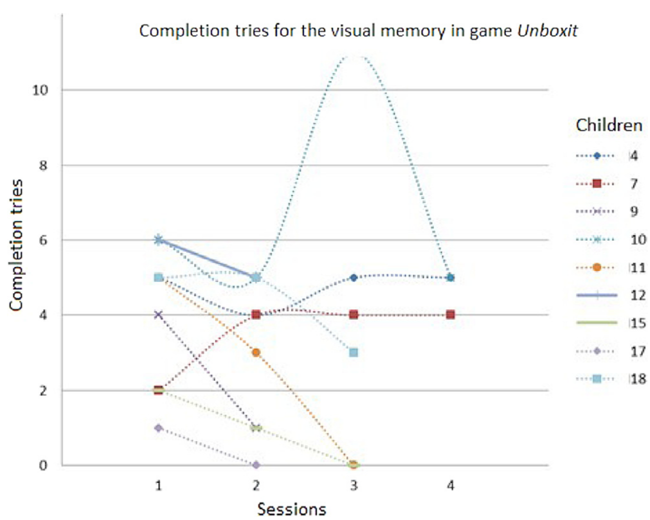


Fig. 2. Completion tries for the *UnBoxIt* game.

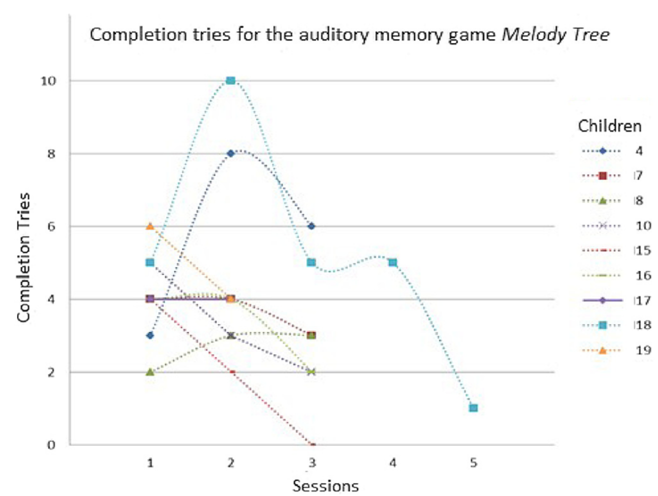


Fig. 3. Completion tries for the *Melody Tree* game.

the games also presented greater improvement between pre- and post-test evaluations. Indicatively, Child11, who continuously improved through *UnBoxIt* game, had a higher performance in post-test of memory of numbers of 8 points (1 point higher compared to the pre-memory test).

5.2. Motor skills improvement—case studies' findings

The second hypothesis (H2) concerned the improvement of the children's motor skills. In order to measure if, and to what extent, the education intervention affected the acquisition of motor skills and particularly kinesthetic abilities (Gk) and psychomotor speed (Gps), an analysis was made of 93 kinesthetic analytics reports of *Farm Walks* and *Space Motif* games, which give special emphasis on such skills.

Regarding the *Farm Walks* game, it was investigated:

- If children improved their kinesthetic abilities (Gk) during the intervention, that is, the "abilities to detect and process meaningful information in proprioceptive sensations (awareness of hand position and movement)" [56].
- If children were improving their psychomotor speed (Gps), that is, "speed and fluidity with which physical body movements can be made" [56].

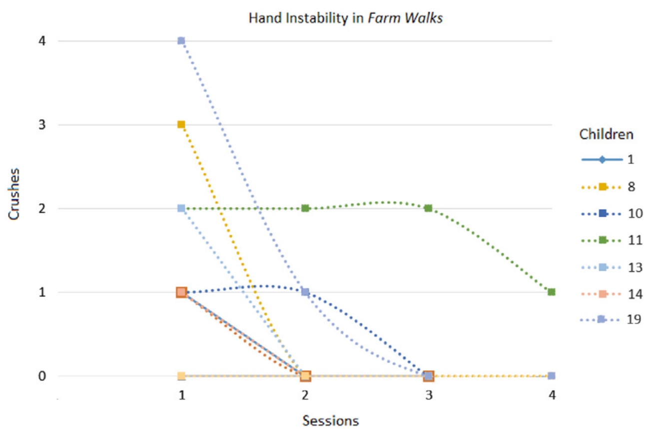


Fig. 4. Hand instability in *Farm Walks* per child during the intervention.

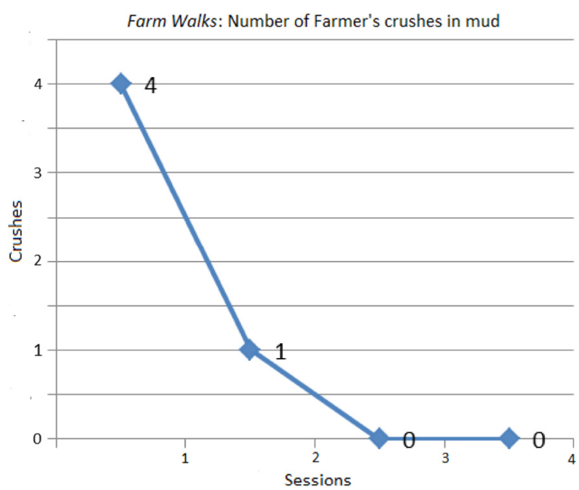


Fig. 5. Measuring the kinesthetic abilities of Child13 at the *Farm Walks* game during 4 sessions.

