Technological Thinking by Children with Special Needs

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Special education interventions involve methodical instruction, teaching, and therapy activities specially developed for children with special needs. Some children referred for special education at younger ages are defined as having developmental delays. Methods commonly in use focus on series of tasks and exercises of generic character, many times detached from relevant contents and contexts for the child. Many studies have shown that critical skills for academic learning can be promoted at young ages, but studies focusing in special education children are scarce. This study focused on the influence of technological thinking tasks on the advancement and improvement of children-with-special-needs' executive functions, problem-solving abilities, and motor and graphomotor skills. During the study, children were exposed to content-rich and context-relevant tasks encouraging design and building processes, problem-solving, and planning and documentation activities. The results of the study indicate a significant improvement in all the functional skills observed: fine motor skills, executive functions (e.g., attentional control, inhibitory control, process control), and problem-solving skills. The intervention implemented in this study follows the assumption that technological thinking might help achieve many therapeutic and learning goals for special education children. The main innovation in the study is the evidence collected on the clear effect of technological thinking tasks on the advancement and improvement of the target skills.

Key Words: Technological thinking, Special education, Problem solving, Design and building, Executive functions.

1. INTRODUCTION

Special education is concerned with methodical teaching, learning, and therapy interventions for children with special needs.

Children accepted to special education pre-schools, characterized as children with delayed development, are mostly children with multiple problems, with recognizable delayed development in most areas of functioning. Any attempts to characterize these children using one diagnostic label are doomed to failure due to their great heterogeneity. Children are characterized and diagnosed by the gamut of their particular problems in the various areas of development: gross and fine motor skills, speech and language, cognition, social/ personal, and ADL - Activity of Daily Living. (Shevell, 2010).

The quality of educational interventions at preschool age and how these are adapted to each individual student has considerable influence on developing children's capabilities in general and preparing them for study at school in particular (Barnett, 2002). Children in special education need, more than anyone, programs that impart knowledge and develop cognitive and performance skills aiming to support their independent learning in the future. Children with learning disabilities are unsuccessful in developing their own effective learning styles. For this purpose, curricula and teaching methods are created aiming to enable good preparation for school (Rimm-Kaufman, Pianta, & Cox, 2000; Heckman, Stixrud, & Urzua, 2006).

Executive functions and fine motor skills are important skills required for academic achievement in school (Cameron et al., 2012; Diamond 2012; Duncan et al., 2007; Grissmer, Grimm, Aiyer, Murrah, & Steele, 2010; Mazzocco & Kovner, 2007; Morisson et al., 2010). It was indeed found that children with the poorest executive

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functions benefited most from intervention programs aimed to advance the acquisition of crucial skills (Flook et al., 2010; Karbach & Kray, 2009; Lakes & Hoyt, 2004). Diamond and Ling (2016) found that executive functions (a set of cognitive processes that are necessary for the cognitive control of behavior, e.g., attentional control, inhibitory control, process control) must be challenged consistently, and practice and training can lead to improvement.

It was found that technological tasks enable children to develop fine motor skills, hand-eye coordination, problem solving ability, and even acquire social skills. Moreover, this type of activity is enjoyable and leads to motivation (Bers, Flannery, Kazakoff, & Sullivan, 2014). Technological thinking arouses curiosity, requires higher order thinking, analytical skills, abstraction, and problem solving, and enables processes of knowledge construction and learning. Technological curricula suitable also for young children have recently been developed (Barron et al., 2011). Bers (2008) saw that construction and design processes support learning and the development of technological reasoning skills

In our study, we hypothesize that the acquisition and practice of technological reasoning skills can contribute to advancing and developing learning skills that are difficult for children with developmental delays (Thomas, 2016) like fine motor skills, graphomotor skills, executive functions and cognitive flexibility.

1.1 Research rationale

The study examined the effect of (1) technological thinking and (2) the involvement in planning, constructing and documenting on reasoning skills development by children with developmental delays in special education preschools.

The research questions were defined to examine the following topics:

- The effect of the exposure to various construction sets and building tasks, on planning and fine motor skills.
- The effect of documenting the built models on children's graphomotor skills.
- The effect of exposure to planning and building tasks using various construction sets on organizing thinking, executive functions, and ability to cope with and solve problems.

2. METHODOLOGY

2.1 Population

The research is a qualitative study that followed ten preschool children, aged 5-6, who had been diagnosed with a developmental delay by a developmental pediatrician and attend a special education kindergarten.

The main characteristics of children's difficulties in preschool are language delays, sensorimotor problems – difficulties in the maturity of the sensory systems, gross and fine motor skill functions, graphomotor performance, and visual perception, organizing thinking and executive functions. Likewise, social-communication difficulties, low frustration threshold, and motivational difficulties. (Shevell, 2010; Thomas, 2016)

An intervention program was created built on exposure to technological thinking tasks, and based on the acquisition, development, and organization of thinking skills, alongside developing language, motor, and social-communication skills. It was designed on the basis of a long-term research plan carried out in regular experimental kindergartens (Kuperman & Mioduser, 2012).

