Does Robot Programming Experience Affect Special Education Children's Development of Executive Functions and Graphomotor Capabilities?

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השפעתה של ההתנסות בתיכנות רובוט על תפקודים ניהוליים ומיומנויות גרפו-מוטוריות אצל ילדים עם עיכוב התפתחותי בחינוך המיוחד

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Abstract

In this work we use robot programming activities as part of a program that aims to improve executive function skills and graphomotor abilities in children with developmental difficulties. We take a "technological thinking" approach for developing educational tasks for children with special needs which is inspired by the way designers work. Specifically, technological thinking tasks demand and afford skills such as initiation, inhibitory control, problem identification and solving, planning and organization capabilities as well as graphomotor capabilities. In our work we investigate the influence of a specific subset of tasks of a larger study, i.e., robot programming tasks, on the advancement and improvement of executive functions and graphomotor capabilities.

Participants included 32 children ages 5-6 diagnosed with developmental delays, attending special education kindergartens in central Israel – 17 children in the experimental group and 15 children in the control group. Experimental group children were involved in performing robot programming tasks in a progression of increasing difficulty. Control group children followed the regular curricular activities. Children's progress in EF was examined through standardized tests and systematic observations carried out 11 times along the year.

The results showed significant improvement in all the executive function skills observed: inhibition, initiation; planning and organization, Additionally, improvement in graphomotor abilities was demonstrated.

Our findings demonstrate the potential of technological-thinking-based tasks for reducing early learning gaps and open up opportunities to integrate special education children within the regular education system.

Keywords: Technological thinking, design and programming, executive functions, graphomotor skills.

Introduction

The development of young children's technological thinking raises questions that still deserve to be examined systematically. Concerning special education children, research is scarce despite convincing preliminary observations evidencing the potential contribution of technological thinking tasks to children's thinking and learning. In 2014 (Levi M., 2014) we conducted a preliminary study in special education kindergartens. Our working hypothesis was that exposure to technological thinking tasks contributes to the development of thinking and performance skills concerning inquiry, planning and problem-solving processes. Our findings indicated that children's motivation to experiment and explore phenomena increased, their experience of failure diminished, they were able to improve thinking skills considerably, and acquired cognitive tools and applied these in various situations. The findings indicated that hands-on technological thinking tasks brought about essential skills' development.

In a larger study being currently conducted, we sought to expand our scope and examine systematically the hypothesis that technological thinking tasks afford the development of meaningful skills by preschool children with developmental delays - such as executive functions, graphomotor and problem-solving skills. We also examined whether this type of exposure allows for a more substantial advancement of skills compared to existing intervention programs.

In this paper we report on preliminary results of a specific segment of the study, focusing on robot programming tasks (part of the whole intervention plan administered). Specifically, we examined whether and how experiences in symbolic manipulation (such as simple robot programming), followed by reflection and documentation, will influence the development of the skills targeted.

Background

Crucial skills for learning

Children with developmental delay often find it difficult to acquire knowledge, organize, remember and use it appropriately. Deficiencies in performance, motor, and graphomotor capabilities are also identified as inhibiting factor in learning. These abilities are some of the significant learning skills essential for subsequent school learning. Cameron and others have examined the role of fine motor skills and executive functions in early childhood achievement in children who are not characterized by any developmental difficulties between the ages of 4-6. They found that mastery of these skills contributes to children's achievement in kindergarten and early schooling, including in reading and writing abilities (Cameron et.al 2012). In general, studies demonstrate that fine motor skills and executive functions contribute to early school learning outcomes (Grissmer et. Al, 2010; Kim et. Al, 2015; Willoughby et. Al, 2017).

Graphomotor skills are essential for the development of writing ability in children, and include perceptual, motor, and perceptual-motor components such as fine motor accuracy, hand-eye coordination, manual manipulation ability. Writing skill develops gradually in both sexes with age (Beery, 1967; Waber & Holmes, 1986; Cameron et. Al, 2015; Graham, Collins & Rigby-Wills, 2017).

