The gradual construction of a constructionist kindergarten program

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Abstract

This paper describes the process and outcomes of a decade long implementation of a constructionist learning program. The program focuses on advancing the technological thinking of kindergarten children and promoting the acquisition of basic programming concepts. During the ten years since its initial implementation, the program has undergone substantial changes and shifts in focus. Each of the six strands composing the program have evolved, and have undergone multiple transformations. The vast majority of changes that have made their way to the program through the years were a direct outcome of events arising from the field (i.e. the day to day experience at the kindergarten). Many have surfaced from the kindergarten children, either through their explicit suggestions or by way of observations of their activities. On a previous paper, the program rationale and theoretical grounding were introduced; eight years on, with the program actively operating in 8 kindergartens, this paper presents reflections, conclusions and main takeaways from the years of implementation.

Keywords

Technological thinking, Kindergarten, Smart-artifacts, Design and Learning, Implementation

Introduction - Program rationale and theoretical grounding

This paper discusses a decade-long implementation of a constructionist learning program focused on advancing the technological thinking of kindergarten children, and on promoting the learning of basic programming concepts. The program is based on the "Design and Learning" (D&L) model (Mioduser, D. 2009), a constructionist learning model based on the premise that "*mindful interaction with the designed world (the human-mind-made-world), and active involvement in designing objects for this world, serve as an intellectual and practical platform for promoting young children's learning about contents, processes, and skills related to the artificial world*" (Mioduser, Kuperman and Levy, 2012). The models' rationale is built around the encounter between technology and learning, both taken in their broadest possible sense (Mioduser, D. 2009; Mioduser, Kuperman and Levy, 2012).

Program scope and implementation

For the past decade, the program has been implemented in 8 kindergartens across Israel. Each kindergarten is attended by 35 children on average, between the ages of 5-7, with an educational team comprising one teacher and one assistant. Before and during the Implementation, the team undergoes comprehensive training consisting of an introduction to core ideas in constructivist and constructionist theory and an introduction to the D&L model. The team also receives active ongoing support during the school year.

The program is composed of 6 strands (Problem-solving; the designed/artificial world; Design; Notations; Smart artifacts and the Integrative project). An additional strand, "Special design for special needs", is not addressed in this paper. Although the program is presented as six separate strands, the order of the strands is not hierarchical, and the strands are in fact closely intertwined. Accordingly, the educational team is encouraged to experiment, change the order of strands and activities or combine among them, and make their personal interpretations - according to what they believe will best suit the children and the unique character of each kindergarten.

Following is a description of the strands and the ways in which they have evolved over the course of a decade-long implementation.

Strand 1- Approaching problem-solving (from haphazard to budding systematically in planning and implementing solutions)

The main objective of the problem-solving strand is to establish a "problem-solving culture" in the kindergarten, and to encourage problem-solving (PB) processes as a commonplace practice and an integral part of the kindergarten life. When engaged in PB, children and teachers act together as co-creators engaged in a structured process, using a PB framework. The framework consists of a simplified version of PB and design processes from the world of engineering. The adaption to kindergarten has fewer steps, posed as a set of four consecutive stages- starting from problem definition, followed by initial solutions, then selection of the best solution and finally, implementation of the selected solution (Kimbell et al. 1966; Mioduser & Dagan 2007). The simplified framework was created in order to facilitate a structural way of thinking but also to encourage freedom and creativity through the process.

Main extensions gradually constructed along the implementation

With the implementation of the program, PB processes have become a key element in kindergarten life, serving as a tool in multiple areas. "*There is a problem*" is a statement often heard across the kindergarten, expressed by the children as an initiation of a problem-solving cycle. The children and educational team regularly use the PB process for tackling dilemmas in versatile fields, ranging from technological tasks (product building and repair, building games, etc.) through solving dilemmas that arise spontaneously during the day (setting rules and establishing kindergarten norms) to social challenges (solving quarrels and disputes, reaching compromises, reaching agreements etc.). Often, children use problem-solving tools independently, without adult mediation on multiple issues and areas. In addition, this practice has expanded beyond the kindergarten walls and parents often report that their child initiates a "problem-solving" processes at home, when they encounter conflicts (such as issues with their siblings).

Initially a simplified, four-stage process scheme, the framework has been extended and further elaborated. Three stages (**Reasoning, Control, Research and exploration**) were added, as a result of practices arising from the field, as detailed below.