Unlike other children, children with developmental delays require mediation, focus, direction, and learning the strategies essential for life in general and learning in particular. The ability of early intervention programs to minimize declines in development has been reported (Guralnick, 1991). As well, technological thinking tasks might serve as effective tool for achieving many therapeutic goals for children in special education (Kuperman & Mioduser, 2012).

The intervention program focused on a wide range of skills: communication and interaction among children, fostering language skills; organization skills in both free and structured task planning and execution; motor skills (e.g., experiencing the body in a space, planning, directionality); fine motor skills (e.g., work with construction sets that require motor and visual perception accuracy); graphomotor and visuomotor skills required for the documentation of the constructed models; bolstering self-image and a sense of efficacy; problem solving – including experiencing defining the problem, raising possible solutions, selecting and implementing the solution, and then re-examining the situation.

The intervention program included a range of components. In this paper we chose to focus on four main areas: Fine motor and graphomotor skills, reasoning skills, executive functions and problem solving.

2.2 Data collection

For gathering the data, the experiences were documented through observations, documentation and photocopying of children's products and construction processes. The learning sessions as part in the intervention program were coducted by the teacher under the guidance of the researcher following prior training. The intervention program was conducted in the kindergarten as part of the regular activities. In addition, individual meetings were held with the children following construction and documentation tasks

Data collection was conducted during eight sessions throughout the school year and focused on three aspects of children's performance: Construction, graphic documentation and problem solving.

Construction – The tasks involved the use of a range of construction kits - the children were asked to build a model of their own free choice, to give meaning to the model we used to explain its uses. The observations focused on hand-eye coordination ability, motor accuracy ability, strength regulation, and hand manipulation ability (Figure 1).

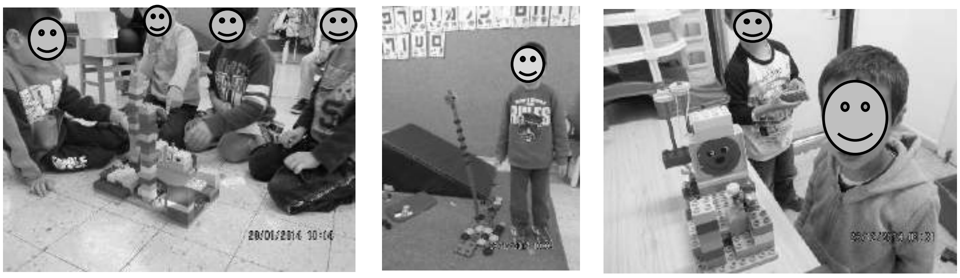

Figure 1: construction tasks

Graphic documentation. After completing the construction, the children were asked to document their creations. The observations focused on hand-eye coordination, visuomotor skills, and ability to plan in a graphic setting. As well as on Pencil control and graphic accuracy and ability to represent, e.g., representation of color, shape, a moving element (Figure 2).

Problem solving - the children were asked to build a path in space using cones and cubes, before or during the construction they were presented with a problem they must solve. Children experienced situations in which they were required to identify a problem, define it, plan a solution, and carry it out. During the day, even beyond the technological tasks, the children were expected to plan and carry out problem solving process linked to the kindergarten's daily activities (Figure 3).

Figure 2: documentation tasks *Figure 3: documentation tasks*

A graded scale was constructed according to the level of performance. The levels were defined in values 0-3 in a multilevel form where 0 describes incompetence and 3 describes an age-appropriate ability.

2.3 Research variables

2.3.1 Independent variables:

The independent variables were the technological thinking tasks administrated during the intervention: Construction, documentation, and problem-solving tasks.

2.3.2 Dependent variables

- Fine motor skills – hand-eye coordination, strength regulation, fine motor accuracy and control, in-hand manipulation ability.
- Graphomotor skills – pencil grip, line quality, and use of line complexity
- Thinking and executive functions – organizational and planning abilities for construction tasks – choosing the parts, matching them, ability to solve problems during construction, and providing significance, planning ability during construction, checking ability during the process, and flexibility of thinking.
- Problem solving – ability to identify and define a problem, raising possible solutions, choosing, implementation, and checking.

3. RESEARCH FINDINGS

The figures below describe group and individual progress during the study at eight assessment points, by the dependent variables examined. The findings are presented according to the research questions.

3.1 First research question: Does experiencing with technological thinking tasks affect the development of fine motor, graphomotor, executive functions and problem-solving skills, by children with special needs?

A significant improvement can be seen in the mean performance of the group for the fine motor skills hand-eye coordination, strength regulation, motor accuracy and control, and in-hand manipulation (Figure 4) The score at the beginning of the year ranged from 0.5-1 and reached 2.3-2.8 at the end of the year.