Executive Functions are high cognitive functions that help us in coping with a world of multiple stimuli, with a constant need for solving problems, attain goals and manage time (Zelazo, Carlson, & Kesek, 2008). These functions enable to act efficiently and independently, initiate actions, set goals, plan meaningful and goal-oriented behavior, execute plans, use strategies, effectively inhibit responses and correct mistakes (De Luca & Leventer, 2008; Lezak, 2004; Stuss & Alexander, 2000; Ylvisaker & Feeney, 2002). Executive functions play an essential role in effective learning, these are an important indicator of school readiness (Duncan et al., 2007; Mazzocco & Kover, 2007; Morisson, Cameron Ponits, & McClelland, 2010). Research indicates that through practice, executive functions can be improved in 4–5-year-olds (Diamond, Barnet, Thomas, & Munro, 2007). Learning difficulties common in children with developmental delays have been associated with deficits in executive functions (Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2004; Mackinlay, Charman, & Karmiloff-Smith, 2006)

Robot programming and technological thinking in the kindergarten

In recent years, educational experiences that include working with robots in several kindergartens in Israel have been incorporated as part of a program of fostering technological thinking in early childhood (Mioduser & Kuperman, 2012; Spektor-Precel & Mioduser, 2015). In these programs, Lego-built robots are programmed using a developmentaly appropriate iconic interface (Mioduser, Levi, & Talis, 2009).

The idea of integrating robotics into education has existed for more than twenty years (Miglino, Lund, & Cardaci, 1999; Papert, 1980). However, a significant advance in educational robotics has been achieved over the last decade - robotics has been removed from the laboratory and efforts have been made to connect it more to education (Chambers, & Carbonaro, 2003; Jung, & Won, 2018; Kachisa, & Gustavsson, 2019). Research shows that if robotic activities are properly designed and implemented, there is a great potential for significant improvement in teaching and learning (Bauerle, & Gallagher, 2003; Papert, 1993). It has also been shown that no age is too young to engage in robotic activities; And regardless of age, educational background, and interests, students see working with robots as a "fun" and "interesting challenge".

Research Rationale

Children with developmental delays exhibit significant difficulties in planning and organizing ability and control abilities, and demonstrate difficulties in fine motor performance and problem solving. Thus, special attention should be paid to the learning and performance needs of these children, and adequate programs should be developed to address such difficulties while raising motivation and accomplishment.

This study examined the impact of programming -symbolic construction of a robot's behavior- and documentation on thinking skills' development in preschool children with developmental delay.

The main goals of the study were:

- To understand whether the exposure of special education children with developmental delays to symbolic construction (programming) assignments contributes to the advancement and enhancement of thinking skills and performance skills that are essential for developing future learning abilities.
- To understand whether the exposure to robot programming contribute to advancing thinking skills in a way that differs from conventional intervention programs in special education.
- To generate research evidence for the development of technological thinking interventions for children with developmental delays.

Method

Population

The study was conducted as a mixed qualitative and quantitative study. Prticipants were 29 preschool children, aged 5-6 years – all diagnosed as children with developmental delay, characterized by a delay in motor, verbal and/or emotional development and attending special education kindergartens. The children were randomly assigned to an experimental group and a control group. 17 children in the experimental group were exposed to our technological thinking intervention assignments and 15 children in the control group were exposed to the regular curriculum intervention activities.

Children's diagnoses included difficulties in executive functions as well as difficulties in graphomotor performance, e.g., in pencil grip, hand-eye coordination, fine motor coordination and visuomotor difficulties.

Intervention

During the year, the experimental group children were exposed to 9 programming assignments of increasing complexity. Each session was held with each child in a separate room working with the researcher. At the end of each session, the children were asked to document the programming process and explain the robot's behavior. Control group children followed the regular curricular activities for special education kindergarten without experiencing technological thinking tasks.

Data collection and analyses

The sessions were documented in video. The videos, as well as children's graphic representations and explanations, were analyzed according to the pre-determined criteria. Approximately 25% of the data were analyzed by 2 independent judges, who reached over 85% agreement.

The study's independent variable was the kind of activities performed by the children, either exposure to the assignments in the intervention plan (experimental group) or the regular intervention activities in the kindergarten (control group).