- **Research and exploration -** "*I want to build a robot*" declared S, 6-year-old. Her friend offers to Google "how to build a robot". The exploration phase was not a part of the original process, but in many kindergartens, the children turned to search engines to explore and understand and ask questions. As a result, circles of inquiry were formed tangentially to the subject being investigated, in a kind of threading process.
- **Control (debugging and problem fixing) -** "*I want to explain why my solution is the best*" Y. 5-year-old told the group of children engaged in a thought process to solve the "tallest tower" problem. Control processes were initiated intuitively by the children as part of the process.
- **Reasoning -** "*I want to explain why my solution is the best*" Y. The 5-year-old girl told the group of children engaged in a thought process to solve the "tallest tower" problem. The children often express their wish to explain and elaborate on the strengths of their solution and a need to explain and justify the choice. As a result, the "reasoning" step was added to the PS process schema.

The evolution of the PB process sprouted in a bottom-up manner. Eventually, some of the changes from the field made their way to the (ever-evolving) framework, but variations of this process remain and are encouraged.

Strand 2 - The designed/artificial world (artifacts and their use and context)

The main objective of this strand was for the children to gain knowledge and understanding of the world of objects, our material culture, through the exploration of different artifacts and structures. An additional goal was for the children to gain an understanding of mechanisms, through disassemble and repair of objects and through engaging in classification processes based on the objects' structural and functional properties.

Main extensions gradually constructed along the implementation

The program created encounters with a rich variety of objects brought by the children. The children were actively engaged in complex classification processes that went beyond the standard kindergarten curriculum and enabled an exploration in a wide technological, cultural and social contexts.

- **Broader and unique categories for sorting** - "*They are both connectors… the phone between people and the stapler between papers*". R. (6 years old) reflected while holding a phone in one hand and a stapler in another. Standard kindergarten curriculum usually calls for external visual parameters such as colour, material, size and shape as criteria for classing objects. The classification process conducted seeking a common basis for seemingly very different objects gave rise to ideas for non-trivial categories suggested by the children, e.g., on properties related to their functionality at a quite abstract level.

- **A holistic exploration of the world of objects**- *"Let's build a plane just like the wright brothers!*" proposed A. (6 years old.) The exploration went beyond the object itself, on gaining a broad understanding of the object, its origin, history, context and more, reaching a more holistic understanding of the object's story and evolution. (See Figure 1).