Significant progress can be seen concerning thinking skills and executive functions (e.g., planning, process control capability, attention, importance and control, see Figure 5). The score at the beginning of the year ranged from 0.2 to 0.7, and at the end of the program it reached 2.6-2.8.

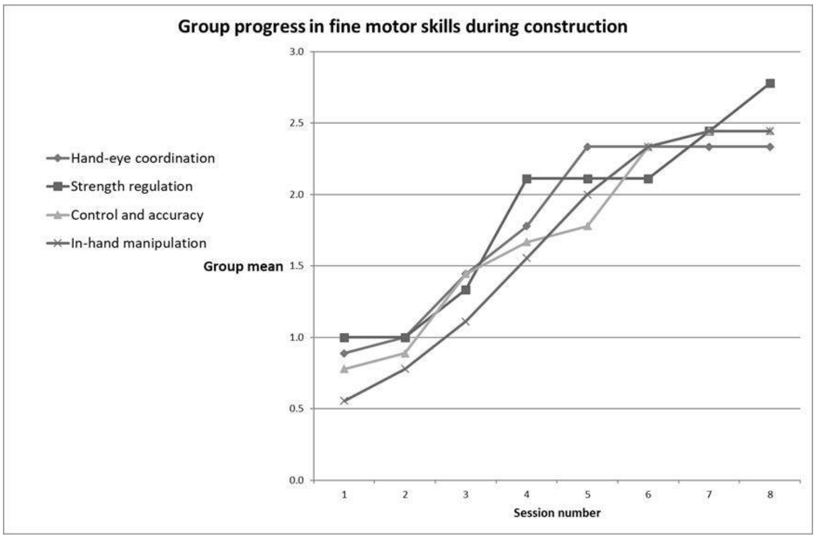

Figure 4: Group progress in fine motor skills along construction tasks

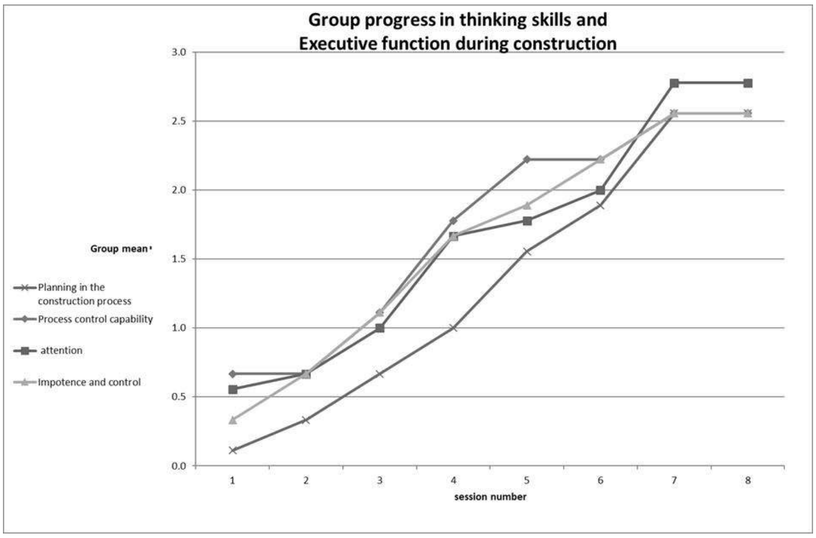

Figure 5: Group progress in thinking skills and executive functions along construction tasks

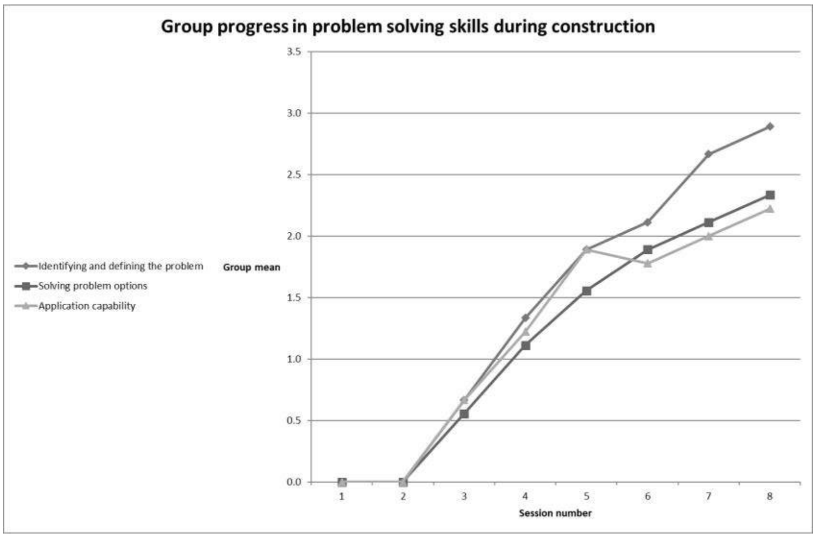

Figure 6: Group progress in problem solving skills along construction tasks

It can be seen that children began with extremely low level of problem solving capability, and there is clear progress along the construction tasks in ability to identify and define the problem and raise and implement possible solutions. Graph 6 presents the capabilities to identify a problem, the ability to raise options for solution and the ability to implement a solution. At the beginning of the year the children showed an inability to solve problems and received a score of **0**, at the end of the year received a score between 1.8 and 2.6.