The dependent variables were:

1. Graphomotor Skills - Pencil grip, line quality, organization and graphic space planning, visuomotor capability.
2. Executive functions - Initiative, degree of inhibition and control, organization and planning ability, overall executive functions ability.

Data on the development of the target skills, i.e., executive functions and graphomotor skills, were collected using standard tests: 1. A questionnaire assessing children's executive functions in daily life was administered to teachers and parents before the intervention -aiming to set the baseline for each child- and at the end of the intervention. (Behavior Rating Inventory of Executive Function (BRIEF); 2. A developmental test of visual-motor integration (Beery) performed by the children at the beginning and the end of the study. (Beery, 2010 ; Gioia, 2002).

Findings

First research question: The effect of the engagement in robot programming tasks on children with special needs' executive functions capabilities.

Figure 1 depicts the change in executive functions by each of the children (from two different kindergartens) in the experimental group during 9 sessions as a result of task exposure. The findings indicate a clear progression path in performance regarding executive functions along the intervention. Points of decrease in quality of performance were observed at points of substantial increase in level of difficulty of a new assignment (e.g., in session 4). However, following the work on the assignment to a gradual and sustained increase was observed.

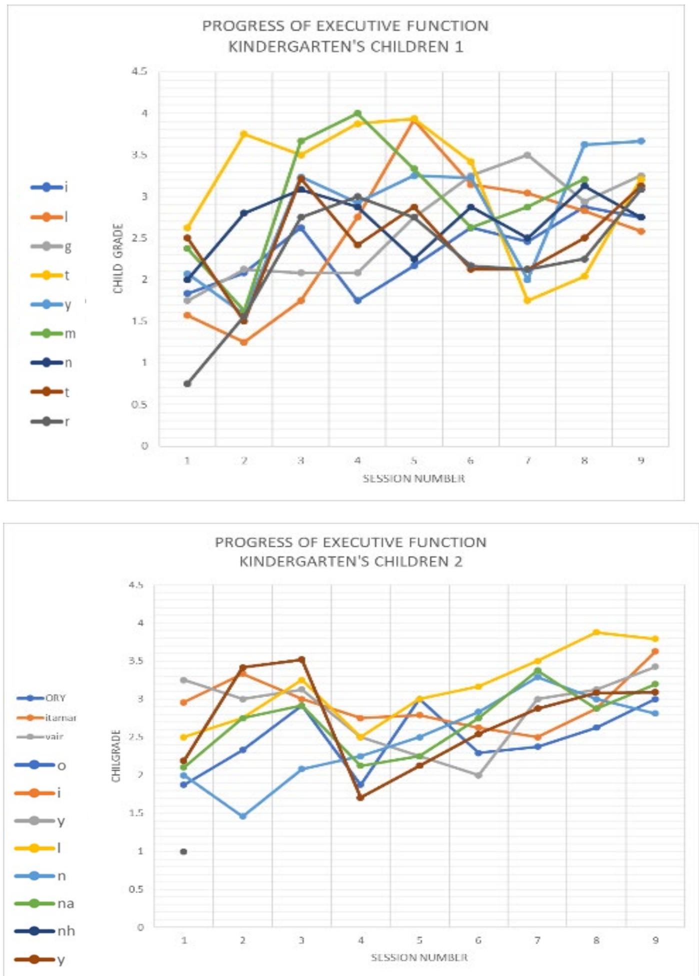


Figure 1. Progress in executive functions for each participant in the experimental groups along the intervention (graphs are shown for each kindergarten - no teacher influence has been observed)

The mean progress in children's executive functions performance by each skill examined is shown in Figure 2. The highest performance was observed for the "initiation" function all along the study's sessions. "Inhibitory control" capabilities increased moderately along the intervention. Progress observed was gradual – inhibition and control of behavior is highly challenging for children with impulsive behavior, yet notwithstanding, gradual improvement was observed. The intervention contributed mostly to an increase in "planning and organization" capabilities, as observed during the accomplishment of the assignments.