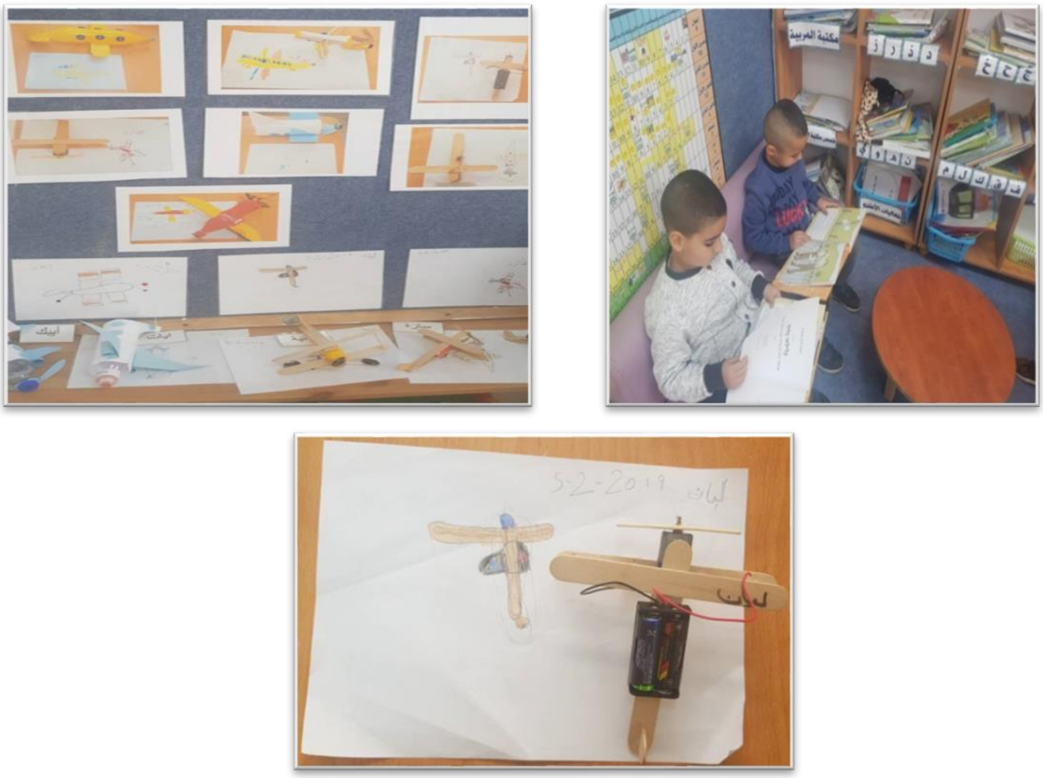

Figure 1. Holistic exploration of the world of objects.

Strand 3 - Design (from free-form building to reflective construction)

The strand involves construction and assembly using building kits and games (such as Lego blocks, Mechanic Duplo, K'nex, Magnetic tiles etc.) and creating sketches of the constructed object, as documentation of it. The main objective of the sketches was to initiate a reflective process, (both on the 3D construction, as well as on the transition from 3D construction to a 2D sketch), in order to support the development of fine-tuned perception of details as well as representational skills.

Main extensions gradually constructed along the implementation

This strand has gained momentum and became a central activity in the kindergartens. As with the problem-solving process described above, the process has expanded beyond its initial scope, due to "natural evolution" in the kindergarten environment.

- **Sketching for planning, not just documentation**- Originally sketching was used for documentation and reflective objectives but it spontaneously became a part of the planning process. The children's sketches serve as designs for constructions by their peers who were interested in creating constructions which they liked. In cases where the sketch (now serving as plan) was not clear (not detailed enough or not accurate enough to build from) the children tried to explain (or "translate") the sketch for their peers. This attempt to decipher the sketch for construction often let to a rich discourse between the child who made the sketch and their peers. Some kindergartens created "catalogues" of past sketches that allow anyone interested in doing so, to select a sketch and use it as a plan for construction. Furthermore, Sketching was used spontaneously by the children in many additional situations during the day, as a means for planning an activity, process or a game.

- **Use of colour to depict structure**- initially the sketches were created in a simple pencil, but the children spontaneously decided to add colours, to better depict the colours of the parts used for the physical model. This was also an effective way to better communicate the sketch to the peers interested in reconstructing it.

Figure 2. Left- original model, right a model- constructed from the sketch.

- **Authentic Construction-**The use of construction and sketching techniques has expanded beyond the building games activity. They have become tools, used on authentic areas in the children's lives for planning the socio-dramatic game (Bretherton & Beeghly 1989) and also as tools for co-planning different constructions (see figure 3).

Figure 3- Sketching and building a "smiling robot".

Strand 4 - Notations (from conventional signs to computer programs)

This strand involves the construction of visual and conceptual representations and symbols, that serve as 'epistemic tools' encapsulating both the represented content as well as the representing means (Mioduser, Kuperman and Levy, 2012), effectively creating a physical, symbolic language. Similarly to "sketching" described above, this strand focuses on symbolic representations, with the symbolic language not constricted to a two-dimensional representation on paper.

Main extensions gradually constructed along with the implementation

The original goal was to introduce the children to notations as an initial, initiation, stage to be followed by the programming (smart artifacts) phase. As part of the activities, the children create routes and mazes; they also experiment and practice receiving and providing instructions. During the program, multiple tracks appeared in the kindergarten built from anything available (blankets, chairs, cubes, and more), representing real and imaginary spaces. Building routes and mazes as part of the sociodramatic play and representing reality became a common practice. Children often engage in discussion with their peers about the choices of symbols and how best to represent objects, facilitating an abstract understanding of language and communication.

The children also create representations (maps) of the routes taken from their home to the kindergarten and include details such as significant objects that they encounter on the way. Maps have effectively become a tool used in multiple context and topics; the children use the map as a tool to explain and represent knowledge.