Concerning graphomotor skills in documentation tasks, significant improvement can be seen for sub-variables such as pencil grip, line quality, use of complex lines, thinking about correct use of page space, size, and presentation (Figures 7 and 8). At the beginning of the year they scored between 0.3-0.6 and at the end of the year they reached the intelligence level 2.3-2.7.

Similar progression has been observed along the tasks for problem solving skills. In Figure 9 the group results for the different sub-skills show a clear progression along the tasks. In Figure 10 the values for the individual children is shown, indicating a clear progression as well.

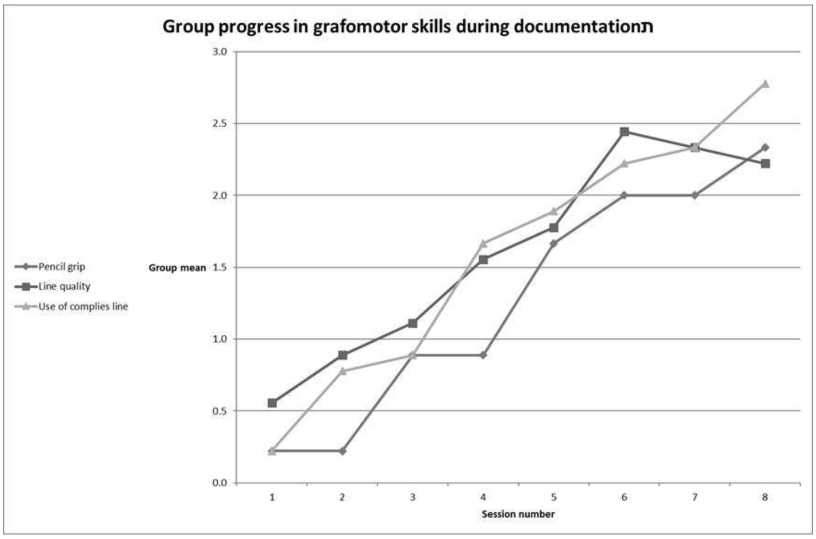

Figure 7: Group progress in graphomotor skills along documentation tasks

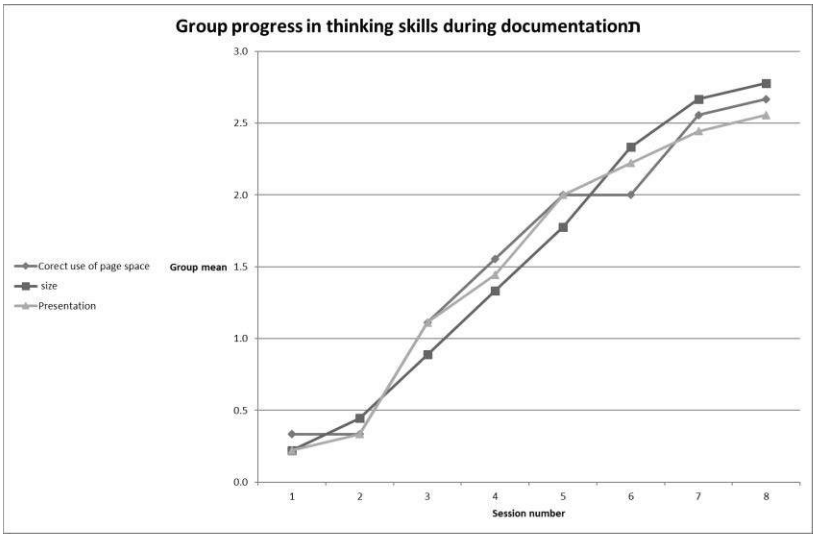

Figure 8: Group progress in thinking skills along documentation tasks

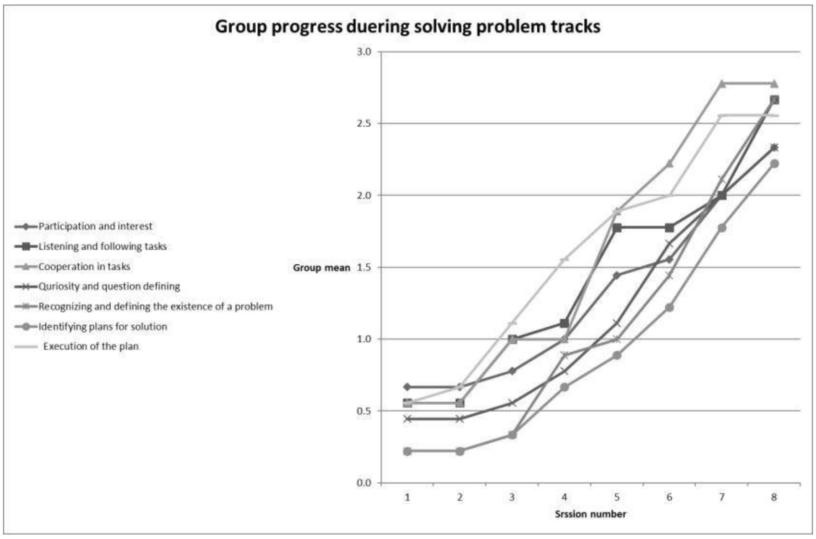

Figure 9: Group progress along problem solving tasks

3.2 Second research question: What characterizes individual children's development of performance and reasoning skills as a function of their involvement in technological thinking tasks - construction, documentation, and problem solving tasks?

The graphs below describe the progress of each child in each field (fine motor graphomotor and problem solving). The progression is described according to the mean scores on the 8 test points.