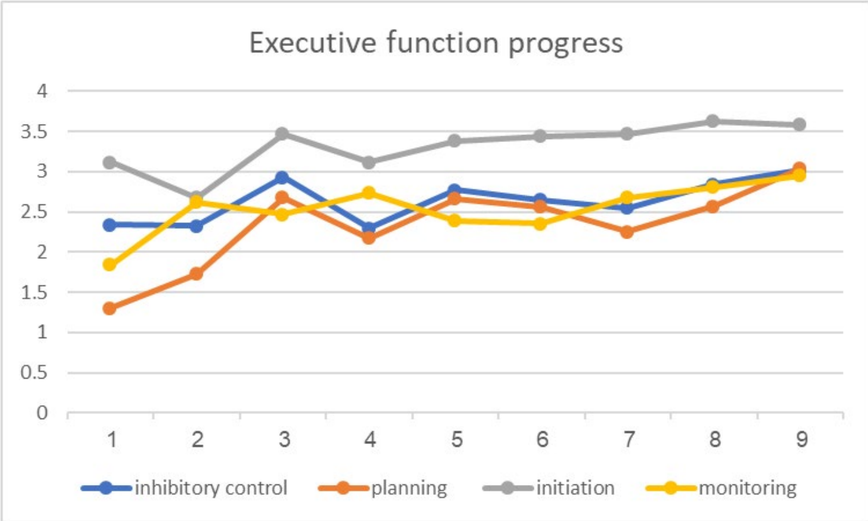


Figure 2. Progress of each component of executive functions tested during the intervention

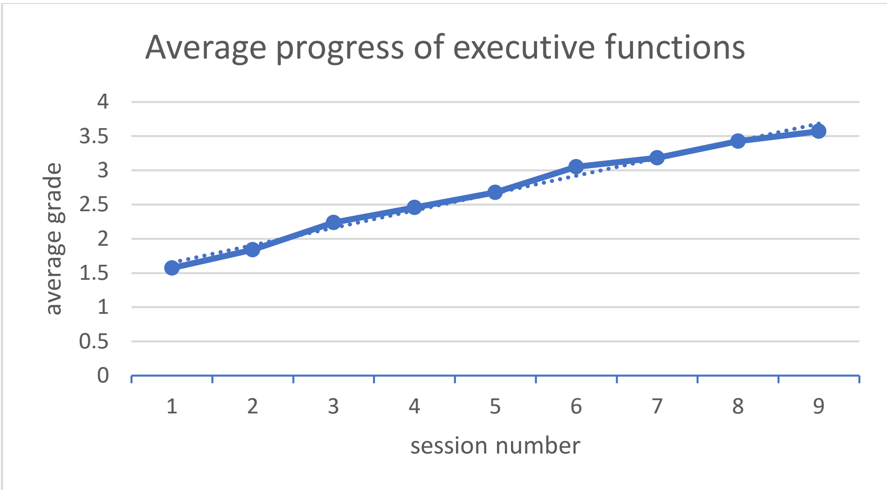


Figure 3. Mean progress of all executive functions tested during the intervention

Table 1. Mean progress in executive functions by group

	Experimental group N=17	**Control group N=15**
	Mean (SD)	Mean (SD)
Inhibitory control	14.9 (7.8)	1.9 (2.7)
Planning and organization	24.8 (9.2)	6.33 (4.4)
Executive functions	19.2 (9.2)	5.6 (2.5)