Children who managed to decrease their hand instability over the sessions (i.e., had better performance in eye–hand coordination over time) are represented in Fig. 4.

When looking into the individual data of each child, the improvement is very vivid. For Child13, there was a diagnosis for "problems in his motor coordination at all stages of ideation, planning and execution of movement". For this reason the educational intervention was mainly based on games like *Farm Walks* in order to improve gross motor skills, planning and middle line-crossing motor skills. Fig. 5 shows the improvement of the kinesthetic skills of Child13, who succeeded in improving visual-motor coordination and the stability of the hand when playing the *Farm Walks* game at 4 different sessions. This was measured by the number of times that the farmer fell at the edges of the path (number of crushes). At the first session the child presented significant kinetic instability, which resulted in four crushes. During the following sessions, there was improvement of the child's hand movement, which resulted in perfect movement (zero crushes) at the last two sessions.

In order to better understand the improvement of Child13's hand instability at the *Farm Walks* game, the diagrams of the hand movement was examined. Figs. 6a–6d visually show the progressive improvement of the child's hand movement along a horizontal path during the four aforementioned different sessions.

Not only did Child13 manage to perform more accurate hand movements but he ended the game in less and less time over the four sessions (see Fig. 7). Thus, it is evident there was clear improvement of the child's psychomotor speed (Gps).

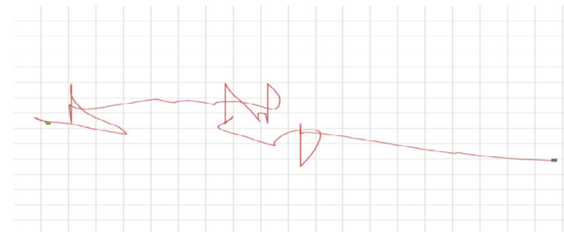


Fig. 6a. Child13's horizontal movement at session 1 of the *Farm Walks* game.

Fig. 6b. Child13's horizontal movement at session 2 of the *Farm Walks* game.

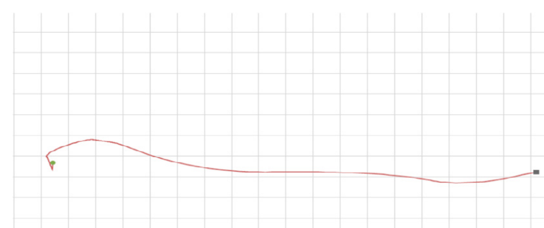


Fig. 6c. Child13's horizontal movement at session 3 of the *Farm Walks* game.

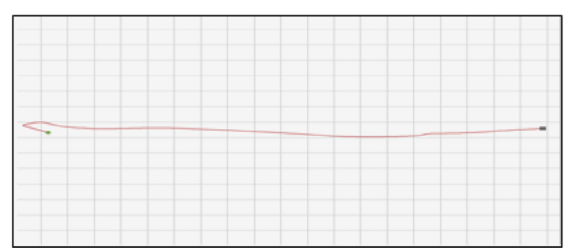


Fig. 6d. Child13's horizontal movement at session 4 of the *Farm Walks* game.

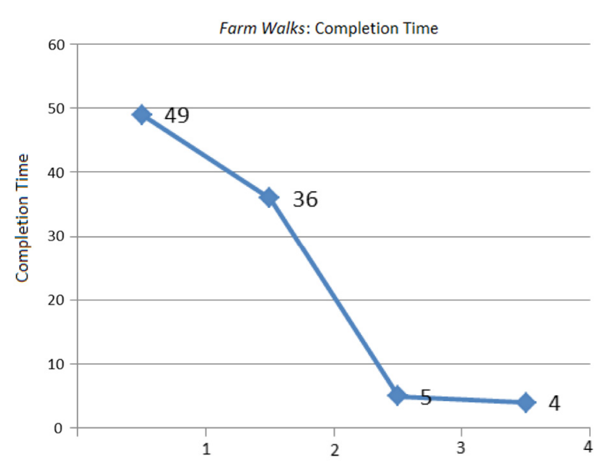


Fig. 7. *Farm Walks* game completion time of Child13 during four sessions.