In Figures 10, 11, and 12 the individual children's means in the construction tasks are presented. The data indicates that all children gained significant progress in fine motor skills, executive functions, and problem-solving abilities along the construction tasks.

The group in the special education kindergarten is obviously heterogeneous. Every child has difficulties of varying degrees in different areas and this is evident in children's performance as observed in the first assessment point of motor skills. Along the construction tasks two sub-groups have consolidated, showing clear gap in performance between them. However, all children in both subgroups gained clearly from the intervention as it is evident in the graphs depicted in Figure 10.

Figure 10: Progress of individual children in fine motor skills along construction tasks

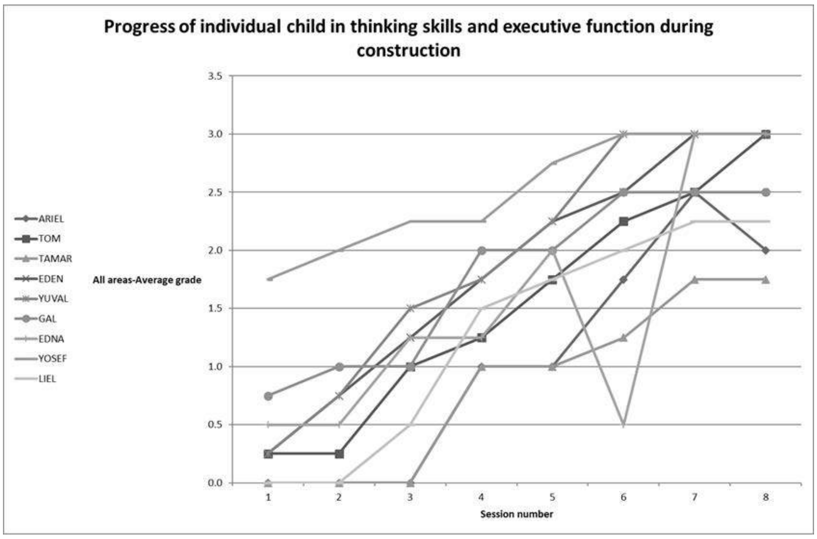

Figure 11: Progress of individual children in thinking skills and executive functions along construction tasks

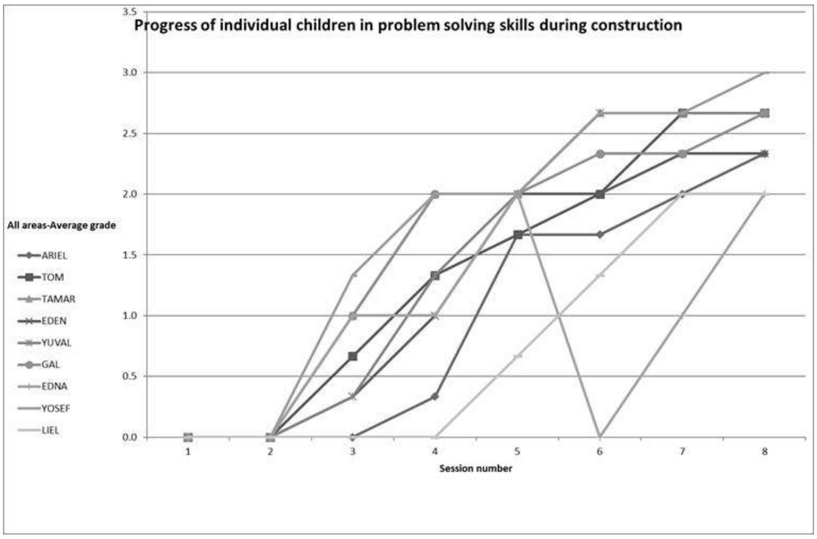

Figure 12: Progress of individual children in problem solving skills along construction tasks

For thinking skills and executive functions (Figure 11) and problem-solving skills (Figure 12) in construction tasks, as well as for performance and thinking skills in documentation tasks (Figures 13, 14) the data shows similar trends, in which progress in skills acquisition and performance is evident along the assessment points.