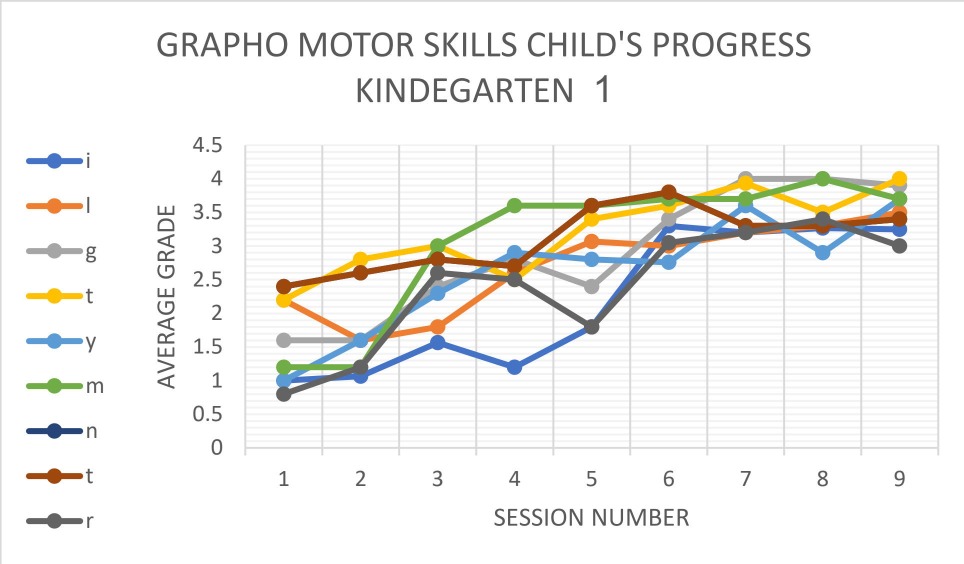
The mean overall progress in executive functions performance is shown in Figure 3. A clear progression path has been observed, from a mean of 1.5 at the beginning of the intervention plan and 3.6 at its end.

Differences in progress path for the executive functions examined between the experimental and control group are presented in Table 1. Data presented in Table was collected using the executive functions questionnaire (Brief) completed by the teachers in each kindergarten.

Data collected showed significant difference between the mean progress of the experimental and control group for the "inhibition and control" function ($F=17.42$, $df=47,2$, $p<0.00$), the "planning and organization" function ($F=25.06$, $df=47,2$, $p<0.001$), as well as for the general executive functions variable ($F=31.01$, $df=47,2$, $p<0.001$).

Second research question: The effect of graphic documentation following the programming task on graphomotor and visuomotor capabilities for children with special needs

Findings regarding progress in children's graphomotor and visuomotor capabilities along the intervention are presented in Figure 4. The findings demonstrate a substantial progression along the intervention in capability and performance for all variables examined: pencil grasp, quality of line, planning of the representation and visuomotor capabilities.



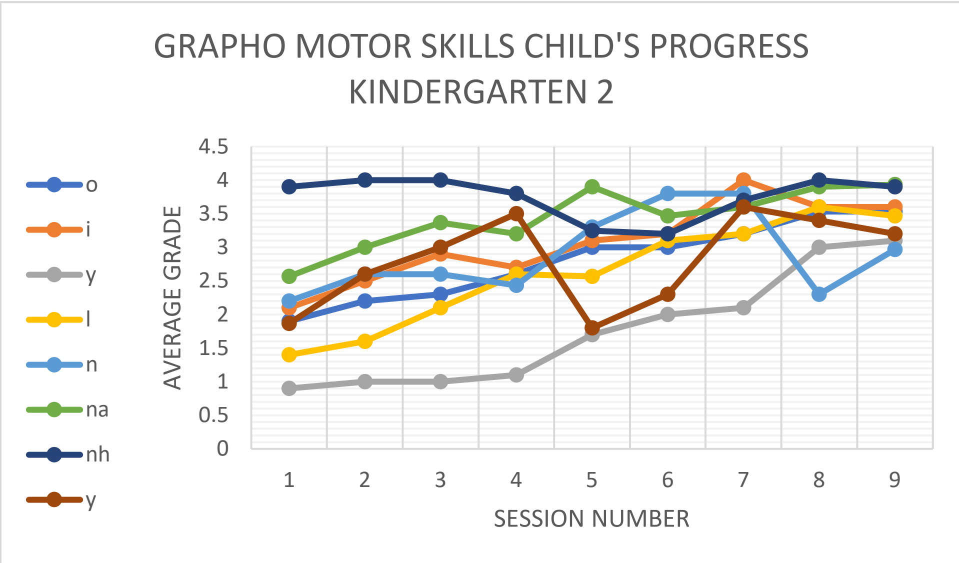


Figure 4. Progress in Graphomotor skills for each participant in the experimental groups during the intervention

The mean progress in children's Graphomotor skills performance by each skill examined is shown in Figure 5. Data shows substantial improvement in all graphomotor skills along the intervention – from low performance in the initial session to considerably high performance in the latest sessions. Particular progress was observed for the "planning" and "viso-motoric" skills. Similar to the improvement in executive functions, the integrated graphomotor performance improved substantially and reached the mean range of the norm.