Similarly, Fig. 8 shows the performance per child in the *Space Motif* game. The diagram demonstrates that the children's

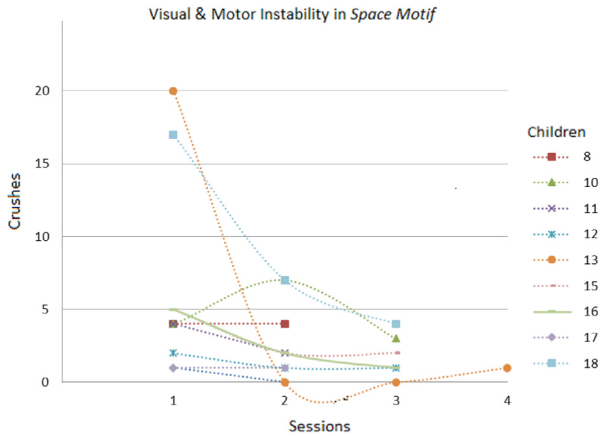


Fig. 8. Hand instability in *Space Motif* per child during the intervention.

performances continuously improved since the number of crushes, which is related to hand instability, was reduced over the sessions. Fluctuations in the performances of some children are also apparent. For example, Child10 in session 2 presented a lower level of motor control. The reason was that the game's difficulty level (i.e., settings configuration) was not appropriate, as the educator stated in her notes. As a result, the educator changed the settings and asked the child to play at an easier level. A note for Child10 refers to the diagnosis that "Child10 faces serious difficulties in motor coordination". Also, his performance at the "Conceptual Thinking & Visual Perception Skills" pre-test was 2/10 (quite low compared to the mean performance that was 8.95/10). Both the child's diagnosis and poor performances at the test of Conceptual Thinking & Visual Perception highlighted the need to improve visual perception and develop motor skills through sessions (mainly through the game *Space Motif*).

5.3. Improvement of academic skills

5.3.1. Descriptive statistics

The third hypothesis (H3) concerned the improvement of the children's academic skills in mathematics. Table 5 shows the mean improvement in children's math performances at the pre- and post-tests related to "Mathematical operations" and the percentage of the mean improvement for measuring the achievement in completion of mathematical operations (the data follow normal distribution). The Cohen d analysis (0.61) shows a medium effect size for mental math calculations that is a positive fact taken into consideration of the short duration of the intervention.

5.3.2. Case studies' findings

Also, an in-depth-examination of each child's performance during the *Mathloons* game play was made using the 72 learning analytic reports. The analysis of children's achievements was examined by taking into consideration the children's scores in relation to the game's difficulty level. The data related to children who had played the game only once was excluded.

Fig. 9 depicts the overall improvement of the learning performance per child during the sessions. The vertical axis of the diagram shows the seven different levels of difficulty according to the game's settings configuration. For instance, the first difficulty level consists of the addition mathematical operation in the numeric range 1–20, while another difficulty level consists of the subtraction mathematical operation for a wider numeric range. Fluctuations in the performance of some children are best explained through the analysis of qualitative comments gathered

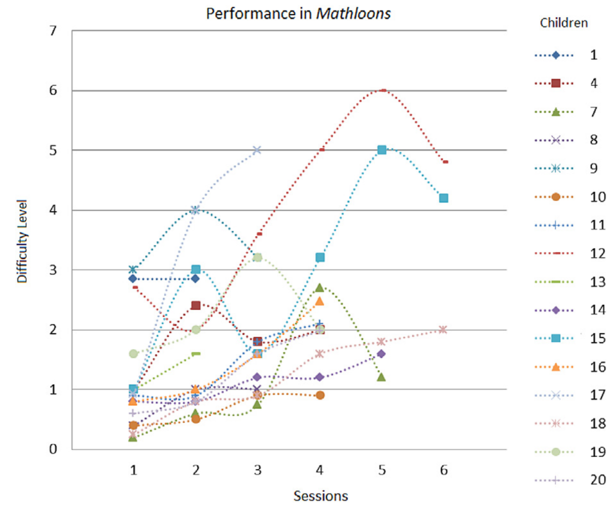


Fig. 9. Performance in *Mathloons* per child during the intervention.

via observation and the educators' notes. For example, Child4 had a performance fluctuation due to inherent lack of good motor control, which did not allow the child to have a stable performance during such a short term intervention. Also, Child4 played several games during session 3 and became tired, which led to some random answers in the *Mathloons* game according to the educator's notes. Respectively, the decreases in Child12's performance at session 2 and Child9's performance at session 3 were due to stress factors because of the addition of the timer in the game.

When looking at the game reports at each session, valuable findings can be drawn about the children's performances. Indicatively, Fig. 10(a)–(d) portray the gradual performance improvement of Child14 with regard to the completion time and score. For Child14, whose diagnosis is dyscalculia, the teacher had organized interventions emphasizing the game *Mathloons*. The improvement in both "success rate" and "time duration" is presented in Fig. 10(a)–(d). Analytically, as indicated in Fig. 10(a), the performance of the child at the two sessions in Level 1 remained high (80% success rate). At the same time, as shown in Fig. 10(c), the cognitive processing speed (Gps) was reduced. This means that although the score remained the same, the child managed to improve the completion time. At the same time, Child14 indicated a constant improvement throughout the *Mathloons* game and also presented a great improvement between the pre- and post-test evaluation. Particularly, he had a performance of 14 points in the post-test of math calculations (1 point higher compared to the pre-test of math).