Figure 15 relates to children's individual progress in problem solving tasks. The overall pattern along tasks and assessment points is similar to that observed for all previous skills in construction and documentation tasks. In problem solving tasks, all children but one showed consistent progress along the assessment points in quite homogeneous path. Yosef outperformed exceptionally in comparison with the other children from the first assessment point, showing high level performance along the tasks. We will refer to Yosef's case in the next section.

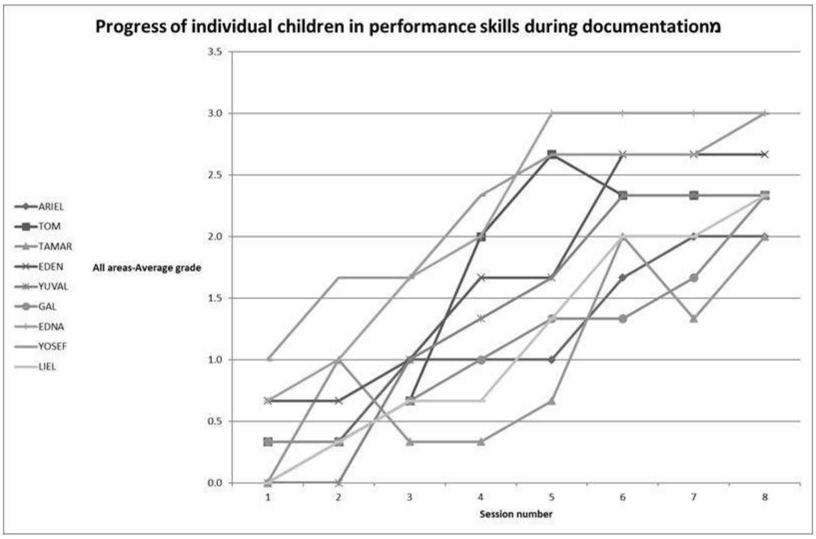

Figure 13: Progress of individual children in performance skills along documentation tasks

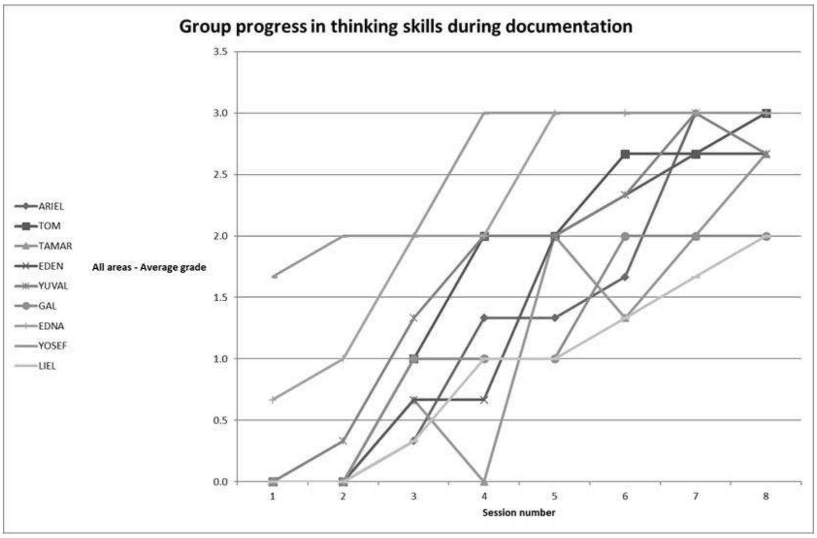

Figure 14: Progress of individual children in thinking skills along documentation tasks

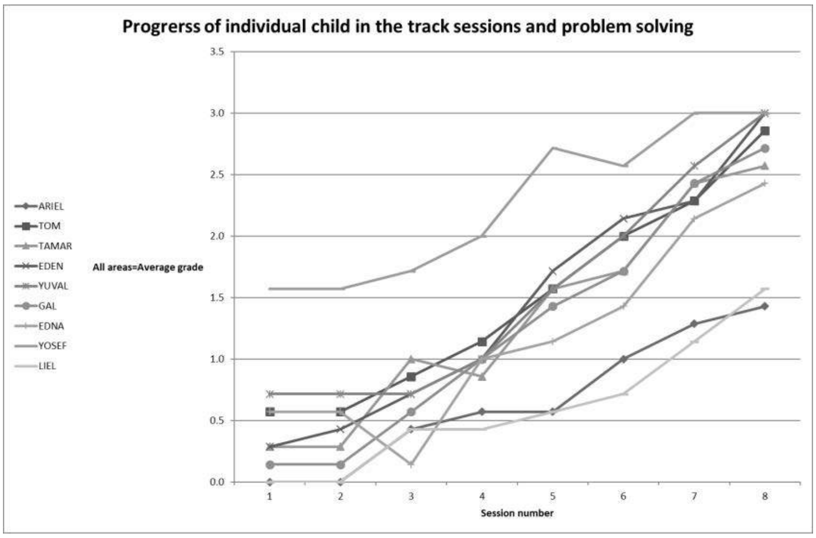

Figure 15: Individual progress along problem solving tasks

3.3 Third research question: Which children will be helped most by the technological thinking tasks?

To answer this question, we examined which children made the greatest progress and every child's performance and difficulties in the various skills. In the following two sample cases are presented (Figs. 16,17).