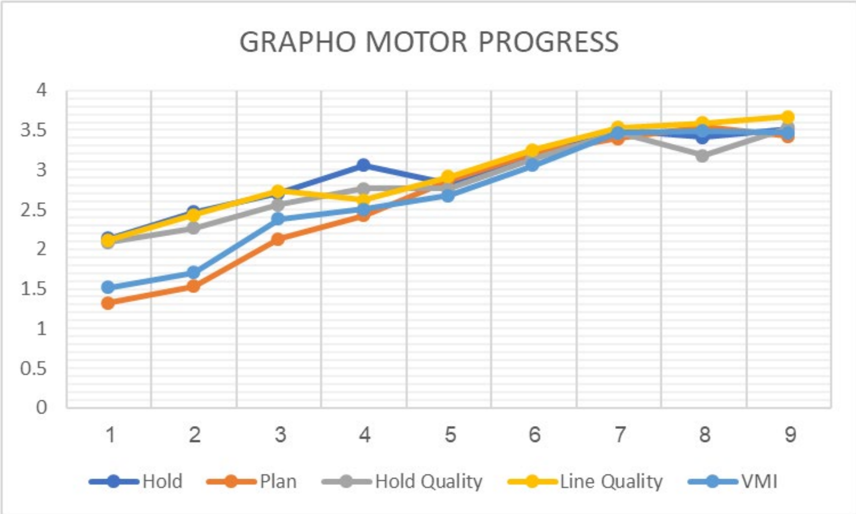


Figure 5. Progress by each component of Graphomotor skills tested during the intervention

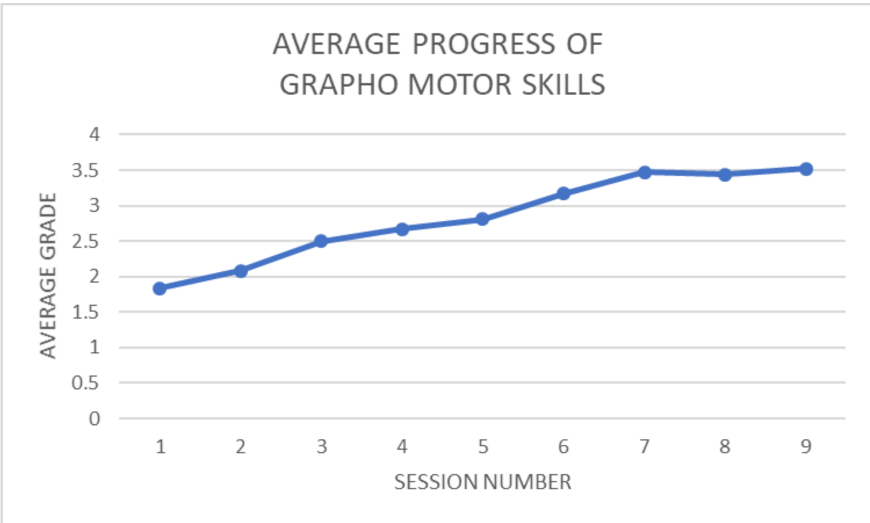


Figure 6. Mean progress of all Graphomotor skills tested during the intervention

The mean overall progress in Graphomotor performance is shown in Figure 6. A clear progression path has been observed, from a mean of 1.8 at the beginning of the intervention plan to 3.5 at its end.

Findings concerning the contribution of the intervention tasks to children's performance and capability is presented in Table 2, in comparison with that of the control group children. Data was collected before and at the end of the intervention using the Beery standard test. The test comprises of two components, VMI (Visual Motor Integration) and the MC (Motor Coordination). The VMI tasks require copying (reproducing) a range of forms of increasing complexity and MC tasks aim to examine the quality and precision of motor performance with a writing/drawing tools.