Moreover, in Level 2, as Fig. 10(b) indicates, even though the child showed a quite low performance in the first two sessions (60%), during the next session a score improvement was achieved (80%). Similarly, as shown in Fig. 10(d), the cognitive processing speed (Gps) had gradually been reduced when the success rate remained stable. However, during the final session the child spent more time thinking about the answers in order to increase the score from 60% to 80%. Actually, the educator mentioned that she asked the child to think more carefully before giving an answer.

5.4. Acceptability of the Kinems learning games

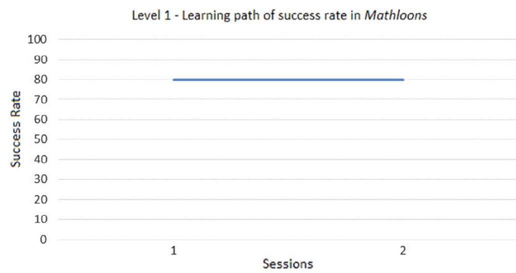
The fourth hypothesis (H4) concerned the children's, parents', and the special educators' opinions about the acceptability of the Kinems learning games. Fig. 10 shows the children's responses to a set of questions posed after the end of the educational process. The goal was to measure their attitudes and feelings toward the integration of Kinems learning games into the teaching practice. Children verbally expressed their opinions on issues concerning their experiences when asked by their special educators.

Level 1

Mathematical Operation: Addition

Numeric range: 1–20

Time: On/Off



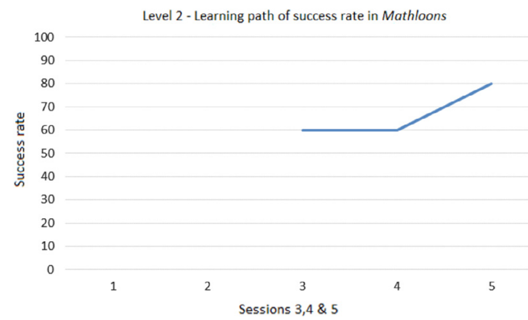
(a) Child14's success rate in *Mathloons* in the 1st Level.

Level 2

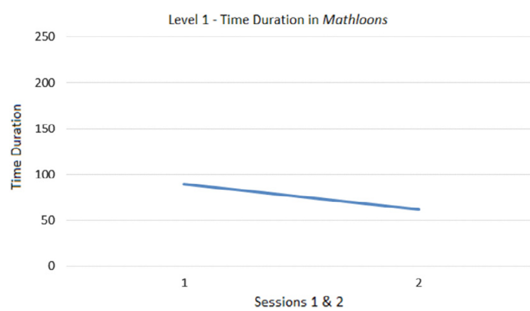
Mathematical Operation: Subtraction

Numeric range: 1–50

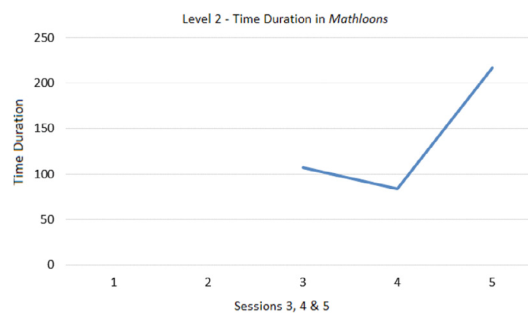
Time: On/Off



(b) Child14's success rate in *Mathloons* in the 2nd Level.



(c) Child14's reaction time in *Mathloons* in the 1st Level.



(d) Child14's reaction time in *Mathloons* in the 2nd Level.

Fig. 10. Child14 gradual performance at the *Mathloons* game.

According to Fig. 11, 75% of the children did not face any difficulty when playing the games and they did not mind the mental and physical effort that they had to put into the games. Also, 95% said that through the games, the learning process becomes easier and more stimulating for them. They would like to have such games included in the curriculum. Finally, all participating children reported that they "enjoyed very much" the use of games in their sessions. Children like all the Kinems games, but their favorite was *Farm Walks* and also *Mathloons* for mathematics. This was obvious because the names of these specific games are mentioned by children during other daily activities (in the regular classroom or at home). Also, their excitement and their active involvement giving advice when another classmate was playing a game like *Farm Walks* ("Be careful! Farmer will get stuck in the mud!") or *Mathloons* ("No! The correct answers is 3!") reinforce their high interest.

The qualitative feedback from the parents' responses indicated:

- Children's enthusiasm for the intervention program. Children made extensive references and highly positive comments about the game-based activities when they returned to their homes.
- The high motivation of children to go back to school the next day.
- The desire of children to use Kinems at home and integrate this approach into their after-school intervention programs at private centers.