Yosef is a boy who came to the kindergarten with a diagnosis of difficulties in gross, fine motor, graphomotor and problem-solving capabilities, in organization and planning both in space and in thinking tasks and a poor self-image. However, he was clearly motivated and had perseverance abilities. We already observed significant progress at the beginning of the sessions. He showed high-level abilities relative to the other children.

Gal moved to the special education preschool after failing to integrate in a regular preschool. No difficulty was observed regarding gross motor skills, but he had difficulties in fine motor skills, language, organization and executive functions, sensory processing, and graphomotor abilities. His performance level corresponded to the age-level of a two-year-old. He was poorly motivated and avoided trying. He had conflicts with the staff and children.

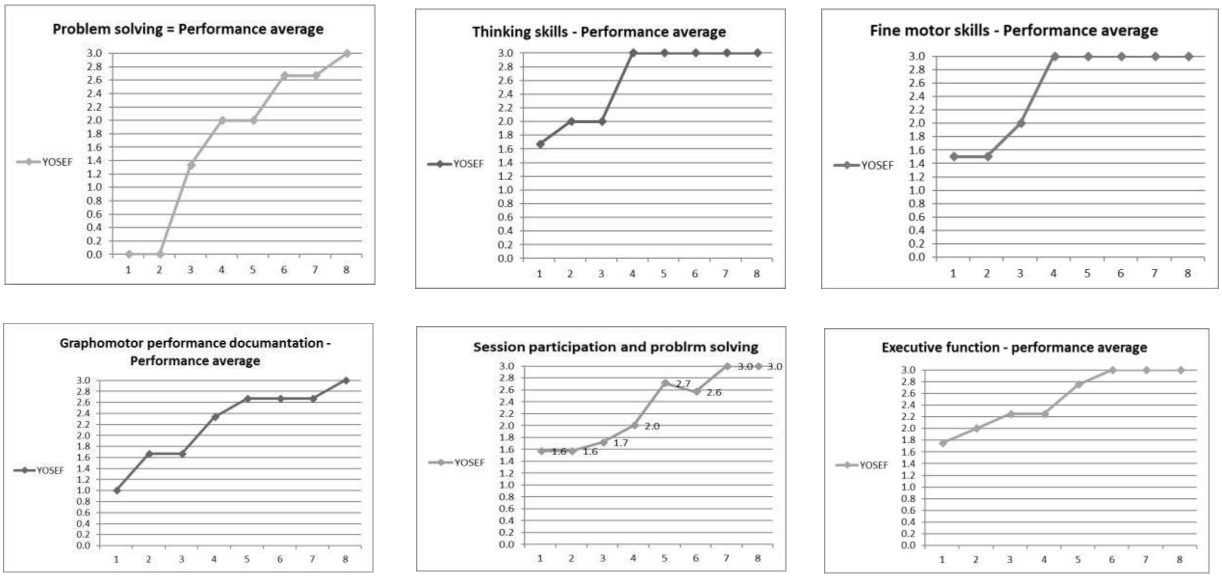

Figure 16: Learning progress along tasks - Yosef

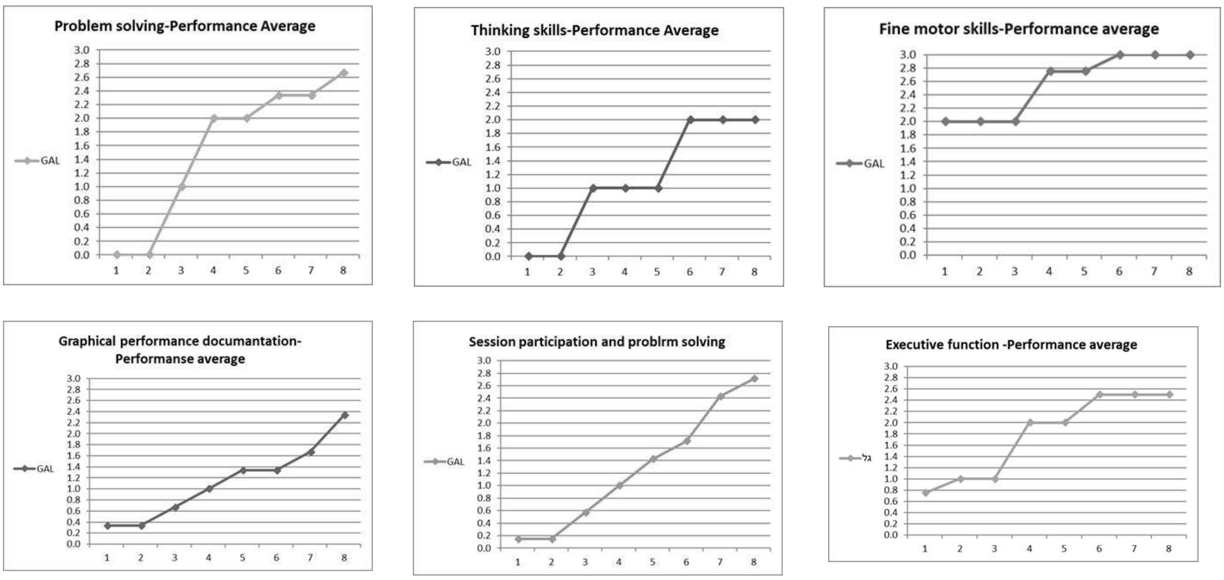

Figure 17: Learning progress along tasks - Gal

For the two children the results showed a significant improvement in all the observed skills. However, while Yosef performed at a higher level from the very beginning of his involvement with the tasks, the case of Gal is notorious. Against the background of his diagnosed problems, the progress in performance and the development of important skills during his involvement in technological thinking tasks was impressive.

4. DISCUSSION

This study, focusing on special education children, was designed on the basis of a long term research plan carried out in regular experimental kindergartens (Kuperman & Mioduser, 2012).

According to published surveys, more than 50% of students in the special education system have learning disabilities (Leizer, 2000). Children with learning disabilities are unsuccessful in developing their own effective learning style. Unlike other children, children with developmental delays require mediation and support in their learning of strategies essential for life in general and for academic performance in particular.

In the majority of cases, the staff in the special education system try to help the children by closing the academic gaps while teaching knowledge using structured methods (Hattie & Yates, 2014; Rowe, 2006). In this study we chose to expose the children to tasks aiming to encourage learning while trying things out and developing thinking skills, and not just acquiring knowledge. We wanted to examine whether significant progress can be achieved with children in special education performing experiential activities in a technological environment that raises possibilities for: (a) construction - employing fine motor skills; (b) documentation - requiring graphomotor skills; and (c) developing reasoning skills for problem solving. Our intervention program was based on the premise that technological thinking can serve as a tool for reaching many therapeutic goals for children in special education (Bers, Flannery, Kazakoff, & Sullivan, 2014; Bers, 2008).