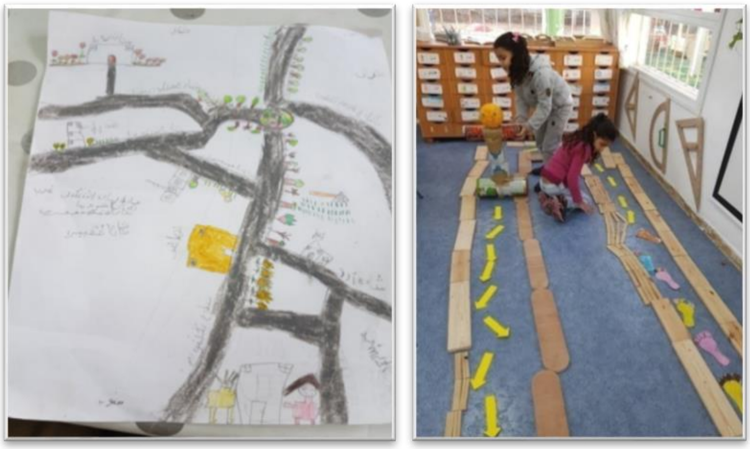

Figure 4- building a track and a map.

Strand 5 - Smart artifacts (Understanding and constructing artificial-behaviour)

The main focus of the strand is to encounter programmable "smart" artifacts and experience behaviour building for smart artifacts while engaging in collaborative processes involving planning, problem-solving and repair processes (Papert, 1987, 1993). During the program, the children are exposed to the world of smart artifacts and coding becomes a part of the daily routine of kindergarten life. The programming (of EV3 robot LEGO) is done through a programming interface (Kinderbot, Scratch etc.). The process includes three phases: building a (physical) route, documenting it (sketching) and programming the robot to pass through the route.

Main extensions gradually constructed along the implementation

This strand has also expanded and was essentially reshaped due to new tools, and to events in kindergarten reality.

- **A shift in focus**- from programming to storytelling - The original objective was to transition from creating a route for the robot to programming the robot's behaviour. In effect, much (if not most) of the focus of the activity was placed on the route (or multiple routes) creation. The route, in fact, became more of a goal of itself, then (as originally planned) a means to an end. Routes were created around varying themes and topics serving as grounds for socio-dramatic play and storytelling, with the smart artifact becoming just one of the players. This shift was not preplanned, but the importance of creating a rich context for the smart artifact, describing its background and "motivation" for travelling through the route was evident in all kindergartens.

- **The move from desktop to mobile-based programming –** As reported on our previous paper (Aladjem, Kuperman, & Mioduser, 2017), the transition from a desktop to mobile-based programming environments contributed to substantial changes including changes in the programmers' perspectives, changes in foci and learning patterns in different programming modes, and changes in patterns of collaboration among peers.

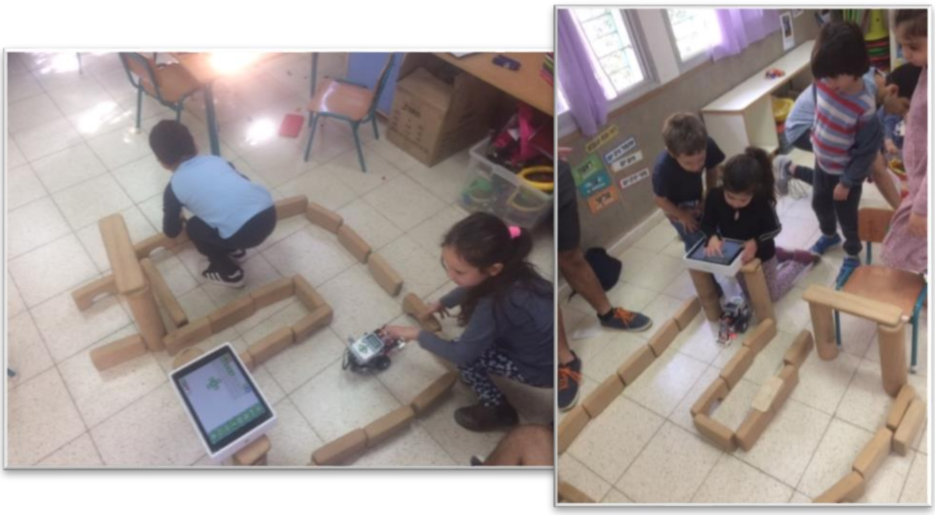

Figure 5- Mobile programing.