Finally, the analysis of the special educators' notes and interview comments emphasized the added value of integrating the Kinems games into individualized programs. They also made the following comments:

- This game-based intervention strengthened the confidence of the children, who usually feel inferior to other children at the same school. Children without SEN started to consider their classmates with SEN very privileged since the latter were playing games as part of their educational programs.
- The natural user interaction strengthened children's interest, enhanced motivation and increased their involvement in the intervention process. The motor skills improvement of some children with SEN seemed quicker compared with the improvement observed using other instructional tools.
- The games helped the development of self-regulatory strategies (self-monitoring strategy and execution of movement) thanks to the autonomy offered.
- Hyperactive children started to restrict their body movements in order to succeed in the game. Shy children started to feel relieved and expressed themselves more openly when playing the games and made body movements in order to achieve a result.
- Kinems games comply with the requirements of inclusive school curriculum and are a very valuable supplementary instructional medium for helping children, especially younger

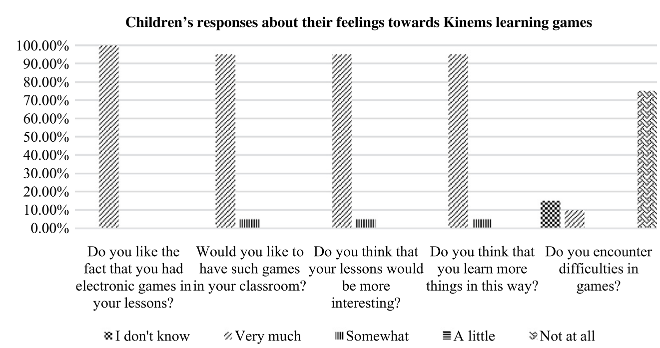


Fig. 11. Children's responses about their feelings toward the Kinems learning games.

Table 5
Mean performance in pre-test and post-test for academic math skills.

Academic (Math) skills	Mean performance pre-test	Mean performance post-test	Maximum performance	Percentage of the mean performance	St.D	p	Cohen d
Mental math calculations	11.68	13.64	15	8.99%	0.13	0.006**	0.61

** $P < 0.01$ = Indicates significance.

ones, to improve cognitive skills such as visual and auditory memory, attention, focus and motor skills (occupational therapy).

6. Discussion

The positive findings of the present study concerning the improvement of children's cognitive, motor and academic skills are very promising and confirm the initial expectations about the effectiveness of Kinems educational intervention in inclusive school environments. Indeed, these findings are in accordance with the outcomes of other studies in non-school environments that had investigated the value of using computer games [8,9,46] or, in particular, Kinect-based games in order to improve language skills [8], strengthen psycho-motor skills [46,35,14,15] and achieve sustained and selective attention [35,14,15,9].

Furthermore, the findings related to the strengthening of the children's interest and the high acceptability of the Kinems-based intervention are in agreement with the results of other studies where general-purpose, commercial Kinect games had been used (see [32,36,17]). All these studies show that teachers need games based on well-grounded therapeutic and learning protocols that allow them to configure the settings according to the individual needs and profile of each child. Also, the existence of Kinems' analytics mechanism enabled teachers and parents to have a good overview of the children's progress. Finally, the teachers appreciated the positive influence of the Kinems-based intervention because of the strengthening of the confidence of the children, the added value of natural physical interaction, as well as the positive influence on the promotion of self-regulatory strategies and cognitive skills. Similar opinions have been reported by other researchers such as Huhtanen [54,66].

Concerning the implementation of the Kinems platform in the schools, the number of students who participate in an intervention session is one of the biggest issues to take into consideration. Obviously, for an individualized one-on-one intervention session, the implementation is straightforward. Similarly, it is quite simple to use Kinems with a group of 2–3 children in the classroom. According to the special educators' comments, children can either take turns or help each other during the gameplay without losing their interest. It is very challenging to the use of the existing games in inclusion settings within a mainstream classroom of 20+ students. An educator should be able to apply cooperative learning strategies, such pairs check, numbered heads together, carousel brainstorming, etc. [67]. Also, students with SEN should be high functioning. To overcome these challenges, the main suggestion is to design new Kinems games that could promote the active participation and collaboration of 2 or 3 or even more children (depending on the complexity of the scenario). Such collaborative games will bring new social and behavioral experiences to the children as it is being suggested in the literature [68,69].

The follow-up activities of the present study involve the organization of a longitudinal study throughout the entire school year in order to further validate the results of the present study. Multi-cultural studies also need to be performed in order to strengthen the evidence about the effectiveness of such Kinect-based learning games and to offer more validated data about how to further enrich the current educational practice with Kinect learning games for the benefit of children with SEN. Finally, for future research, it would be interesting to evaluate whether the improvement of specific skills (such as memory or motor skills) is transferrable to other related skills in a real environment and daily life.