Following the exposure to the various construction kits, their repeated use in varied tasks, together with imparting significance to the construction, and using it for documentation - we could see that fine motor skills, including hand-eye coordination, strength regulation, in-hand manipulation control and accuracy, greatly improved. The areas of greatest improvement were strength regulation and control and accuracy abilities. The reasoning skills required for attentional control, inhibitory control, planning the construction, and evaluating it during the process, were very poor at the beginning of the study and demonstrated clear progress at its end. It could be seen that the constructions were of very low complexity at the beginning of the process: the children tended to build with two components, it took a very short time, and there was clear difficulty in conferring the construction authentic significance. The complexity of the constructions increased over time, the time spent on it significantly rose, and the children learned to impart their artifacts with significance, and even build an artifact according to an advance plan. The motivation to try out and develop the constructed artifacts increased, and there was increased ability to sustain interest and not give up if they encountered a problem. Regarding problem solving skills, there was progress in identifying and defining the problem, the ability to raise possible solutions, and in implementation strategies and skills. Significant progress has been observed as to the ability to transfer problem solving skills to daily life situations. During the early sessions, we observed many situations in which a child stopped working and immediately moved to a different activity as soon as he had difficulty in performing a task. Later on we saw motivation to struggle, change, and correct, so as to continue building, and even developed the ability to identify that they had encountered a problem and needed to turn to someone for help. There was a significant improvement in executive functions that affect, among other things, everyday learning and problem solving.

The study has several implications on both the theoretical and practical-educational levels. On the theoretical level, we increased our understanding that children with difficulties in the areas of performance and reasoning can improve their performance, reasoning skills, and executive functions, after performing suitable technological thinking tasks.

On a practical level, the results can serve as a basis for creating suitable programs for special education aiming to advance significant skills for successful learning. The results serve as a sound base for understanding that it is important to focus in general and in special education in particular, on advancing learning skills and not just teaching information. It is important to expand the studies in this field and gather additional data.

Following the results of this study, a more extended study was carried out recently including five kindergartens, part experimental and part control groups. Our working hypothesis, also in the new set of studies, is that in contrast with the structured and decontextualized sets of curricular tasks in use in special education - technological thinking tasks, by their authentic, hands-on, creative and motivating nature, and the set of strategies and skills addressed, are of great potential for supporting children's learning and the development of skills and thinking processes crucial for further learning and schooling in regular educational frameworks.

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