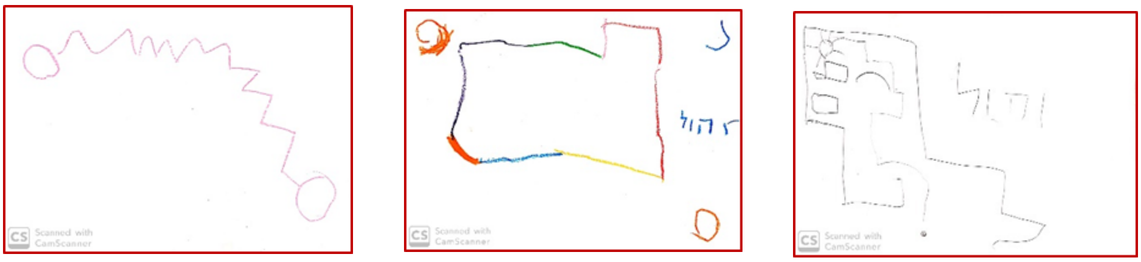
Data from the pre-tests show similar results for both groups. Data on progress between pre- and post-test showed significant difference between the experimental and control group in the VMI test (mean dif. = 13.38, p=0.00) but not in the MC test.

The findings reinforce our assumption that the graphic documentation created after the programming task affects substantially children's viso-motor capabilities. The actual spatial planning and its implementation in a program, and the demands of the subsequent graphical representation, seem to contribute to the development of graphomotor skills.

Table 2. Mean progress in Graphomotor skills by group

	Experimental group – N=17	**Control group N=14**
	Mean (sd)	Mean (sd)
Pre-test VMI	17.24 (8.86)	16.33 (5.48)
Pre-test MC	18.88 (5.73)	17.5 (5.01)
Increase in VMI between pre/post	20.59 (9.04)	7.25 (0.97)
Increase in MC between pre/post	15.29 (1.58)	14.08 (2.87)

Experimental group children's graphic representations were qualitatively analyzed (results not reported here). An illustration of the increase in graphomotor capabilities by children in the experimental group is shown in Figure 7. In the example, representations by one child at three different points of the intervention show a substantial improvement in quality of line, graphic precision and planning and organization of the representation.



Session 1 session 4 session 9

Figure 7. A child's representations at three points in the intervention

Discussion

This study is part of a comprehensive research in which children with developmental delay were involved in performing technological thinking tasks that included physical and symbolic construction tasks, documentation, and problem-solving assignments. In this report we focus on the contribution of the intervention plan to children's executive functions and graphomotor capabilities, regarded in the literature as predictors of learning success in school.

It has been found that executive functions predict achievements at the kindergarten and are an important indicator of school readiness (Duncan et al., 2007; Mazzocco & Kovner, 2007; Morisson et al., 2010). Executive functions are critical to school success, work, social relationships, and good quality of life (Alloway & Alloway, 2010; Borella, Carretti, & Pelgrina, 2010; Duckworth & Seligman, 2005; Gathercole, Pickering, Knight, & Stegmann, 2004).

Special education children experience difficulties in the development of executive functions. Thus, substantial intervention programs should be developed to promote and improve children's capabilities and performance in support of their learning and readiness for schooling. Our working hypothesis in the reported study was that technological thinking tasks are of great potential to support the practice and development of such substantial capabilities. We investigated the use of technology as an effective channel for increasing motivation and reducing barriers, affording cognitive coping with complex tasks and supporting the realization of the learner's personal potential (Waks 1993). We investigated whether technological thinking assignments can serve as a nurturing and enriching environment.and enable progressing in target skills.

In our study, we observed that the children, although low in thinking and executive functions capabilities at the baseline as well as low graphomotor abilities, showed significant improvement along the intervention sessions. In addition, improvement in daily life performance of the children has been reported by teachers and parents. Performing post-programming documentation contributed to improved graphomotor performance and visuomotor capability, as observed in the standard tests administered. These results showed statistically significant improvement over a control group which was exposed to the regular existing preschool curriculum for the target population

Thus, we conclude that the use of technological tasks in special education has the potential to promote and improve executive function and graphomotor capabilities in children with development disabilities.

Finally, this study has also important implications at the practical level. Our results can serve a basis and driver for the development of intervention programs built specifically for special education, aiming to promote significant support for the development of substantial skills for learning.

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