Acknowledgments

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References

[1] G. Gerald, P. Isquith, L. Kenworthy, R. Barton, Profiles of everyday executive function in acquired and developmental disorders, Child Neuropsychol.: J. Norm. Abnorm. Dev. Child. Adolesc. 8 (2) (2002) 121–137.
[2] D. Murray, M. Lesser, W. Lawson, Attention, monotropism and the diagnostic criteria for autism, Autism 9 (2) (2005) 139–156.
[3] B. Pennington, S. Ozonoff, Executive function and developmental psychopathology, J. Child Psychol. Psychiatry 37 (1) (1996) 51–87.
[4] D.P. Hallahan, J.W. Lloyd, J.M. Kauffman, M. Weiss, E.A. Martinez, Learning Disabilities: Foundations, Characteristics, and Effective Teaching, Allyn and Bacon, Boston, 2005.
[5] P.A. Zirkel, T. Rose, Scientifically based research and peer-reviewed research under the IDEA: The legal definitions, applications, and applications, J. Spec. Educ. Leadersh. 22 (2009) 36–50.
[6] B. Charlton, R.L. Williams, T.F. McLaughlin, Educational games: A technique to accelerate the acquisition of reading skills of children with learning disabilities, Int. J. Spec. Educ. 20 (2) (2005) 66–72.
[7] R. Jordan, Social play and autistic spectrum disorders A perspective on theory, implications and educational approaches, Autism 7 (4) (2003) 347–360.
[8] A. Cassar, E. Jang, Investigating the effects of a game-based approach in teaching word recognition and spelling to students with reading disabilities and attention deficits, Aust. J. Learn. Difficulties 15 (2) (2010) 193–211.
[9] M. Frutos-Pascual, B.G. Zapirain, A.M. Zorrilla, Adaptive tele-therapies based on serious games for health for people with time-management and organizational problems, Preliminary Res. Int. J. Environ. Res. Public Health 11 (2014) 749–772.
[10] K. Porayska-Pomsta, C. Frauenberger, H. Pain, G. Rajendran, T. Smith, R. Menzies, M.E. Foster, A. Alcorn, S. Wass, S. Bernadini, Developing technology for autism: an interdisciplinary approach, Pers. Ubiquitous Comput. 16 (2) (2012) 117–127.
[11] W. Lee, C. Huang, C. Wu, S. Huang, G. Chen, The effects of using embodied interactions to improve learning performance, in: 2012 IEEE 12th International Conference on Advanced Learning Technologies, ICALT, 2012, pp. 557– 559.
[12] L. Malinverni, B. Lopez Silva, N. Pares, Impact of embodied interaction on learning processes: design and analysis of an educational application based on physical activity, in: H. Schelhowe (Ed.), Proceedings of the 11th International Conference on Interaction Design and Children, ACM, New York, NY, 2012, pp. 60–69.
[13] Z.G. Smyrnaiou, C. Kynigos, Interactive movement and talk in generating meanings from science, Bull. IEEE Tech. Comm. Learn. Technol. 14 (4) (2012) 17–20.
[14] L. Bartoli, F. Garzotto, M. Valoriani, Touchless motion-based interaction for therapy of autistic children, in: M. Ma, L. Jain, A. Whitehead, P. Anderson (Eds.), Virtual and Augmented Reality in Healthcare, Springer-Verlag, UK, 2014.
[15] L. Bartoli, F. Garzotto, M. Gelsomini, L. Oliveto, M. Valoriani, Designing and evaluating touchless playful interaction for ASD children, in: Proceedings of the 13th International Conference on Interaction Design and Children IDC 2014, 2014, pp. 17–26.
[16] R.A. Schmidt, C.A. Wrisberg, Motor Learning and Performance, fourth ed., Human Kinetics, Champaign, Ill, 2008.