Strand 6- The integrative project

The main objective of this strand is to create an opportunity to concretely implement the knowledge (construct), tools and skills that the children have acquired, by creating a tangible, integrative project. The project is created through collaborative work, leveraging creative thinking in order to plan, explore, solve, and finally to create an end product. In other words, the integrative project effectively "ties" all the strands together into a hands-on, holistic product-oriented product.

Main extensions gradually constructed along the implementation

The plan for this strand has emerged impromptu since there was room for interpretation; there was substantial variation between kindergarten classes. The ideas for the projects were raised by the children or identified together by analyzing situations, events or needs in the daily life of the kindergarten. Projects carried out in all kindergartens reflected the skills that the children acquired during the school year of the program. Starting with the planning stage - the organization, the equipment lists, the process, collaborative work, exploration processes, problem-solving processes and more. Examples of projects included different types of factories (such as a chocolate factory and a notebook factory), different customer-facing businesses (such as a café and a restaurant) and complex physical environments (such as a palace and mazes). The second part of the school year in all the kindergartens revolved around the integrative project, beyond constructing the project environment, the project was discussed and approached from multiple perspective and angles (such as historical, political and economic perspectives) and became the centre and focal point for much of the kindergarten activities.

Summary and Conclusions

During a decade long implementation, the program has undergone evolutionary transformations both in scope and focus as well as in some of the tools used. This paper is an opportunity to revisit the fundamental principles upon which the program was constructed (constructionist theory and the D&L model) and to reflect upon the agents and processes who have contributed to its gradual construction.

The paper illustrates how integrating a constructionist program as part of the kindergarten curriculum can create a unique experience and an added value. Beyond the acquisition of programming skills, the program supports the development of an extensive skillset, authentically arising from children's curiosity and needs (Papert, 1987; Resnick, 2007). Skills and practices acquired throughout the program become tools (or a tool-set) used in multiple contexts in kindergarten and beyond.

The program has undergone a gradual construction since its inception up until its current state, with the vast majority of changes emerging from the field (i.e. the kindergartens where the program has been running) or more specifically, from ideas, opinions and needs raised by the children. Flexibility is an inherent principle of the program, and it allowed for different interpretations and implementations in each kindergarten. This principle, combined with the sensitivity of the educational team, gave room for the children to express themselves and in turn, contributed to substantial changes which made their way to the "official" program.

Each of the six strands composing the program evolved, expanded and transformed in ways which have exceeded our plans and expectations. Furthermore, in each of the kindergartens where it has been implemented, the program has gradually become a core activity and its underlying philosophy has, in many ways, permeated all activities. Following, we briefly present what we view as three of the more substantial takeaways observed in the past decade, across program strands and kindergartens.

- **The child as an equal partner and co-designer**- A guiding principle of this program and of constructionist thought in general, places the child in the centre, acting as an explorer, a researcher, following their curiosity and learning through hands-on experience with technological tools (Piaget, 1975, Papert 1980, 1993). Over the years, through our observations, we found fundamental support to the perception that the child should be a part of all aspects of the program. This was observed on all strands, with the children expressing needs and ideas and acting as active agents and significant contributors to the design and construction of the program.
- **Collaboration amongst peers-** Learner interaction can stimulate cognitive development, as the individual contributes to the group knowledge and in turn, the group knowledge contributes to the individual's understanding (Kolodner et al. 2003). Collaboration among peers was observed on all the strands, often happening naturally and spontaneously with no need for encouragement or mediation from the educational team. For example, while Sketching, in many cases, the children shared the process of "deciphering" a sketch and using it as a basis for construction. Problem-solving was also conducted in spontaneous cooperation.
- **Use of multiple tools –** Using tools for designing, creating, and manipulating objects, both in the physical and virtual world is a powerful idea that can empower the individual (Papert 1980, 1993; Resnick, 2008). It seems that the type of tool used often dictates the nature of the artifact. For example, each type of building game, ked to similar constructions across kindergartens. Each game has different rules and structures (connections stabilizing mechanisms etc.) and effectively requires the use of different techniques. This observation highlights the importance of using a variety of tools for developing concrete thinking and learning about abstract phenomena.

In closing, a decade long implementation brings with it many insights, many of which were presented in this paper. As our next steps, we plan to expand the program to more kindergartens with diverse populations and to expose more educational teams, children and communities to constructionist philosophy, thinking and learning.

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