[17] A. Wang, J. Gonzales Ibanez, Learning Recycling from Playing a Kinect Game, Department of Computer Science and Technology, Norwegian University of Science and Technology, Trondheim, 2014.
[18] E. Jensen, Teaching with the Brain in Mind, second ed., Alexandria, VA: Association for Supervision and Curriculum Development, 2005.
[19] J.E. Donnelly, K. Lambourne, Classroom-based physical activity, cognition and academic achievement, Prev. Med. 52 (2011) 36–42.
[20] Y. Ahamed, H. Macdonald, K. Reed, P. Naylor, T. Liu-Ambrose, H. McKay, School-based physical activity does not compromise children's academic performance, Med. Sci. Sports Exerc. 39 (2) (2007) 371–376.
[21] Z. Gao, P. Hannan, P. Xiang, D.F. Stodden, V.E. Valdez, Video game-based exercise, Latino children's physical health, and academic achievement, Am. J. Prev. Med. 44 (2013) 240–246.
[22] C.H. Hillman, M.B. Pontifex, L.B. Raine, D.M. Castelli, E.E. Hall, A.F. Kramer, The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children, Neuroscience 159 (3) (2009) 1044–1054.
[23] C. Pesce, C. Crova, L. Cereatti, R. Casella, M. Bellucci, Physical activity and mental performance in preadolescents: effects of acute exercise on free-recall memory, Ment. Health Phys. Act. 2 (1) (2009) 16–22.
[24] J.M. Monti, C.H. Hillman, N.J. Cohen, Aerobic fitness enhances relational memory in preadolescent children: the FITKids randomized control trial, Hippocampus 22 (9) (2012) 1876–1882.
[25] H. Budde, C. Voelcker-Rehage, S. Pietrabyk-Kendziorra, P. Ribeiro, G. Tidow, Acute coordinative exercise improves attentional performance in adolescents, Neurosci. Lett. 441 (2) (2008) 219–223.
[26] M.T. Mahar, S.K. Murphy, D.A. Rowe, J. Golden, A.T. Shields, T.D. Raedeke, Effects of classroom-based program on physical activity and on-task behavior, Med. Sci. Sports Exerc. 38 (12) (2006) 2086–2094.
[27] D.M. Castelli, E. Glowacki, J.M. Barcelona, H.G. Calvert, J. Hwang, Active Education: Growing Evidence on Physical Activity and Academic Performance, Research Brief, San Diego, CA: Active Living Research, 2015.
[28] P.D. Tomporowski, Effects of acute bouts of exercise on cognition, Acta Psychol. 112 (3) (2003) 297–324.
[29] K. Kamijo, M.B. Pontifex, K.C. O'Leary, et al., The effects of an afterschool physical activity program on working memory in preadolescent children, Dev. Sci. 14 (5) (2011) 1046–1058.
[30] N. Khan, L. Raine, E. Drollette, M. Scudder, M. Pontifex, D. Castelli, S. Donovan, E. Evans, C.H. Hillman, Impact of the FITKids physical activity intervention on adiposity in prepubertal children, Pediatrics 133 (4) (2014) e875–e883.
[31] E. Shoval, Using mindful movement in cooperative learning while learning about angles, Instr. Sci. 39 (4) (2011) 453–466.
[32] L. Malinverni, J. Mora-Guiard, V. Padillo, A. Hervás, N. Pares, Pico's adventure: A Kinect game to promote social initiation in children with autism spectrum disorder, in: Presented at ITASD 2nd International Conference on Innovative Technologies for Autism, Paris, France, 2014.
[33] A. Bhattacharya, M. Gelsomini, P. Perez-Fuentes, G.D. Abowd, A. Rozga, Designing motion-based activities to engage students with autism in classroom settings, in: Proceedings of the ACM SIGCHI Conference on Interaction Design for Children, IDC, 2015, pp. 69–78.
[34] H.-M. Hsu, J. , The potential of Kinect in education, Int. J. Inf. Educ. Technol. 1 (5) (2011) 365–370.
[35] L. Bartoli, C. Corradi, F. Garzotto, M. Valoriani, Exploring motion-based touchless games for autistic children's learning, in: Proceedings of the 12th International Conference on Interaction Design and Children, IDC 2013, 2013, pp. 102–111.
[36] L. Malinverni, J. Mora-Guiard, V. Padillo, L. Valero, A. Hervás, N. Pares, An inclusive design approach for developing videogames for children within the Autistic Spectrum Disorder, J. Comput. Hum. Behav. (ISSN: 0747-5632) (2014). Available online 6 September 2015.
[37] D. Walker, W. Keay-Bright, D. Cobner, Autism and somatics: Capturing behaviour in the wild, Proc. Measuring Behav. (2012) 319–323.
[38] S. Bickerstaff, Building Tech-Powered Public Services, Institute for Public Policy Research, London, 2013.
[39] M. Kandroudi, T. Bratitsis, Exploring the educational perspectives of XBOX Kinect based video games, in: Proc.ECGBL, 2012, pp. 219–227.
[40] M. Heidegger, Being and Time, Harper & Row Publishers, New York, 1962, translated by J. Macquarrie and E. Robinson.
[41] J. Piaget, The Origin of Intelligence in the Child, Routledge, Keagan and Paul, London, 1953.
[42] C. Kontra, S. Goldin-Meadow, S.L. Beilock, Embodied learning across the life span, Topics Cogn. Sci. 4 (4) (2012) 731–739.
[43] A. Swartz, Wisdom, the body, and adult learning: Insights from neuroscience, in: E. Tisdell, A. Swartz (Eds.), Adult Education and the Pursuit of Wisdom, Jossey-Bass, San Francisco, 2012, pp. 15–24.
[44] F. Schrodt, G. Layher, H. Neumann, M.V. Butz, Embodied learning of a generative neural model for biological motion perception and inference, Front. Comput. Neurosci. 9 (2015) 79.
[45] M. Zembylas, The specters of bodies and affects in the classroom: a rhizo-ethological approach, Pedagogy Cult. Soc. 15 (1) (2007) 19–35.
[46] K. Karadimitriou, M. Roussou, Studying player experience in a collaborative embodied interaction game, in: Proceedings of the 2011 Third International Conference on Games and Virtual Worlds for Serious Applications, VS-GAMES'11, IEEE Computer Society, Washington, DC, USA, 2011, pp. 199–206.
[47] C. Johnson-Glenberg Mina, Savio-Ramos Caroline, Henry Hue, Games Health J. 3 (4) (2014) 241–251.
[48] C. Dede, Reshaping the role of technology in education breakthrough teaching and learning, in: T. Gray, H. Silver-Pacuilla (Eds.), Breakthrough Teaching and Learning, Springer, New York, NY, 2011, pp. 1–3 (Chapter 1).
[49] A. Hamilton, Hernand, T.C. Zi Ye, N. Graham, D. Fehlings, L. Switzer, Designing action-based exergames for children with cerebral palsy, in: CHI 2013, 2013, pp. 1261–1270.
[50] A. Serrano-Laguna, J. Torrente, P. Moreno-Ger, B. Fernández-Manjón, Application of learning analytics in educational videogames, Entertain. Comput. 5 (4) (2014) 313–322. 12/2014.
[51] J.B. Hauge, R. Berta, G. Fiucci, B.F. Manjon, C. Padron-Napoles, W. Westra, R. Nadolski, Implications of learning analytics for serious game design, in: Proceedings of the 2014 IEEE 14th International Conference on Advanced Learning Technologies, ICALT'14, IEEE Computer Society, Washington, DC, USA, 2014, pp. 230–232.
[52] G. Altanis, M. Boloudakis, S. Retalis, N. Nikoy, Children with motor impairments play a Kinect learning game: First findings from a pilot case in an authentic classroom environment, Interact. Des. Archit. (IxD&A) Int. J. Spec. Issue Game Learn. 19 (2014) 91–104.
[53] M. Jonshon-Glemberm, E. Heckler, "Alien health game": Embodied exergame to instruct nutrition and MyPlate, Games Health J. 2 (6) (2013) 354–361.
[54] M. Huhtanen, Kinetic Kid: Guiding Child Interaction within a Motion Game, Pixartprinting, Italy, 2014.
[55] G. Herrera, X. Casas, J. Sevilla, L. Rosa, C. Pardo, J. Plaza, R. Jordan, S. Groux, Pictogram room: Natural interaction technologies to aid in the development of children with autism, Annu. Clin. Health Psychol. 8 (2012) 39–44.
[56] K. McGrew, CHC theory and the human cognitive ability projects: Standing on the shoulders of the giants of psychometric intelligence research, Intell.: Multidiscip. J. 37 (1) (2009) 1–10.
[57] J. Stilwell, The development of manual midline crossing in 2- to 6-year-old children, Am. J. Occup. Ther. 41 (1987) 783–789.
[58] P. Anderson, Assessment and development of executive function (EF) during childhood, Child Neuropsychol.: J. Norm. Abnorm. Dev. Child. Adolescence 8 (2) (2002) 71–82.
[59] H. Williams, E. Monsma, Assessment of gross motor skills, in: B. Bracken (Ed.), Psychoeducational Assessment of Preschool Children, New Jersey, London, 2004, pp. 204–233.
[60] S. Pickering, The development of visual-spatial working memory, Memory 9 (2001) 4–6.
[61] D. Porpodas, Diagnostic Evaluation of Learning Disabilities in Primary School (Reading Skills, Writing Skills, Dyslexia, Math), EPEAEK Project Ministry of Education, Greece: Patra, 2003.
[62] E. Gonida, V. Iossifidou, Psychometric Criterion of Cognitive Adequacy for children and adolescents, Deliverable of the Project Psychrometrics-differential evaluation of children and adolescents with learning difficulties, Greek Ministry of Education, 2008.
[63] A. Kaufman, N. Kaufman, Kaufman Assessment Battery for Children-II, KABC-II, AGS Publishing, Circle Pines, MN, 2004.
[64] D. Flanagan, S. Ortiz, V. Alfonso, Essentials of Cross-Battery Assessment, third ed., Wiley, Hoboken, NJ, 2013.
[65] M. Fabbri-Destro, V. Gizzonio, P. Avanzini, Autism, motor dysfunctions and the mirror mechanism, Clin. Neuropsychiatry 10 (5) (2013) 177–187.
[66] L. Malinverni, N. Pares, Learning of abstract concepts through full-body interaction: A systematic review, Educ. Technol. Soc. 17 (4) (2014) 100–116.
[67] G. Jabobs, M. Power, L.W. Inn, The Teacher's Sourcebook for Cooperative Learning, Practical Techniques, Basic Principles and Frequently Asked Questions, Corwin Press, Inc., California, 2002.
[68] L. Malinverni, N. Pares, The medium matters: the impact of full-body interaction on the socio-affective aspects of collaboration, in: Proceedings of the 14th International Conference on Interactions Design and Children, IDC'15, ACM Digital Library, 2015, pp. 89–98.
[69] S. Retalis, T. Korpa, C. Skaloumpakas, M. Boloudakis, M. Kourakli, I. Altanis, F. Siameti, P. Papadopoulou, F. Lytra, P. Pervanidou, Empowering children with ADHD learning disabilities with the Kinems Kinect learning games, in: The 8th European Conference on Games Based Learning, vol. 1, 2014, pp. 469–477.